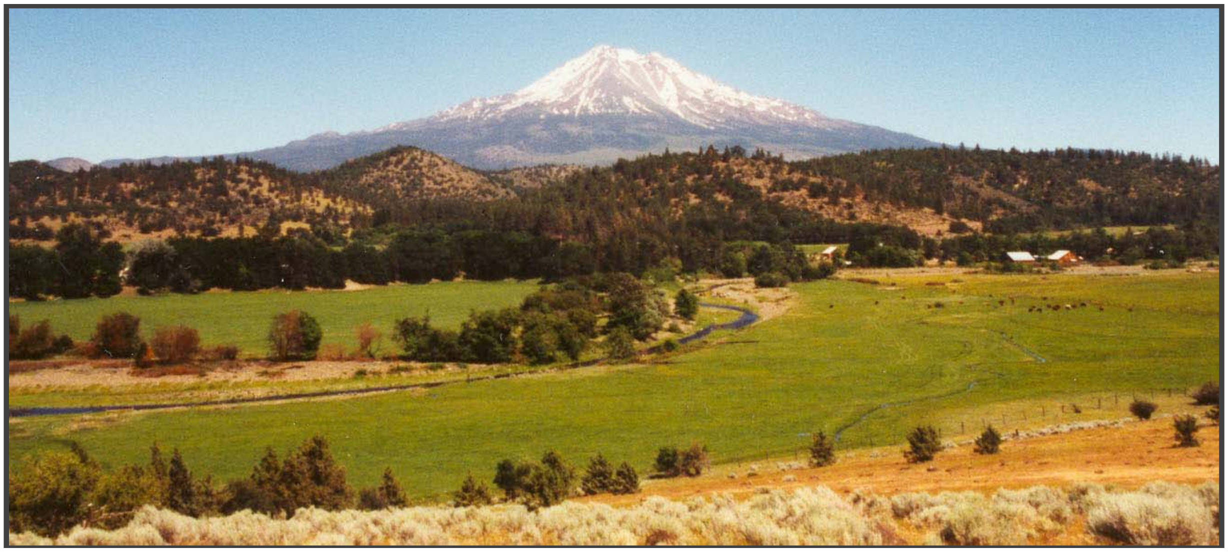
Shasta River Watershed Stewardship Report


Shasta River Valley

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1. Executive Summary

The Shasta River Watershed Stewardship Report is a non-regulatory document that identifies successful stewardship actions and presents a roadmap for future stewardship actions to continue to improve water quality conditions in the Shasta River watershed. The Shasta River Watershed Stewardship Report is intended to introduce a watershed-scale, stewardship-based, adaptive management approach with opportunities for direct and interactive feedback from local stakeholders and partner organizations. In general, the stewardship approach can be summarized as a collaborative framework to improve water quality that supports beneficial uses and habitat for sensitive species, such as coho salmon (*Oncorhynchus kisutch*).

This report is a pilot project of the Klamath Basin Monitoring Program (KBMP) intended to promote the use of science-based assessment to guide water quality improvement activities and projects. The Shasta Valley Resource Conservation District (SVRCD) has coordinated partnerships with local landowners, local agencies, state and federal agencies, tribes, and other non-governmental organizations for the development of this report and to begin the development of a watershed stewardship framework. The watershed stewardship framework is based on partnerships coalesced around shared environmental outcomes, respect for the working landscape, and a voluntary commitment to collaboration. An anticipated benefit of the proposed watershed stewardship approach includes increased sharing of information on actions and projects completed by participants to track the progress made in the Shasta River watershed. Another benefit of this watershed stewardship coordination report is the increased level of identifying the shared funding by participants on mutually beneficial projects. This is the first watershed stewardship report and it is intended to be a living document, building on hard work accomplished by partners across the watershed, guiding adaptive management as conditions change. The report will live on the KBMP website (http://www.kbmp.net/stewardship) and will be updated as watershed stewardship accomplishments and assessments are completed.

In addition to the stewardship action updates, the Shasta River Watershed Stewardship Report identifies current water quality monitoring taking place and identifies water quality trends as they relate to sensitive beneficial uses. As part of the Stewardship Program, the scope of the Shasta River Watershed Water Quality Monitoring Plan has been expanded to provide a collaborative opportunity for all partner programs currently conducting water quality monitoring in the Shasta River Watershed. Rather than being a single-purpose monitoring plan, this plan utilizes an integrated multi-organizational approach to water quality monitoring. By leveraging water quality monitoring at a broad spatial scale, this monitoring plan provides a more holistic and up-to-date understanding of water quality conditions and presents a collaborative opportunity for identifying solutions to water quality impairments. The watershed stewardship approach is based on a science-based assessment of conditions to inform stewardship activities, and builds on partnerships and local collaboration.

What are the key actions for the Shasta River Watershed?

Six key stewardship actions were identified for the Shasta River Watershed including:

- Riparian fencing;
- tailwater management;
- fish barrier removal;
- riparian planting;
- flow augmentation; and
- spring restoration.

At the time of writing, consistent progress has been made to implement these key actions. This includes the installation of 24 stockwater systems, 8 irrigation efficiency projects, 6 projects that re-use tailwater return flow, and 3,750 linear feet of riparian plantings. Approximately 133 miles of riparian fencing have been installed since the adoption of the Shasta TMDL Action Plan, protecting 91% of the mainstem of the Shasta River, 60% of the Little Shasta River, 49% of Parks Creek, 60% of Yreka Creek, and a cumulative 61% of the entire stream reach length of the Shasta River system. Additionally, 23 ranches have received assistance with ranch planning which includes assessing water quality impacts. Information regarding the ranch planning process and approach utilized by the Shasta Valley RCD can be found here: http://svrcd.org/wordpress/shasta-river-tmdl/water-quality-ranch-planning/. Since 2006, over $11 million in grants have been awarded to SVRCD to complete these projects and to support ongoing stewardship efforts within the watershed to implement the Action Plan. These funds were largely from federal and state agencies but also from private organizations. Much work has also been done by both private land owners and non-governmental organizations.

Monitoring and Trend Analysis

Much effort has gone into collecting and analyzing data from multiple partner groups and agencies to develop the foundation for adaptive management. The analysis focused on two conditions in which the Shasta River is impaired: water temperature and dissolved oxygen concentrations. The analysis performed shows that, for both conditions, areas where the key stewardship actions were implemented showed improving trends. This analysis provides evidence that these key stewardship actions do indeed lead to water quality improvements when implemented at a scale appropriate to the impact of operations that have led to discharges, and should be continued in areas that have not yet shown improvement.

The result of this analysis has been a deeper understanding of what works in the watershed to improve conditions. Information has been gathered regarding riparian planting optimization, riparian fencing protocols, tailwater capturing and re-use strategies, and irrigation efficiency approaches. With this information, projects can be implemented more effectively and water quality goals can be achieved at an increased pace, especially in priority areas that are at a higher risk to water quality impacts.

Adaptive Management Recommendations

Based on the analysis performed, there is evidence that the stewardship practices described in this document protect and enhance water quality. In addition, it is apparent that the scope and scale of watershed stewardship practices need to be expanded to pollutant sources not yet addressed and restoration opportunities not yet realized. What is needed now is a deeper understanding of which of the identified sources of nutrients contribute most to dissolved oxygen impairment, and a continued effort on protecting, enhancing, and expanding cold water refugia as an interim measure to support cold water beneficial uses in the watershed. Currently cold-water and oxygen-rich refugia exist to provide limited habitat for salmonids. The continuation of voluntary activities that address nutrient hot spots, recover riparian vegetation, increase cold-water flow instream, and improve tailwater management practices will help expand cold-water habitat. However, overall improvements in flow, temperature, and dissolved oxygen conditions are necessary to achieve an acceptable level of supporting conditions for Shasta River beneficial uses. A full analysis of temperature and dissolved oxygen conditions, as well as a description of specific actions that will accomplish this, are described in Chapter 8.

2. Shasta River Watershed Stewardship Approach Overview

SVRCD has been working for decades with local landowners, tribes, NGOs (e.g., The Nature Conservancy), State and Federal resource management agencies, and the North Coast Regional Water Quality Control Board implementing and coordinating watershed stewardship projects. Volunteering to serve as the coordinating lead for the initial Klamath Basin Monitoring Program sub-basin watershed stewardship report was a natural extension of their mission. The SVRCD Board supported the staff proposal to serve as the local coordinating lead to develop the Shasta River Watershed Stewardship Report and to build the partnerships necessary towards completion of that goal.

SVRCD has been a member of the Klamath Basin Monitoring Program (KBMP) since 2007, and SVRCD staff has been a member of the KBMP Steering Committee for several years. Membership in KBMP is voluntary and its approximately seventy member organizations have developed a cooperative framework to coordinate and improve water quality monitoring and assessment throughout the Klamath Basin. KBMP members voted to begin developing watershed stewardship reports in 2010 to ensure that monitoring and associated assessments were broadly available to all stakeholders interested in promoting and completing watershed stewardship activities.

This document is the result of that undertaking. It was a far more difficult task than originally anticipated but the resulting partnerships with participating organizations and individuals are much stronger as a result of this effort. This report will contribute to an improved awareness of all that has been accomplished to improve water quality in the Shasta River, a better understanding of the challenges that remain, and strengthened partnerships to tackle those challenges together.

The following sections provide some introductory background information on the watershed stewardship approach, which is the general process used to build the voluntary water quality improvement coordination framework.

Stewardship Process, Purpose and Audience

The stewardship approach is intended to provide interactive feedback from local stakeholders regarding water quality conditions and stewardship actions in the Shasta River Watershed. Unlike a TMDL, the stewardship approach addresses surface water status for both 303(d) listings and other surface-water-related concerns, such as restoration actions and upland conditions. Additionally, the stewardship approach holistically evaluates the ecological status of the Shasta Basin.

The Shasta River Watershed Stewardship Report is divided into six primary sections: Watershed Description and Setting, Water-Related Issues of Concern, Stewardship Approaches Taken to Improve River Conditions, Stewardship Action Planning, Watershed Partners Programs and Activities, and Data for Adaptive Management. Appendix A presents a coordinated status and trends monitoring framework that will provide the information necessary to sustain an adaptive management watershed stewardship framework. Appendix B presents the assessment of current water quality conditions.

Shasta River Watershed Action Plan

The Shasta River Watershed Action Plan in Section 6 of this report outlines the future stewardship actions prompted by the water quality status identified by the assessment of current conditions (Appendix B). The Action Plan includes partner program monitoring and restoration organizations' efforts toward ecosystem rehabilitation in the Shasta River Watershed.

The Shasta River Watershed Action Plan will employ adaptive management principles; therefore refinements will be continuous (Figure 2.1). The adaptive management framework is a six-step process:

1) **Build Partnerships and Define Goals** – Several monitoring organizations collect water quality data in the Shasta Region. Partnerships are key to generating a collaborative monitoring framework guided by a common set of monitoring goals and objectives.
2) **Characterize River Watershed –** Through the collaborative monitoring framework, a holistic understanding of water quality conditions in the Shasta Basin can be generated.
3) **Identify Problems and Develop Solutions –** Sources of water quality impairment can be identified based on the status and trend results from the collaborative monitoring framework.
4) **Implement Solutions –** Non-regulatory and direct actions may be taken to address the sources of impairment.
5) **Measure and Evaluate Progress –** Mechanisms for measuring progress may include regulatory metrics. For example, environmental benefits are calculated as part of the Klamath Tracking and Accounting Program (KTAP) and physiological thresholds are established for sensitive beneficial uses.
6) **Make Adjustments –** Following the progress assessment and the direct actions, the various approaches may be evaluated and refined to better address the sources of water quality impairment. Steps 3 through 6 will be repeated until there is forward progress toward ecosystem rehabilitation.

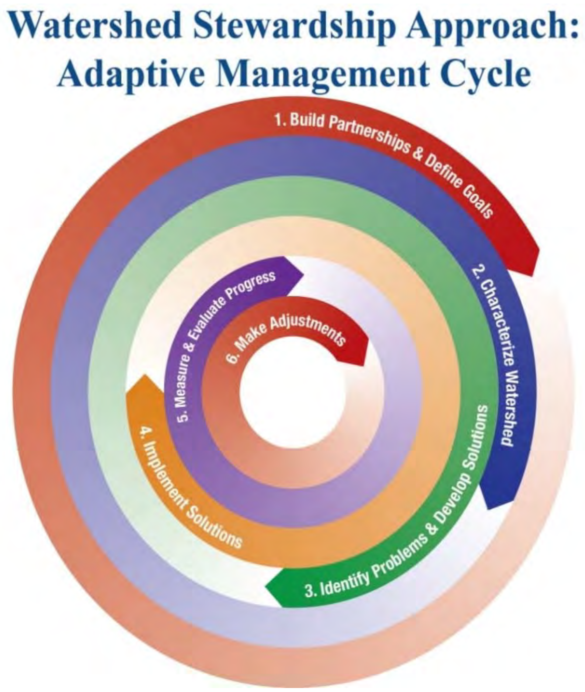

Figure 2.1: Adaptive management cycle

The adaptive management cycle is maintained through the collaborative effort of program partner organizations and supported by the Klamath Basin Monitoring Program (KBMP). Established in 2007, KBMP is a multi-organizational program designed to coordinate and implement water quality monitoring for the stewardship, protection, and restoration of all beneficial uses within the Klamath River Basin. KBMP members participate in two annual membership meetings designed to enhance collaborative monitoring, assess water quality conditions, identify sources of impairment, and recommend non-regulatory actions. KBMP is supported by staff and a volunteer steering committee.

The Shasta River Watershed Stewardship Report is not the final product of the Shasta River Watershed stewardship approach process. Rather, the document will be updated and amended over time with further input and communication from Shasta River Watershed stakeholders. This plan is the first version based on available information and the plan will be formally updated as appropriate. Up-to-date stewardship reports and stewardship success stories can be found on the KBMP website: http://www.kbmp.net/stewardship.

3. Watershed Description and Setting

3.1 Physical Setting

The Shasta River is located in Siskiyou County, California, and is a major tributary to the Klamath River. The Klamath Basin is a bi-state basin spanning sections of Northern California and Southern Oregon. For discussion and planning purposes, the Upper Klamath Basin and Lower Klamath Basin are split at Iron Gate Dam and the Cascade Range crossing the basin (Figure 3.1); the Shasta River feeds into the Lower Klamath Basin.

The Shasta River Watershed is approximately 800 square miles (507,000 acres) in area. It is bounded by the Siskiyou Range to the north, the Klamath Mountains to the west, the Cascade Range to the east, and by the volcano Mount Shasta to the south (Figure 3). The Shasta River marks the divide between metamorphic and sedimentary rocks of the Klamath Mountains and the volcanic rock of the western Cascades (Mack 1960). The Shasta River Watershed consists of two major landforms: the low-gradient floor of the Shasta River Valley and the surrounding steep mountains punctuated by Mt. Shasta (at 14,162 feet above sea level) at the southern border of the watershed. The Shasta River Valley is a key agricultural area that is dominated by low-lying, slightly undulating agricultural lands. These agricultural lands are primarily used for cow-calf operations relying on pasture, hay and grain production.

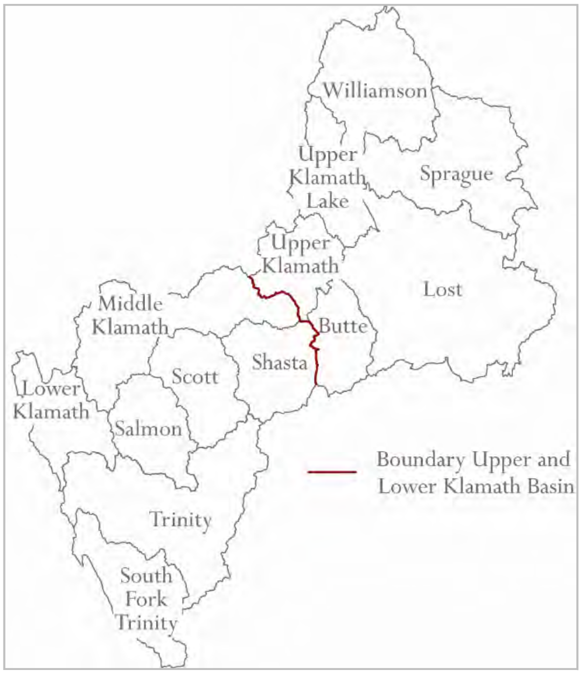

Figure 3.1: Klamath Basin and Sub-basins

The Shasta River, which flows south to north, originates from surface runoff in the Eddy Mountains and springs that originate on the flanks of Mt. Shasta, along with surface flow and springs originating from other Cascade volcanic mountains on the east side of the watershed. From its origin, the Shasta River travels approximately 50 miles until it converges with the Klamath River. Water from the Shasta River travels an additional 175 miles in the Klamath River before it empties into the Pacific Ocean.

The upper quarter of the Shasta River lies upstream of Dwinnell Dam and its reservoir, Lake Shastina (Figure 3.2). Dwinnell Dam was constructed in 1928 and is located approximately forty miles upstream from the confluence of the Shasta River and the Klamath River. The slope of the river is high as it descends the mountain slopes toward the lake. Below Lake Shastina, the river is much slower and meanders across the Shasta River Valley floor before steepening and passing through the six-mile Shasta Canyon to the Klamath River.

Figure 3.2. Shasta River Watershed and major tributaries

3.2 Geology and Hydrology

The low-relief portion of the Shasta River was formed by two significant geologic events. The central part of the Shasta River has a complex topography that was formed about 300,000 years ago by a massive debris avalanche (Crandall 1989). This deposit formed when the northern flank of an ancestral

Mt. Shasta collapsed and flowed through the central part of the river, covering it with a layer of mud, sand, gravel, and large intact blocks. Approximately 160,000 years ago, a lava flow erupted from a vent northeast of Mt. Shasta which produced repeated lava flows that eventually covered much of the eastern part of the river and buried the eastern margin of the debris flow deposit. This basalt lava flow formed the Pluto's Cave Complex — a major collection area and conduit for groundwater flow which also surfaces as springs in the Big Springs area. The most recent volcanic eruption activity occurred just two hundred years ago.

An important geologic feature related to the natural resources in the Shasta River watershed is the relatively low stream gradient created by the debris flow. This low gradient makes it difficult for water to attain the velocity necessary to move any available spawning gravels downstream to improve physical spawning conditions for anadromous fish. The debris flow has also had an impact on water quality in the Shasta River. In particular, it has created an area of young soils that have not been leached by hundreds of years of rainfall. As a result runoff from the Shasta Valley tends to be naturally nutrient rich and serves as the foundation for unusually high aquatic organism levels in the Shasta River. These two factors may be responsible for the tremendous salmonid productivity in the Shasta River.

The Shasta River is a spring-fed river, with summer flows sustained despite low precipitation. Snowmelt from annual snowfall and glaciers on Mt. Shasta provide a constant source of cold water for springs throughout the watershed. The relative permeability of the debris flow allows water to easily infiltrate underground to later surface as springs in the area below Dwinnell Dam. Park Creek, a large tributary to the Shasta, is highly snow-driven from the Eddy Mountains to the west. Parks Creek also has springs that contribute to its flow, some of which may be linked to Shasta or Dwinnell storage. The extent to which storage behind Dwinnell Dam influences flows from these springs is largely unknown. Field observations made during 2014 and 2015, when storage was significantly lower than average in Lake Shastina, showed that certain springs below Dwinnell were significantly reduced or ceased to flow.

As such, groundwater plays a significant role in feeding surface water. However, the infiltration, movement, and linkages to surface flows are inadequately understood. A joint investigation by the SVRCD and the DWR indicate that the overall groundwater basin is comprised of 8 sub-areas, each of which is somewhat independent of the others. Groundwater recharge comes from natural sources, percolation from irrigation reservoirs, irrigation conveyance leakage, and infiltrating irrigation water.

The local geology of the Shasta River Watershed strongly influences groundwater chemistry, which is generally characterized as magnesium bicarbonate and calcium bicarbonate type water. The chemical makeup of the groundwater within the watershed depends on the area of the watershed from which it originates. The serpentine areas produce groundwater high in magnesium and silica, while high calcium levels result from limestone areas. Water from the volcanic formations is high in salinity, sodium, silica, and boron (Mack 1960). Understanding groundwater chemistry can help to identify likely infiltration source areas, as different rock types tend to leach different minerals.

The Shasta River has several tributaries, the largest of which include Little Shasta River, Parks Creek, Big Springs Creek, and Yreka Creek. Minor tributaries include Oregon Slough and Carrick, Julian, Willow, and Eddy Creeks (Figure 3.2).

3.3 Climate

The Shasta River Watershed is predominantly a low rainfall, high desert environment characterized by hot, dry summers and cool winters (NCRWQCB 2006). Temperatures range from above 100° F in the summer to well below freezing in the winter. Mount Shasta and the other mountains surrounding the Shasta Valley create a rain shadow, resulting in little rain in the valley while the majority of precipitation falls at the higher elevations. The majority of precipitation occurs between the months of October and March. The annual mean precipitation in the watershed ranges from 2.5-9 inches in the river valley to 85-125 inches in the mountains (NCRWQCB 2006). Average growing season in the Shasta Valley is 180 days.

Since the Shasta Valley receives little precipitation, snow is an essential component of the watershed's hydrograph and supplies the otherwise small Shasta River with spring-fed cold water. Approximately 39% of the snow and ice from Mount Shasta drains into the Shasta River. Recent severe drought years in the region brought little snow on Mt. Shasta and no snow on Mt. Eddy. Generalized climate model predictions for the Pacific Northwest include:

- Increased ambient temperatures
- Increased average air temperature
- Increased number of extreme heat days
- Changes to annual precipitation, including prolonged drought conditions and reduced snow pack
- Changes to annual stream flow and groundwater hydrology
- Changes to water quality
- Vegetation changes

3.4 Land Cover and Use

The National Land Cover Database (NLCD) serves as a commonly used satellite-based land cover dataset. NLCD data are used to understand land use changes as they relate to ecosystem status and health. The data are captured by a Landsat satellite at 30-meter resolution (Figure 3.3) and NLCD provides spatial reference and descriptive data for thematic land use classes such as urban, agriculture, and forest. Additionally, the satellite can also capture the percentage of impervious surfaces and percentage of tree canopy cover in a sampled area.

In the Shasta River Watershed, the predominant NCLD land cover classes are evergreen forest (37%), scrub brush (24%), and grass land (19%) (Figure 3.4). While urban development has increased in recent years in the city of Yreka and the Lake Shastina area, only a very small portion of the watershed is developed, with high density development at 0.04% of the entire watershed. Medium intensity development is at a slightly larger percentage (0.3%) which occurs in smaller communities throughout the watershed (Figure 3.4).

One concern regarding high and medium intensity development is the increase in impervious surfaces; however, this concern is minimal due to the low percentage of area in these classes. Impervious surfaces, such as asphalt roads, cement driveways, and parking lots, are a result of increased urbanization. Impervious surfaces can influence natural hydrology by preventing infiltration, interception, and evapotranspiration, which increases the rate of prompt discharge at the expense of season-long discharge. Additionally, runoff from impervious surfaces can carry pollutants into stormwater drains and local waterways. Currently, issues related to impervious surfaces only affect Yreka Creek and Lake Shastina.

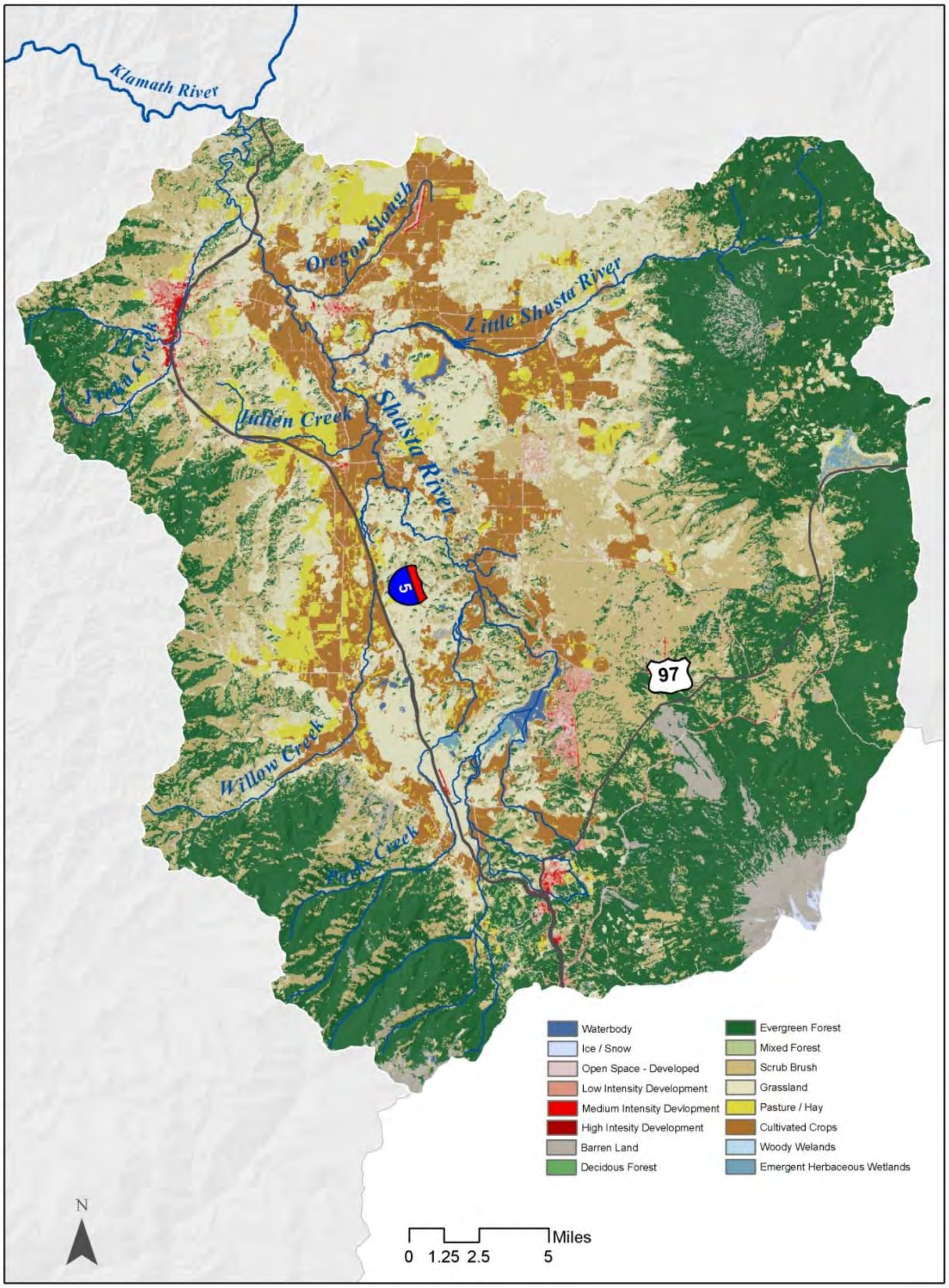

Figure 3.3: Land Cover Classes in the Shasta River Watershed (National Land Cover Dataset 2006)

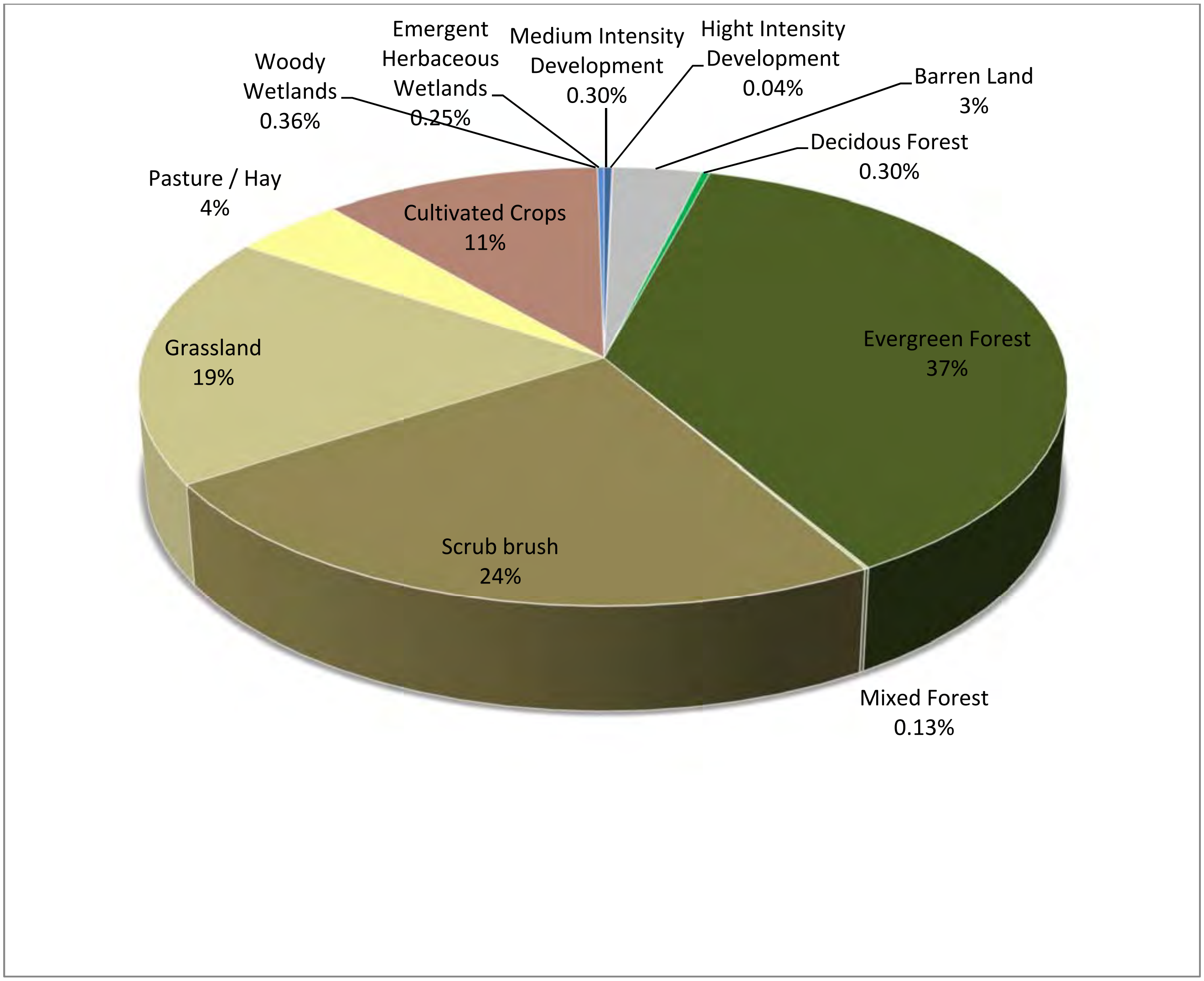

Figure 3.4: Shasta River Watershed percent of total acres by NLCD Class

In terms of watershed ownership, 65% of the Shasta River Watershed is privately owned, followed by 30% federal ownership and 5% state ownership. The U.S. Forest Service, U.S. Bureau of Land Management, and the California Department of Fish Wildlife own large parcels in the watershed. The Nature Conservancy, a non-profit organization, also currently owns key parcels on the mainstem Shasta River and Big Springs Creek.

Early European fur trappers explored the Shasta River Watershed in the 1820s, noting the prevalence of beaver and successfully trapping them throughout the watershed (Tappe 1942). The fur trappers were followed by cattlemen herding cattle from the Sacramento River to Oregon. The onset of the Gold Rush in 1849 initiated permanent European settlement near the town of Yreka. With the discovery of gold, the demand for lumber, food, and supplies increased and by the end of the 1900s, farming, ranching, and timber were the dominant land uses within the Shasta Basin.

Today, the primary land use of the Shasta River Basin is agriculture at 59% of the area. Irrigation season in the mainstem runs from April–September and in the tributaries from March–October. Stream gages at Montague / Grenada Road (USGS) and near Yreka (USGS) often show sharp declines in flow with the onset of irrigation season and rapid recovery at the end of the season (NCRWQCB 2006). During the growing season, most ranchers rely heavily on either in-stream water or groundwater to irrigate crops and water livestock, causing many surface diversions and ground water wells to have been developed over the last 150+ years. Today, approximately 60,000 acres of the watershed are irrigated, with 50,000 acres irrigated by surface water and 10,000 acres irrigated by groundwater. In addition to agricultural demands on groundwater, several schools, communities, and individuals rely solely on groundwater for their domestic water supply.

Broad variability in elevation, precipitation, and soil depth results in diverse vegetation types within the Shasta River Watershed. The following dominant habitat types were provided by *A Guide to Wildlife Habitats of California* (Mayer and Laudenslayer 1988).

> **Subalpine Conifer:** Dominated by open forests with needle-leaved evergreen trees in the harsh alpine environments at elevations between 7,000 and 9,500 feet on Mt. Shasta. Dominant tree species include subalpine fir, mountain hemlock, western white pine, lodgepole pine, and whitebark pine. Understory shrubs include manzanita, mountain heather, big sagebrush, lupine, and a variety of flowering annuals.
>
> **Montane Hardwood-Conifer:** Occurs at elevations of 1,000 to 4,000 ft, primarily in steep mountainous terrain. Dominant species include a variety of mixed, vigorously-growing conifer and hardwood species such as ponderosa pine, Douglas-fir, incense cedar, California black oak, and big-leaf maple, with very little understory.
>
> **Sagebrush:** Dominates a majority of the non-pasture areas of the Shasta Valley. Occurs in large open expanses at middle to high elevations. The primary species is big sagebrush but can also include rabbitbrush, western chokecherry, and bitterbrush.
>
> **Juniper:** Consists of woodlands dominated by junipers, either in the open or in dense aggregates of trees.
>
> **Montane Riparian:** Occurs in narrow strips along sections of the Shasta River and its tributaries. Species composition is variable and vegetation is generally structurally dense.
>
> **Pasture:** Consists of a mixture of perennial grasses and legumes, the composition of which varies according to management practices addressing the type of seed mixture, fertilization, soil type, livestock type, and irrigation method.

3.5 Anadromous Fish

The Shasta River has historically been one of the most important tributaries for anadromous fish spawning in the Klamath Basin. Records of Fall Chinook spawners were as high as 81,000 in the early 1930's, even after declines throughout the basin and the completion of Dwinnell Dam on the upper Shasta in the late 1920's. Observations of steelhead in the early 1960's indicated counts ranging from the hundreds to the thousands. Steep declines in fish populations over the past several decades have been documented, dropping as low as single digits in the Shasta River for coho and at times under 1,000 for Chinook. The decline in coho populations along the west coast led to the Federal listing of coho as a threatened species under the Endangered Species Act in the Klamath Basin in 1997, and a State listing as threatened followed in 2004.

The possible causes of the salmonid population decline are inferred from the analysis of limiting factors discussed in Chapters 4 and 8. Food source, however, is not considered limiting, and may be due the unique geology of the Shasta River Watershed supporting a spring fed, cold water, nutrient-rich environment that spurs a productive food source for salmonids. As snowmelt percolates through recent volcanic sand and ash on Mt. Shasta, it picks up phosphorus along the way. Phosphorous is then delivered to an area known as Pluto's Cave and eventually supplies the springs. In some areas of the Shasta River, such as Big Springs, the phosphorus-rich subsurface flow comes in contact with nitrogen-rich marine deposits. When the nutrient rich water surfaces, it creates ideal habitat for growth of in-stream vegetation and invertebrates, providing the foundation for the food web supporting juvenile salmonids.

3.6 Agricultural Sustainability and Economics

Economically, the Shasta River Watershed consists of disadvantaged communities, in which well-paid job opportunities are few. The region's economy is based on government jobs, ranching and farming, as well as tourism. There is a limited amount of timber harvesting on the watershed perimeter as well as some recreational gold mining. Although sport fishing opportunities in numerous mountain lakes and productive streams still draw tourists to Siskiyou County, most of the Shasta River is now closed to fishing. Lake Shastina provides motor boat recreational opportunities and the California Department of Fish and Wildlife's Shasta Valley Wildlife Refuge is also a draw for outdoor activities.

Agricultural income is primarily derived from cow-calf operations and their associated irrigated fields. Due to a short growing season, crops grown economically in the Shasta Valley are limited to grass hay, alfalfa hay, grains grown for livestock feed, and limited specialty crops. Because these agricultural activities tend to yield a low net-value product, opportunities for self-funded improvements in water usage and quality are very limited. Most of the farmers and ranchers in the Shasta River Watershed have long-standing cultural practices, many of which depend on the river for irrigation of pasture and hay fields, as well as riparian grazing. The land and water of the Shasta Valley is very valuable to the local economy and its residents. The 2015 Siskiyou County Crop and Livestock Report can be viewed at http://www.co.siskiyou.ca.us/sites/default/files/docs/AG-20160806_CropReport2015.pdf
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3.7 Water Use

The *Water Quality Control Plan for the North Coast Region* (Basin Plan) lists the existing beneficial uses of the Shasta River, its tributaries, and Lake Shastina as follows :

- Municipal and Domestic Supply
- Agricultural Supply
- Industrial service Supply
- Groundwater Recharge
- Freshwater Replenishment
- Navigation
- Water Contact Recreation
- Non-Contact Recreation
- Commercial and Sport Fishing
- Warm Freshwater Habitat
- Cold Freshwater Habitat
- Wildlife Habitat
- Rare, Threatened, or Endangered Species

- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development
- Aquaculture

The Basin Plan (NCRWQCB 2005) can be accessed at: http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/basin_plan.pdf.

Water law of 1914 included provisions that allowed water users to ask the courts to sort out conflicting claims for water (adjudication processes), and in turn created the Department of Water Resources (DWR). The DWR was therefore given the authority to provide watermasters with the legal authority to assure adherence to the court's findings.

Furthermore, the water law of 1914 gave riparian landowners 10 years to implement any plans they might have had to further develop their riparian rights. So as 1924 neared, throughout the state, irrigation districts were formed to take advantage of unclaimed water. This was also when water users in many watersheds, including the Shasta River Watershed, requested that adjudication of the water rights be done to eliminate the constant fighting over water. In 1932, as a response to landowner requests, all water use information was gathered in the Shasta Valley and the Siskiyou County Superior Court issued a decree listing how water was to be divided amongst all the existing water users in the Shasta Valley. While this settled agricultural water use issues, there was no solution to the looming issue of how fisheries and other beneficial use issues would be met.

3.8 Historical Ecology

Native Americans have inhabited the Shasta River watershed for more than ten thousand years with the first European settlers arriving in the early 1800s. All inhabitants left a distinctive legacy of changes on the landscape and the landscape continues to change today. Without a detailed understanding of the former characteristics of the region, and how these characteristics changed in response to human alterations to the landscape, appropriate ecological and hydrological restoration targets can be difficult to determine. The purpose of this section is not to define conditions at a particular point in time as a restoration target, rather it is to provide historical context for the trajectory of conditions over time to inform more completely a discussion of restoration or reconciliation targets for the Shasta River watershed.

Historical ecology is the study of landscapes and ecosystems in the historical period, defined here as the period of written human record. In the Shasta River watershed, this corresponds to a time of rapid change following the arrival of early trappers and miners. This report identifies key events beginning in the 1850s with the onset of mining, which led to broader settlement, and agriculture that we see in the watershed today. The information included in this report provides a good foundation upon which to continue to expand and refine the historical ecology trajectory for the Shasta River watershed. Information included on the Shasta River watershed historical ecology chart (Figure 3.5) includes:

- Historical events (1850 to 2012);
- Irrigated agriculture (acres – 1910 to 2015);
- Adult chinook population (1930 to 2015);
- Average recorded discharge (flow April – June 1945 to 2005);
- Average unimpaired discharge (calculated flow April – June 1945 to 1994);
- Number of days flow volume exceeded 70 cubic feet per second (cfs) for September 1st through 15th from 1930 to 2015 – plotted with annual adult Chinook population numbers;

- Number of days flow volume exceeded 70 cubic feet per second (cfs) for September 1st through 15th from 1930 to 2015 – plotted with annual adult coho population numbers;
- Number of days cfs was greater than 70 from July 1 to September 14 with Lamprey, juvenile coho, and juvenile Steelhead population numbers for the period 2000 to 2016.

Below are some brief notes, definitions, and references for the parameters included in the historical ecology diagram.

Irrigated Acreage: Irrigated Acreage data is used here as a surrogate for water diversions. Data was hard to obtain prior to 1998 (DWR keeps a good, public record for these recent years) so a trend line is used to portray the overall increase of irrigated lands, and thus, increased water diversion for the Shasta Valley. The R squared value of the trend line is 0.8838, a relatively good fit.

Adult Chinook: The most complete records of fish counts for the Shasta River are for Adult Chinook. This record was obtained from a California Department of Fish and Wildlife (CDFW) study done on assessing the Biological needs of Anadromous Fish in the Shasta River. At that time, work by the well-known fishery researcher John O. Snyder studying the Klamath system, described the fish runs in the Shasta River as 'gone', suggesting that severe decline had already taken place (Snyder, 1931). Counts by DFW show a continuing decline from 1930 through 1945. This period follows the construction of Dwinnell Dam, and it is widely recognized that dams block adult anadromous fish from returning to their spawning grounds. The blockading of spawning grounds up river of Dwinnell would logically leads to less fish in future years. Diminishing numbers could also be linked to loss of flow, though that is harder to discern as the data record for flow during this time period is incomplete. Lake Shastina and the irrigation system to which it delivers water are also widely reported within the community to be quite leaky during this early period. This adds even more uncertainty to the water balance in the Shasta River during this period of Chinook decline, making a direct tie to flow-related population impacts difficult. Nevertheless, the construction of Dwinnell is a key event that limited access to spawning grounds for adult Chinook, and modified the winter hydrograph essential for maintaining historic stream morphology by limiting the magnitude of high flows. Lacking pre-1930 data unfortunately masks the accumulating impacts of previous historical events along the timeline of human history in the Shasta Valley, such as a documented severe dewatering of the mainstem Shasta beginning in 1918 that ultimately led to the court adjudication of water use in the Shasta River (CDWR, 1922). While this uncertainty makes it impossible to know in absolute terms how great each impact to the system was, all collectively brought us to where we are now, with an abundance of opportunities for improvement within the watershed.

Recorded Flow vs. Unimpaired Flow: Recorded Flow vs. Unimpaired Flow uses flow and unimpaired flow estimates from the Bureau of Reclamation. Blue bars are unimpaired flow estimates, green bars are recorded flow, and the red line is the trend in difference between the two. Difference is included to give an insight in how we are increasingly moving away from natural flows. The unimpaired flow estimates were calculated using the following equation:

Unimpaired Flow = Recorded Flow + ((Annual Unimpaired TAF [thousand acre-feet] – Annual Impaired TAF) x Monthly % Diversion) ÷ # Days in month ÷ 1.9835

A DWR Preliminary Unimpaired Flow Study done in 1994 provided annual impairment quantities. Monthly % Diversion estimates were based upon crop estimates and ETIW provided by the Irrigation Training and Research Center. Recorded flow data were obtained from the USGS gauge at Yreka. Monthly unimpaired flow estimates were averaged to get a yearly estimate, as were the recorded monthly flows. Due to lack of values for annual unimpaired flows (see equation above), monthly unimpaired flows for years after 1995 could not be calculated and were not included in the record discharge versus unimpaired discharge graph.

The charts comparing daily mean flows greater than or equal to 70 cfs for several different species for specified time-periods (July 1 – September 14 and September 1-15) help to illustrate the relationship between critical flow thresholds with species populations.

Life Histories of Anadromous Fish in the Shasta River

The time anadromous fish rear in freshwater prior to their migration to the ocean is different for each species. For example in the Shasta River, approximately 8o% of the total Fall Chinook produced annually will emigrate to the Klamath River by April 15th spending as little as four months in the natal stream before they start their migration to the ocean . Coho salmon typically spend 18 months in freshwater before heading to the ocean. The most common life history tactic observed for steelhead in the Klamath watershed has 2 years of freshwater rearing prior to emigration to the Klamath River. Pacific Lamprey have the longest period of freshwater rearing for any anadromous fish in the Klamath watershed with the amoecete life stage spending up to seven years in the gravel prior to emigration.

Of all the species included in the historical ecology chart, Fall Run Chinook spend the shortest time in freshwater (Spring Chinook once present have been extirpated due to water use practices). Most Fall Chinook salmon in the Shasta River complete their egg, fry, paar, and smolt life stages after the end of the irrigation season (September 30th) and before the irrigation season begins on April 1st of the next year.

Coho, steelhead and lamprey must endure low flow conditions and elevated water temperatures due in part to numerous irrigation diversions and large amounts of returning irrigation water (tailwater). The status of these species with the extended freshwater life histories may be better examples of the status of anadromous populations than Chinook salmon.

Shasta Valley Historical Ecology

Historical Events

Native American land tenure for an estimated 12,000 years in the Shasta Valley.

Late 1820s: European/American settlement of the Shasta Valley

1851: City of Yreka Settled

1851: Gold Discovered in Siskiyou Couty

1854 - 1856: Yreka Ditch Constructed

July 4, 1871: Yreka Fire

1888: So. Pacific RR CO. builds a railroad through the Shasta Valley

1892: First Hydroelectric power facility built in Shasta Canyon

1910: The Shasta Tribe population drops from 2,000 in 1770 to 100

1912: Shasta River Water Users Assoc. Formed

1916: Grenada Irrigation District Formed and installs first pump

1918: Grenada Irrigation District installs second pump for 25 cfs

1919: Completion of the Original HWY 99 (Now Old Shasta Rd)

1920-1932: Shasta River Adjudication

1925: Montague Water Conservation Dist. formed

August 31st, 1926: First Water Master appointed on trial basis

1927: Big Springs Irrigation Dist. formed

1928: Dwinnell Dam Construction completed

1930: Two lane replacement of Old Hwy 99 (Now HWY 263)

1934: Watermastering formally begins

1941: Efforts to found the State of Jeffereson begin

1953: Shasta Valley Resource Conservation Dist. (RCD) formed

1955: Dwinnell Dam expanded from 35,000 AF to 50,000 AF

1959: Greenhorn Dam construction started

1968: Yreka gets water supply from Fall Creek

1970s: I-5 Contruction completed

1988: Shasta Valley RCD initiates first water quality study

1992: Shasta River added to the 303(d) list for DO

1994: Shasta River added to 303(d) list for Temperature

1997: Coho Salmon listed as a threatened species under Endangered Species Act (reaffirmed in 2005)

2006: Shasta River TMDL adopted

2012: Scott-Shasta Watermaster Dist. begins providing watermaster services

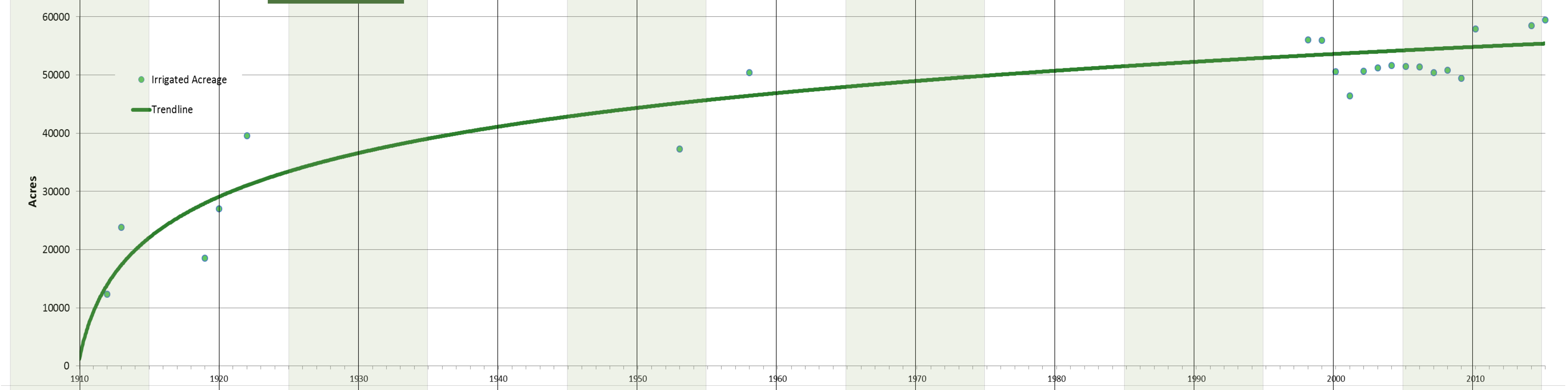
1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

Then and Now: A View of Grass Lake

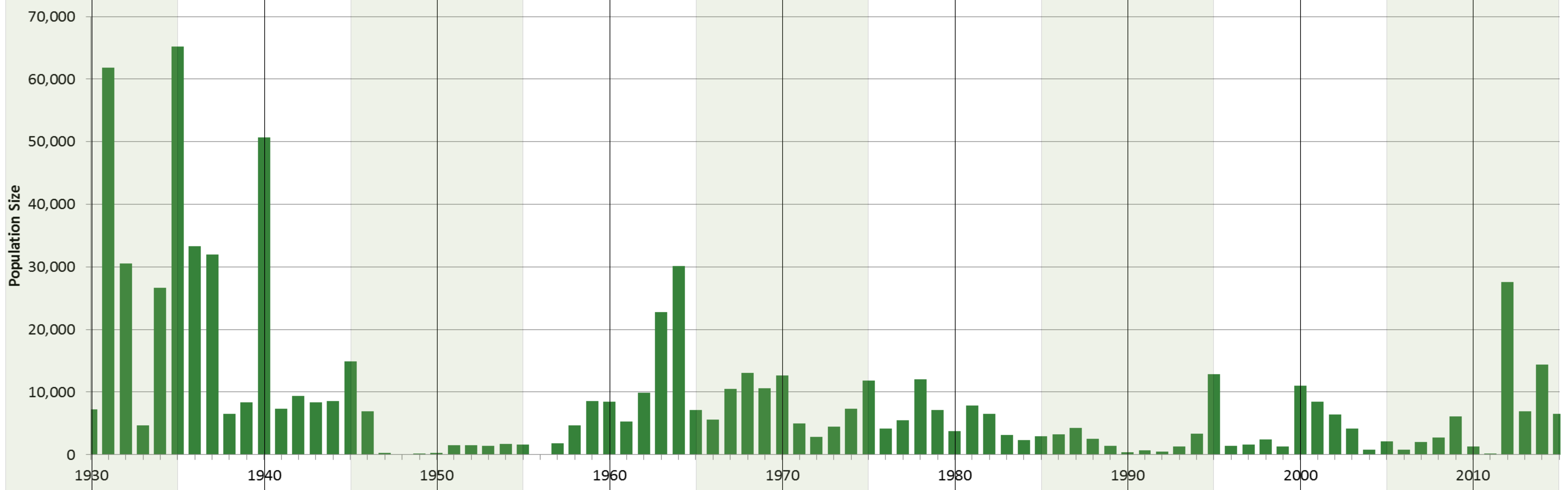
Summer, 1906:

Winter, Present Day:

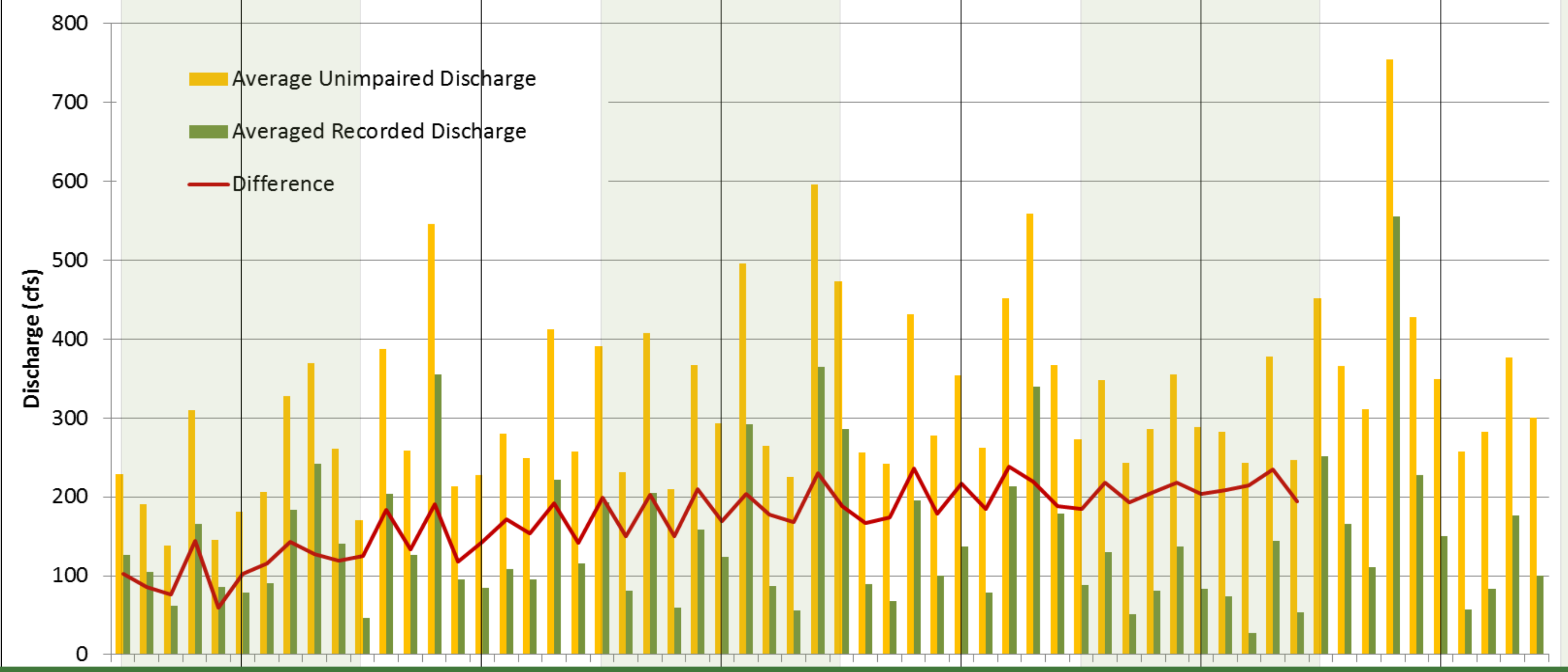
Irrigated Acreage (acres)
1912 - 2015



Adult Chinook Population
1930 - 2015

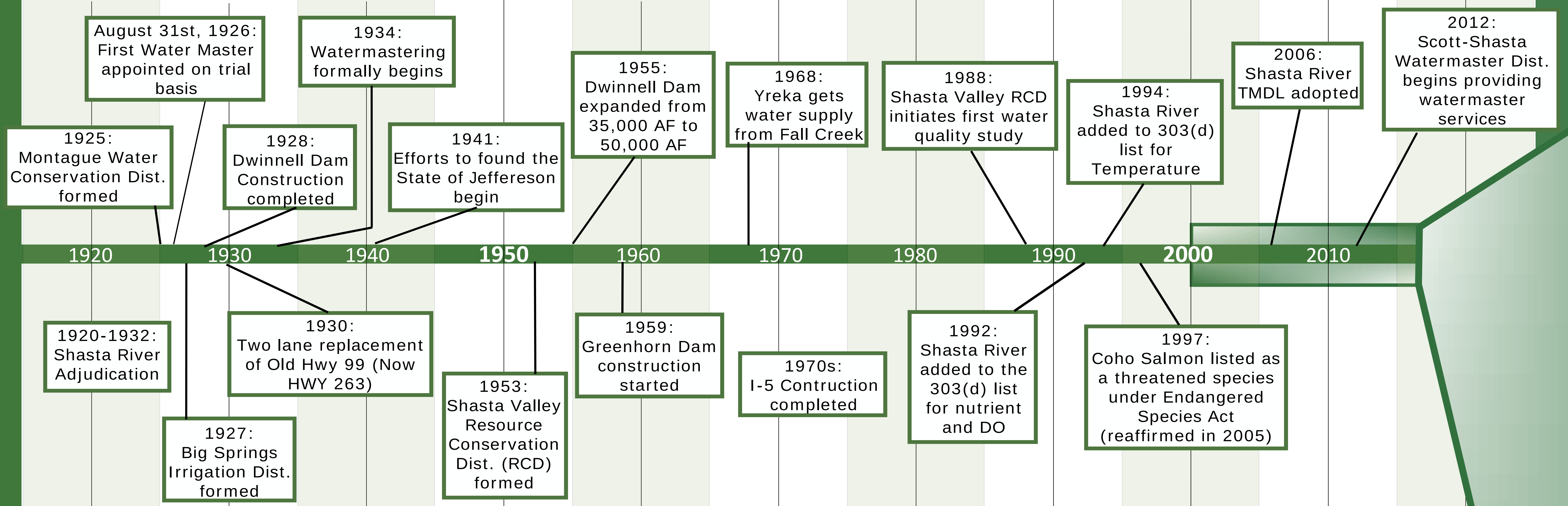


Recorded Discharge vs Unimpaired Discharge
April - June
(cfs)
1945 - 2004



1850 1860 1870 1880 1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

Historical Events (1920-2015)



1920-1932: Shasta River Adjudication

1925: Montague Water Conservation Dist. formed

August 31st, 1926: First Water Master appointed on trial basis

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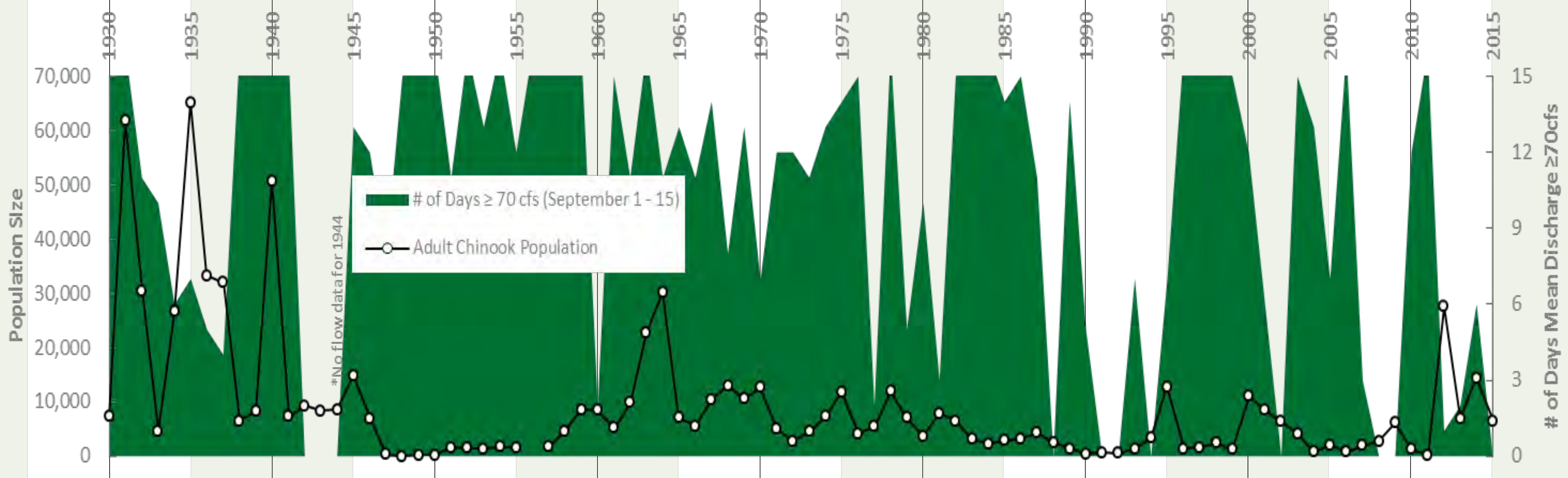
1994: Shasta River added to 303(d) list for Temperature

1997: Coho Salmon listed as a threatened species under Endangered Species Act (reaffirmed in 2005)

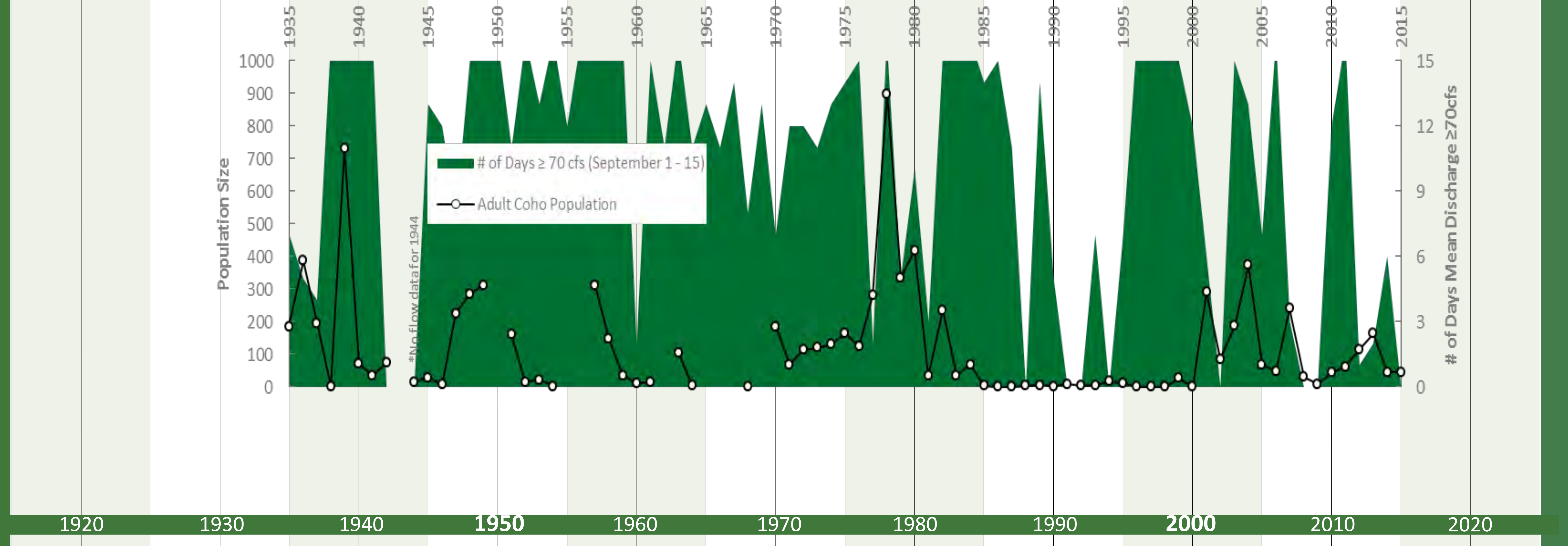
2006: Shasta River TMDL adopted

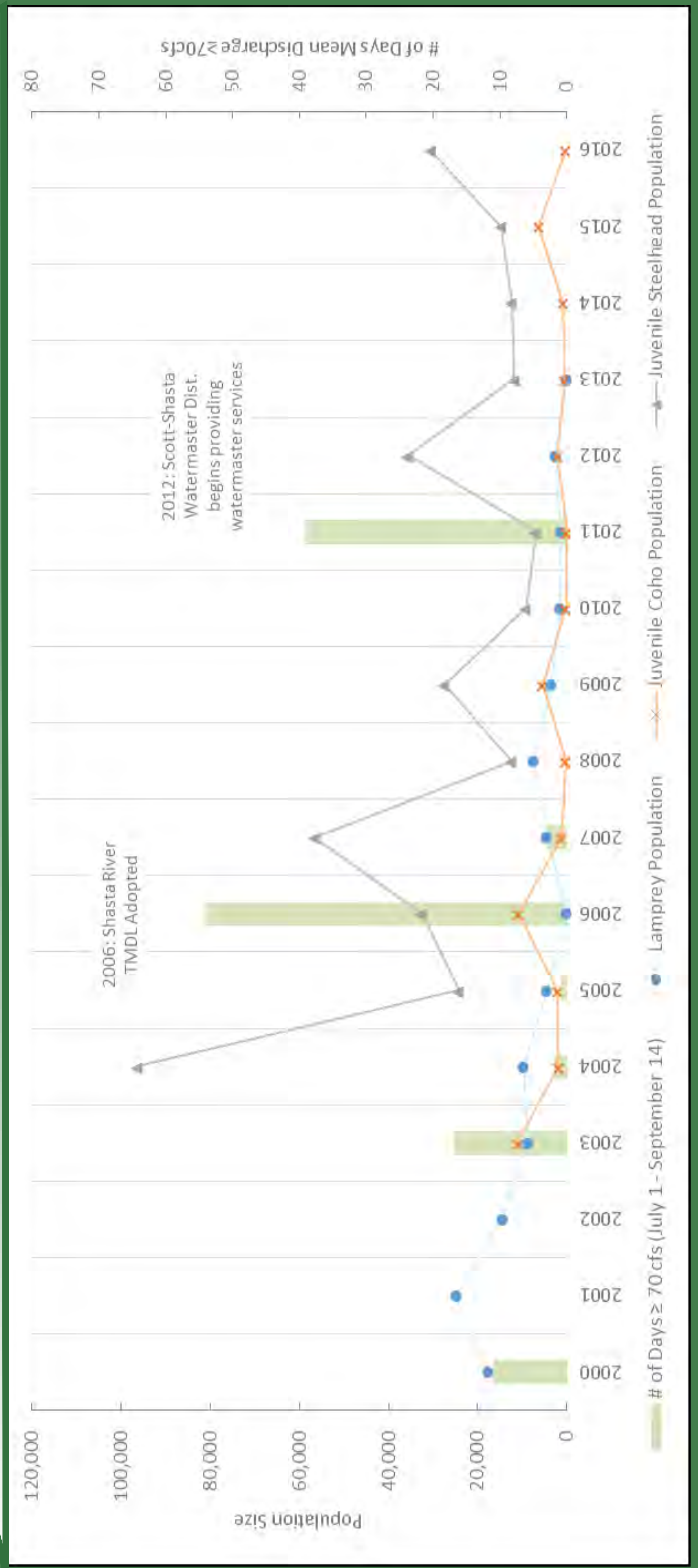
2012: Scott-Shasta Watermaster Dist. begins providing watermaster services

Number of days > 70 cfs v. Adult Chinook Populaiton (1930-2015)



Number of days > 70 cfs v. Adult Coho Populaiton (1935-2015)





Comparison of Lamprey, Juvenile Coho, and Juvenile Steelhead Populations to Number of Days > 70 cfs from July 1 - September 14 (2000-2016)

4. Water-Related Issues of Concern

In 1994, the Shasta River was added to the U.S Environmental Protection Agency 303(d) list of impaired watersheds. The Shasta TMDL was developed by the North Coast Regional Water Quality Control Board and adopted in 2007 for high temperature and low dissolved oxygen (NQRWQCB 2006). Agencies and local groups agreed the Shasta River had great potential for improvement success. The water-related issues of concern compiled by the Shasta Watershed stewardship partners are described below. Efforts aimed at better meeting all the beneficial uses of the river are necessarily focused on meeting supporting conditions for the most sensitive beneficial use – cold freshwater habitat - while working to avoid negative effects on agriculture. See the Shasta River Watershed Action Plan in Section 6 for stewardship efforts targeting these issues of concern.

4.1 Assessment of Current Conditions

The watershed stewardship approach uses adaptive management, a two track method to evaluate progress towards water quality goals. The first track involves keeping a record of watershed stewardship practices (e.g., riparian fencing, reduced tailwater return flows, riparian restoration) by reach (Figure 4.1) as they are implemented. This consists of both a simple inventory and the voluntary registration of projects by project sponsors in a database found at http://www.kbmp.net/stewardship. The second track involves a water quality monitoring program with strategically placed monitoring stations to evaluate overall progress towards water quality improvement goals (Table 1, Section 8 and Appendix B). The purpose of this monitoring network is not to identify individual sources of pollution but to track general water quality conditions by reach for status and trends over time. Although the effects of improvements tend to be cumulative, the information from these two tracks can be compared making it possible to help assess which practices are effective and which are not, and to better determine project priorities. This document includes a water quality temperature and dissolved oxygen assessment of monitoring data collected from participating partners (Appendix B) and a coordinated strategic monitoring program that will provide information to better inform and determine priorities regarding future water quality improvement projects (Appendix A). In addition, detail on projects implemented by SVRCD and detail on specific types of projects is included in the body of this report.

The analysis of existing water quality data involved obtaining data from several organizations. This required extensive quality assurance which resulted in a consolidated data set that was sufficient to conduct dissolved oxygen and water temperature trend analysis. Results from the constituent trend analysis are presented in section 8. The coordination with monitoring entities to acquire the water quality data used in the analysis and the completed dataset provide the foundation for future water quality trend analyses.

The Klamath Tracking and Accounting Program, under pilot development by the SVRCD for the Shasta, establishes a voluntary watershed stewardship project registry and verification protocols. This database provides information on watershed stewardship projects completed and anticipated benefits which will help better inform future management decisions.

The Shasta Watershed Stewardship Monitoring Program, developed by NCRWQCB and SVRCD staff, is a strategic ambient status and trends water quality monitoring network which coordinates the monitoring resources of several participating organizations (See Shasta River Monitoring Plan - Appendix A). The five participating agencies identified 14 permanent monitoring stations. All elements of the monitoring program were evaluated and discussed by participating agencies to provide information needed to provide the water quality information to address questions related to each organizations resource management responsibilities. The decision was made to use strategic locations to better assess general progress towards water quality improvement and overall stewardship program effectiveness. The Shasta River Watershed Stewardship monitoring program is not designed to address individual compliance issues. The network includes sampling for the following key parameters: water temperature, dissolved oxygen, pH, nutrient concentrations, benthic algal biomass, and riparian conditions (Figure 4.1 and Table 4.1).

Figure 4.1. Shasta River Watershed Reaches and Tributaries

Location	River Mile	Selection Rationale
Shasta River near mouth	0.61	● Downstream end of Reach 1 ● USGS stream flow gage ● Existing monitoring location, easy access
Shasta River at "Salmon Heaven"	5.60	● Temperature TMDL Compliance Point ● Easy access
Shasta River at HWY 263	7.29	● Downstream end of Reach 2 ● Downstream of anthropogenic impacts ● Upstream of TMDL compliance point at RM 5.6 ● Easy access
Shasta River at Montague Grenada Road	15.51	● Downstream end of Reach 3 ● Temperature TMDL Compliance Point ● USGS stream flow gage ● Easy access
Shasta River at Highway A-12	24.11	● Downstream end of Reach 4 ● Temperature TMDL Compliance Point ● Site likely to show beneficial temperature effects of rehabilitation work completed in the primary cold water source areas upstream. ● Existing monitoring location, easy access
Shasta River below Big Springs	33.66	● Downstream end of Reach 5 ● Existing monitoring location, easy access.
Shasta River below Parks Creek	34.92	● Downstream end of Reach 6 ● Existing monitoring location.
Shasta River below Dwinnell Dam	39.94	● Downstream end of Reach 7 ● Represents the water quality released from Lake Shastina.
Shasta River at Edgewood Road	47.52	● Downstream end of Reach 8 ● Montague Water Conservation District stream flow station. ● Represents water quality entering Lake Shastina.
Big Springs Creek near mouth	0.04	● Temperature TMDL Compliance Point ● Most downstream point accessible
Oregon Slough at Ager Road	2.33	● Most downstream point easily accessible
Little Shasta River Below DFG diversion	6.43	● Most downstream point easily accessible
Parks Creek near mouth	0.03	● Temperature TMDL Compliance Point ● Most downstream point accessible
Willow Creek at West Louie Road	8.72	● Most downstream point accessible
Yreka Creek near mouth at Anderson Grade Road	0.59	● Most downstream point accessible ● Existing monitoring location, easy access

Table 4.1. Selected Water Quality Monitoring Locations in the Shasta River Watershed

4.2 Temperature

Elevated water temperature is the most widespread stressor for salmonids in the watershed. Elevated water temperature can have adverse effects on growth, feeding rates, and early development (NMFS 2012). Additionally, warmer water temperatures can increase salmonid susceptibility to disease and negatively impact other life history events. In the Shasta River Watershed, the life stage that is most adversely affected by elevated temperature is summer-rearing juvenile coho. According to a 2008 coho habitat and migration study, all rearing coho were associated with areas of cold springs input (Chesney et al, 2010).

Water temperatures in the mainstem Shasta River are influenced by solar radiation, air temperature, stream flow volume, stream depth, inputs of colder or warmer water from surface flows or springs, and withdrawals of water (affecting stream flow volume and travel time). Although the relationships are intertwined, some factors play a larger role on water temperature than others. Elevated water temperature can be associated with lack of riparian shade, inadequate tailwater management, impoundments, elevated air temperature, and aggraded stream channels as a result of sediment inputs. At a regional scale, climate change and the associated increase in air temperature could have an impact on water temperature. A detailed analysis of all available temperature data is presented in section 8.1.

4.3 Dissolved Oxygen

Dissolved oxygen is influenced by a host of factors, including water temperature. The amount of oxygen that can be dissolved in water decreases with increasing water temperature. Primary factors beyond water temperature that impact the amount of dissolved oxygen in a stream include: turbulence (aeration), biological/biochemical oxygen demand exerted by organic debris and chemical transformations, aquatic plant productivity (oxygen production by day and respiration/oxygen consumption by night), and nitrogen and phosphorus in sediments and the water column which can increase plant productivity. Depressed dissolved oxygen affects all aquatic organisms and can impair growth, development, and mobility and increase susceptibility to diseases. Extremely low dissolved oxygen levels can impair fish to the point of death. A detailed analysis of all available dissolved oxygen data is presented in section 8.2.

4.4 Water Use and Instream Flow

Water use in the Shasta Valley has periodically generated controversy over many decades. The economy of the area grew out of extensive surface water diversions implemented to support both agriculture and mining. As mining and mineral extraction gave way to more extensive agricultural activities, additional water diversions were built to meet the growing local demand for irrigation water. As water demand exceeded supply, conflicts developed, and water users turned to the state to help clarify and formalize rights to water use in the valley. This process was never geared towards understanding the needs of the environmental systems that support water quality, public health, or environmental health in the river. As such, past efforts to resolve water conflicts only set the stage for future conflict by failing to balance water use vital to support the agricultural and economic engine of the Shasta Valley with the volume of water essential to support the systems that sustain the river's ecological health. Of course, flow restoration in any river system must be done in ways that are simultaneously sensible, achievable and legally sound. Each river system has its own natural physical, social, and legal constraints, all of which must be understood if progress is to be made. Understanding water availability and usage in the Shasta Valley requires an understanding of both the workings of surface water and the workings of groundwater and the inter connections of the two. What follows is a brief overview of those constraints to understand where we are and where we need to go to steward equal goals of environmental and economic sustainability.

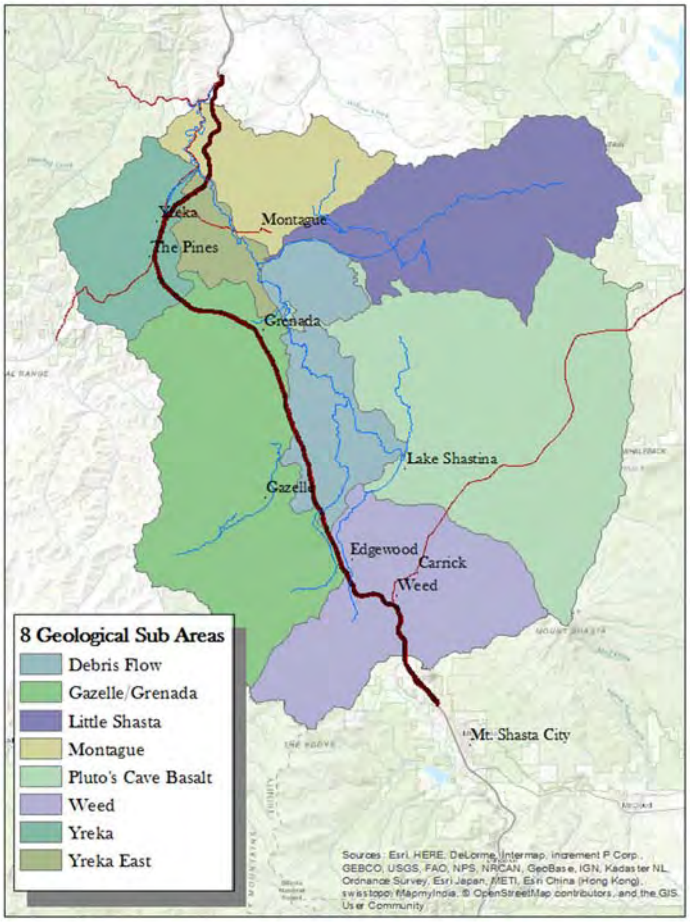
Diversions and Adjudication

The diversion of Shasta River surface water for agriculture is the primary water use in the Shasta River Watershed. Beginning early in the irrigation season, surface water is fully appropriated and streamflow is drastically reduced until the end of the mainstem irrigation season on October 1 (SWRCB 1998).

Following the formation of the Grenada Irrigation District, conflicts over water among the people living in the Shasta Valley became so severe that in 1921 a number of water users in the Shasta Valley sent a request to the State of California asking for help to sort out and prioritize the conflicting demands for water. That resulted in a court adjudication completed in 1932. The adjudication attempts to allocate to each user a defined amount of water for their use. However, water rights are set to promise an amount expected during wet years, and as seasonal flow variations vary water allocations can be dialed back and deliver less than the adjudicated amount to more junior water right holders. For all but the most senior rights, the actual amount being diverted is unpredictable from one year to the next. Regardless of the above, in all years low flows result from diversions during the summer irrigation season. This leads to increased water temperatures: less water has less thermal mass, more surface area relative to wetted perimeter, and a longer travel time to the mouth, which allows for more heating to occur. In its present form, the adjudication applies primarily to the main stem of the Shasta River and its larger tributaries, but excludes Yreka Creek, Willow Creek, and some minor springs that do not connect with surface streams.

Following the court adjudication of the Shasta River in 1932, the California Department of Public Works established a watermastering service for the Shasta River, as they had done in many other streams throughout the state since 1914. The primary role of the watermaster is to ensure an unbiased, qualified person allocates water according to established water rights, as determined by the court adjudications. The aim of this service is to reduce water rights related litigation and law enforcement workload. Initially, the costs of watermastering services were split evenly between the water users in a given river system and the state. State budget issues in the mid-2000s led to a shifting of costs to the water users only. This led to the formation of a state-authorized and locally managed watermaster special district (the Scott-Shasta Watermaster District). A board elected by the water users directs the Scott-Shasta Watermaster District and a staff of watermasters working for them continue the tradition and duties previously provided by the state watermasters.

Functionally, the watermaster is available all year. The vast majority of their work occurs during the summer irrigation season when they must regularly visit points of diversion, measure stream flow, and adjust the amount of the water delivered to each user. Watermasters base their decisions on the quantity of water available and each person’s water right, as described in the Shasta River adjudication. Additionally, the watermaster is often called on to explain to new landowners the proper workings of water law and otherwise help people understand how they must work together in sharing a river system



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 4.2 - Geologic sub areas in the Shasta watershed.

incapable of meeting everyone's needs and desires for water. What the watermaster does not have authority to do is to either determine what instream flows should be, or where they should come from. Since the court adjudication was only intended to make sure that all the water in the river was distributed for irrigation and similar purposes, it set the foundation for current conflicts over personal water use and environmental water use. Because of details of the law at the time of the adjudication, holders of riparian rights can and do simultaneously have both adjudicated rights subject to watermaster control and riparian rights legally beyond the watermaster's control, creating a difficult management environment.

As water law is a constantly evolving process based on case law, predicting the outcome in any particular conflict situation is difficult or impossible to do.

Groundwater

While the use of surface water was largely systemized via the Shasta River Adjudication, the use of groundwater is unmanaged, unregulated, and largely un-monitored. Investigations by the SVRCD, working with DWR, between 2004 and 2009 determined that unlike most similar sized valleys with a single groundwater basin, groundwater in the Shasta Valley is geologically divided into 8 sub areas (See Figure 4.2)

These basins appear relatively independent of each other, both in terms of infiltration source areas and water yield. This complex hydrogeology is a result of the combined effects of the position of the Shasta Valley as the contact zone between the coastal accretions forming the Klamath Mountains and the Western Cascades, the volcanic activities of the east side of the Shasta Valley, and the presence of the large lahar flow, filling the center of the Shasta Valley (Figure 4.2).

This aquifer system is the primary source of cold water inflow to the Shasta River below Dwinnell Dam during summer and fall months, a flow that is critically important to coho and other salmon and to every person with a surface water right below Dwinnell. Groundwater extractions from the Shasta Valley have historically affected groundwater discharge to the river. Future residential and agricultural development—and corresponding increases in groundwater usage—may further reduce this source of cold water supply to the river (DWR, 2011).

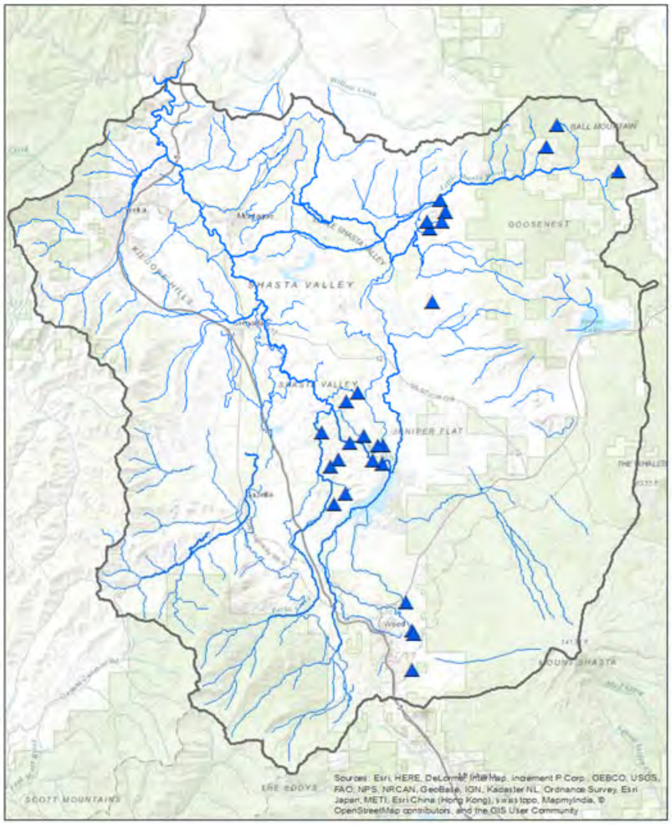


Figure 4.3 - Major springs in the Shasta watershed.

The most important areas of agriculturally useful groundwater volumes and those linkages to surface flows are the fractured rock areas of the Pluto's Cave Basalt, the headwater slopes of the Little Shasta River, and the slopes of Mt. Shasta itself. These areas transmit large quantities of water from infiltration zones on Mt. Shasta and volcanic areas on the east side of the valley to springs that feed the Shasta River near Weed, Big Springs, and the Little Shasta River (See Figure 4.3).

The Pluto's Cave Basalt in particular yields a significant quantity of water. This contribution of groundwater is responsible for nearly the entire reliable unimpaired summer base flow of >100 cfs in the Shasta River.

For the approximately 16,000 residents of the Shasta Valley, except for those living within Weed (pop 3000) or Yreka (pop 7000), groundwater is the only source of domestic water. While some areas of the Shasta Valley have high quality water, other areas are problematic. Naturally occurring arsenic, along with sodium, boron or other marine derived minerals have been encountered in groundwater. Table Rock Springs has saline carbonated waters high in sodium, chloride, and boron. Some areas have high conductivity, boron, and calcium. Locally high magnesium, iron, fluoride, nitrate, chloride, sodium, sulfate, hardness, and total dissolved solids concentrations, occur within the basin. Total dissolved solids range from 131- to 1,240-mg/L, averaging 406 mg/L (DWR 2003).

Based on DWRs review of well completion reports, groundwater development in Shasta Valley has primarily been for domestic use, which accounts for approximately 82 percent of all groundwater wells. Irrigation wells, the next largest category, account for approximately 9 percent. The number of domestic and irrigation wells constructed within each hydrologic sub-area is summarized by well use in Figure 4.4.

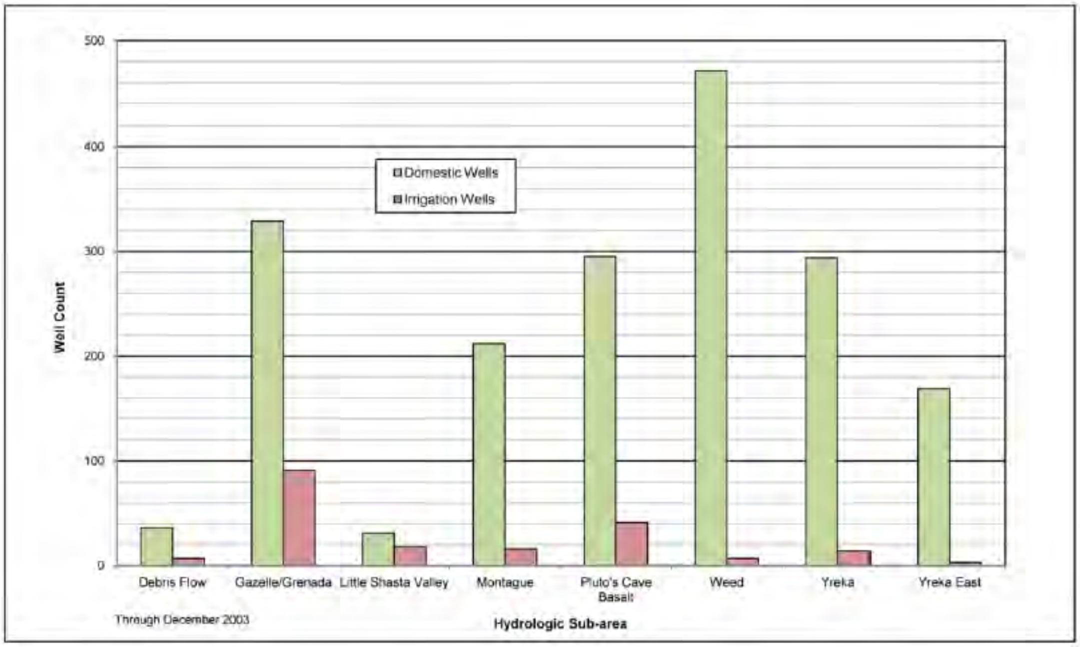


Figure 4.4 - Groundwater development by hydrologic sub-area (DWR 2011).

Based on available well log data, wells installed within the area range from 20 to 780 feet in depth, while irrigation wells with total depths of 40 to 810 feet below grade are necessary to extract groundwater. Ultimately most uses of groundwater occur only where it is of reasonable quantity, quality, and depth. Domestic well yields in the area range from an average of 19 gallons per minute (gpm) to 52 gpm, while irrigation well yields range from an average of 255 gpm to 517 gpm (DWR 2011).

Groundwater in the Shasta Valley is derived from both natural and human-induced infiltration. Leakage from Lake Shastina, from irrigation delivery ditches, and from deep percolation from flood irrigation all contribute to human-induced infiltration. Natural infiltration is presumably the vast majority of the total infiltration. Ditch leakage occurs primarily in the summer, when recharge is most needed. Efforts to improve water use efficiency via ditch lining along with conversion from flood irrigation to sprinkler irrigation have the potential to affect local groundwater levels.

Well Monitoring and Management

Depth to water has been monitored in a number of wells by DWR over the years. In an effort to improve groundwater management throughout the state, the California Legislature has initiated the California Statewide Groundwater Elevation Monitoring Program (CASGEM) in 2009 to more fully understand changes in groundwater elevation and aquifer storage. DWR currently monitors 27 wells located in the Shasta River Watershed. Two additional wells in the Shasta River Watershed have been recently monitored by Siskiyou County. Water level measurements are selected based on measurement date and well construction information (where available) and approximate groundwater levels in the unconfined to uppermost semi-confined aquifers. Collecting these data over time allows for the evaluation of changes in groundwater elevation, gradient, and changes in storage.

In September of 2014, Governor Edmund G. Brown, Jr. signed a three-bill package known as the Sustainable Groundwater Management Act (SGMA). The Sustainable Groundwater Management Act:

- Authorizes management tools for local groundwater sustainability agencies

- Requires that Groundwater Sustainability Plans (GSPs) be adopted by 2020/2022[1]
- Provides for a limited role for the State Water Board as a "backstop" if local agencies opt out management responsibilities
- Establishes a definition of "sustainable groundwater management"

SGMA required, by June 30, 2017, the formation of locally-controlled Groundwater Sustainability Agencies (GSAs) for all alluvial basins identified by the DWR Bulletin 118 as high or medium priorities. A GSA is responsible for developing and implementing a GSP to meet the sustainability goal of the basin to ensure that it is operated within its sustainable yield and without causing undesirable results.

Currently the Shasta Valley Basin GSA is the Siskiyou County Flood and Water Conservation District. To date the focus of SGMA is only on alluvial groundwater basins, regardless of whether or not fractured rock basins are of greater local importance. However, local stakeholders and state agencies acknowledge that much of the Shasta Valley's groundwater resources exist in volcanic fractured rock.

According to the *DWR Shasta Valley, Siskiyou County Groundwater Data Needs Assessment 2011*, the following assessment measures are recommended:

- Develop groundwater budget.
- Assess water conveyance ditch losses.
- Expand groundwater monitoring – private and dedicated wells.
- Characterize groundwater recharge sources
- Expand stream temperature monitoring.
- Provide water quality testing in support of groundwater/surface water interaction assessment.

Stream Flows and Fishery Health

The demand for irrigation water has substantially altered the natural flows of the Shasta River. At the time of the adjudication, no apparent consideration was given to the importance of instream flows, and there has been a recent effort by agencies to understand flow volumes prior to diversion. These pre-irrigation flows are referred to as "unimpaired" while instream flows affected by irrigation are considered "impaired".

According to the 2013 *Study Plan to Assess Shasta River Salmon and Steelhead Recovery Needs (SVRCD et. Al, 2013),* the unimpaired annual snowmelt flows below Parks Creek was estimated to be 200-300 cfs and the unimpaired annual snowmelt flows below Big Springs was estimated to be 300-425 cfs. Those flows are believed to have persisted through April and May for most water years and through June for wetter years. Compared to unimpaired flows, the current spring and summer baseflows under impaired conditions have been dramatically reduced due to the on-set of irrigation season and snow melt capture by Lake Shastina (ibid). Currently, springtime impaired baseflows at the mouth of the river range from 50-120 cfs. Summer baseflows at the Shasta River mouth that historically ranged from 170-250 cfs of baseflow have been reduced to 10-40 cfs (ibid).

The overall altered hydrology, stream channel geomorphology, riparian habitat, and instream habitat resulting from irrigation water use presents varying levels of stress to the different life stages of salmonids. Due to the reduced summer flows in the Shasta River and the importance of summer rearing temperatures to juvenile coho, the SVRCD initiated efforts to identify and reconnect key cold-water

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[1] Groundwater basins identified as areas of critical overdraft are required to have GSPs adopted by 2020.

springs, increase instream flows through in-stream water rights dedications, and develop voluntary water transactions to provide for salmonids' short term needs.

In an effort to mesh local water needs with good basin-wide stewardship, a variety of flow related efforts have been initiated over the years. The first flow augmentation efforts in the Shasta Valley were pulsed flows to assist outmigrant salmonids, which began in 1993 by the SVRCD and the Coordinated Resources Management & Planning (CRMP) group. Pulsed flows were initiated to assist juvenile outmigration in May or early June, after the start of the irrigation season, but before the onset of potentially lethal water temperatures. Pulsed flows were dropped following the coho salmon listing due to the possible risk of stranding individual coho juveniles. Since 2009, there has been a coordinated and voluntary effort among landowners to leave portions of their water right instream when water was needed to assist salmonid migration. These efforts have been completed either informally or by written forbearance agreements. The program, largely coordinated by the SVRCD and The Nature Conservancy, has been refined over the years to provide critically needed water to assist salmonid fry outmigration in the spring and spawning Fall Chinook entering the Shasta River in the fall. There is also a coordinated voluntary ramping and staggering of diversion start up in the spring to avoid stranding of fish from rapid decline in water level.

In an effort to quantify some of the results for these efforts by members of the irrigation community, The Nature Conservancy and UC Davis prepared a paper published in the October 2015 Journal of Water Resources Planning and Management. The paper presented data showing how in the fall of 2012 the increased stream flows had measurable water quality benefits to adult Chinook salmon who were holding in pools in the lower Shasta River prior to completing their migration to spawning areas. This study found that the increased stream flows were particularly effective when flows were low, and large numbers of fish returned. The results indicate that water transactions may mitigate potential water quality impairments by decreasing the residence time of water in holding habitat. These actions are particularly effective during periods when flows are low, holding habitats are near carrying capacity, and dissolved oxygen demand by fish is elevated. Documents such as this help validate and encourage continued leadership in developing ground-up collaboration for balanced management of water resources.

CDFW has recently renewed efforts to investigate instream flow needs throughout the state, including for the Shasta River, and has worked with a consultant to develop a comprehensive study plan for doing the necessary flow-related investigations. Information about the state-wide program and information on the Shasta regarding that effort are held by CDFW at: https://www.wildlife.ca.gov/Conservation/Watersheds/Instream-Flow/Studies/Scott-Shasta-Study .

In addition to the above legislatively mandated focus on groundwater, the California Natural Resources Agency, the California Environmental Protection Agency, and the California Department of Food and Agriculture developed the California Water Action Plan (WAP), which was signed by Governor Edmund G. Brown Jr. and released to the public on January 22, 2014 (SWRCB, 2014). The WAP has been developed to meet three broad objectives: more reliable water supplies; the restoration of important species and habitat; and a more resilient, sustainably managed water resources system (water supply, water quality, flood protection, and environment) that can better withstand inevitable and unforeseen pressures in the coming decades. Through a coordinated effort between the State Water Board and CDFW the Shasta River has been identified as one of the five priority stream systems for the initial WAP effort. The agencies involved in the WAP process will be considering all water bearing units within the Shasta Valley as contributing towards the water budget, including infiltration from irrigation. This bodes well for decision-making based on the analysis conducted by the California Water Action Plan, as it will begin with a more complete picture of the Shasta Valley's water budget.

4.5 Fish Passage

The relatively flat and mineral-rich soils of the Shasta Valley present excellent opportunities for agriculture. However, the Shasta Valley rainfall pattern severely limits non-irrigated agriculture. Beginning in the 1850s, individuals and groups initiated a variety of efforts to divert water from the Shasta River and its tributaries into ditches and canals to facilitate crop irrigation. While some operations were quite small in scale, consisting only of a few rocks piled in the stream to divert water to nearby fields, others were large and consisted of formal structures installed each spring consisting of a permanently installed framework and removable flashboards. The largest water management project, Dwinnell Dam, was a 60 foot high earthen structure completed in 1928 with a 21-mile-long main delivery canal supplying both irrigation and drinking water.

While these diversion methods worked well for irrigation, they posed significant barriers to fish passage. For example, irrigation diversions can entrain fish and create passage problems for juveniles looking for cold water refugia. Furthermore, barriers block the movement of spawning gravel from upslope sources to the spawning grounds. Larger barriers also influence the hydrograph and the discharge over time by storing water during peak flow events. Additionally, barriers may impound large volumes of water which can act as a heat source due to thermal loading of the water body over the summer months.

Efforts to install fish screens on diversion ditches began in the 1920s and fish ladders were installed on most of the flashboard diversion dams in the early 1980s. By the mid-1990s, fishery and water quality improvement efforts began to focus on the challenging task of removing all but the largest diversion structures, while still retaining the original design function of supplying water for irrigation.

4.6 Biostimulatory Conditions - Nutrient Loading

Nutrients can be both a benefit and detriment to aquatic ecosystems. Adequate nutrients support a productive environment for plants and invertebrates; this environment then serves as the base of a productive food web supporting healthy salmonid populations. However, excess nutrients in combination with other factors such as low flow, high temperatures, reduced riparian canopy, and reduced channel depth and complexity can overwhelm an aquatic environment by encouraging nuisance aquatic vegetation (e.g., algae) blooms that create low dissolved oxygen conditions, elevate pH levels, and potentially increase ammonia toxicity. Biostimulatory (nutrient loading) conditions exist when any combination of the above factors begins to diminish water quality conditions to a point where sensitive fish populations and other aquatic life are negatively impacted.

One of the primary measures of the degree of biostimulatory conditions is the daily range in dissolved oxygen concentrations. Aquatic ecosystems with higher degree of biostimulatory conditions show a much wider range in daily dissolved oxygen concentrations than waters without excessive biostimulatory conditions. This range is caused by increased dissolved oxygen levels from daytime photosynthesis and decreased dissolved oxygen levels from nighttime aquatic vegetation and algal biomass respiration.

Due to the unique geologic nature of the watershed, the Shasta River is naturally high in nutrients such as nitrogen and phosphorous. This, in combination with the naturally cold and highly oxygenated waters of the Shasta River, explains why the river historically had supported such large and robust populations of anadromous fish. However, when temperatures and nutrient and organic matter loads increase, the biostimulatory equilibrium moves to conditions that are generally less supportive of a healthy ecosystem and native species, especially salmon and steelhead populations.

4.7 Fine Sediment

Excess sediment is defined as soil, rock, and/or sediments (e.g. sand, silt, or clay) from human related activities that is discharged to waters of the state in an amount that could be deleterious to beneficial uses or cause a nuisance. High sediment loads can pose a threat to the migration, spawning, reproduction, and early development of cold water fish such as coho salmon, Chinook salmon, and steelhead trout. Excess sediment loads can fill in and simplify pool habitat, prevent the establishment of riparian vegetation, and alter channel morphology. In addition to harming aquatic life, excess sediment can limit water use for domestic consumption, agriculture, industry, wildlife, fishing, and recreation and can contribute to flooding.

While the Shasta River is not listed under the TMDL for excess fine sediment, regions of the Shasta have exhibited elevated fine sediment levels and, at the same time, often restricted coarse sediment which serves as spawning gravel. Some of the less obvious effects of low stream flow include the reduced ability to flush fine sediment from spawning gravels and the inability to move coarse gravels downstream and/or create the gravel bars necessary for riparian trees to establish.

Sediment oxygen demand (SOD) is the sum of all biological and chemical processes in sediment that utilize oxygen. SOD can be an important part of a stream’s dissolved oxygen budget and the effects of SOD can be long lasting, occurring well after the pollution discharge ceases (Flint et al. 2004). SOD is an important factor in water bodies with an abundance of sedimentary organic material from soil erosion and plant and algal detritus, as well as in water bodies containing impoundments. Since the Shasta River is susceptible to increased SOD due to nutrient and sediment inputs, stewardship actions that address these potential impacts can benefit coho by helping ensure adequate dissolved oxygen levels.

Degraded riparian conditions can lead to erosion, reduced stream bank stability, and ultimately the introduction of excessive fine sediments to the river. In turn, this can reduce the amount of instream habitat by filling in spawning gravels. A healthy riparian zone helps to strengthen and stabilize stream banks, slow floodwaters, and shield banks from erosion during high flow events. Additionally, vegetated riparian buffers serve to filter fine sediments and, in turn, filter organic matter and nutrient inputs.

Agricultural activities can increase fine sediment loads to the river through unmanaged livestock activity destabilizing stream banks and altering riparian vegetation. The introduction of fine sediments through livestock activity (i.e. through nutrients sorbed to fine sediments) and the direct application of manure can increase nutrient levels further contributing to reduced dissolved oxygen conditions.

5. Stewardship Approaches Taken to Improve River Conditions

5.1 Completed Key Stewardship Actions

The key stewardship actions provide multiple benefits for improving salmonid habitat and water quality. These actions reduce stream temperatures, increase dissolved oxygen concentrations, and aim to improve instream flows through the summer and fall. Tailwater management reduces the delivery of nutrients, sediment, and warm water to the Shasta River and its tributaries. Improved irrigation efficiency can leave more instream flow for salmonids. Riparian fencing protects riparian habitat through managed livestock access to waterways, thereby reducing nutrient and sediment delivery and increasing stream-side shade. Riparian planting further provides stream-side shade and reduces instream temperatures. Fish passage improvement reduces fish entrainment and increases access to habitat. The combination of these efforts has improved habitat and water quality conditions throughout the basin over the past thirty years, and more stewardship actions are both underway and planned.

During the past decade there has been a multi-agency effort to implement key stewardship actions, achieved with marked success. Agencies have been working alongside local landowners to improve habitat and water quality conditions in the Shasta River Watershed. These efforts are part of a long-term effort to systematically address limiting factors in the Shasta River Watershed. This report provides detail on projects completed by SVRCD in the past decade by project type and reporting reach (Table 5.1).

One of the most compelling examples of successful stewardship actions is the Big Springs Ranch Complex. In 2005, TNC purchased the Nelson Ranch, a large upper Shasta River property in Reach 4. TNC also purchased an adjacent large property extending into Reach 5 along the Shasta River and Big Springs Creek in 2009, which included a conservation easement along Big Springs Creek up to the outfall of Big Springs Lake. Since these purchases, TNC and partners have worked to improve land management and irrigation practices while maintaining a working ranch on the property. Additionally, TNC has worked to restore cold water flows and physical habitat in Big Springs Creek and to increase cold-water inputs to the Shasta River. TNC has conducted stewardship actions such as tailwater reduction, installation of cattle exclusion fencing and off-channel stock watering systems, development of a method to monitor and manage return flows, and performed riparian planting. Simply excluding cattle from the riparian zone yielded increased growth of in-stream vegetation and a subsequent decrease in stream water temperatures. The result of this simple stewardship action benefited water quality and provided spawning and rearing habitat for coho salmon. The success of this project demonstrates how stewardship activities can potentially benefit water quality and fisheries.

5.1.1 Fish Passage Improvements

Fish barriers can impede the movement of fish upstream and downstream of the barrier, which can include culverts, flash-board dams, water diversions, and dams. Depending on the type of barrier and stream flow, barriers can impede or block access to spawning habitat and prevent migration downstream, which affects the survivorship and success for a fish population. Instream impoundments created by these barriers can also impact water quality and can create a temperature barrier for salmonids. The Shasta River Watershed has two permanent dams, Dwinnell Dam and Greenhorn Dam; the direct stress level of these barriers on various life stages of coho are considered to be low. Cooperative efforts to replace small irrigation structures with boulder riffles, as pictured below, provide the structure needed for irrigation pumping while providing access for migration and thermal refugia for all life stages of salmonids (Figure 5.1).

Figure 5.1. Shasta River Water Association Flashboard Dam fish passage improvement project implemented in 2008, shown in pre-project and post-construction photos.

The SVRCD, along with other agency and community partners, has made much progress over the past thirty years, and especially in the past decade, in removing small barriers such as flashboard dams. The Shasta Water Association and Araujo flashboard dam removal projects provide an excellent example of how ranchers and agencies worked together to improve fish passage. Continued efforts are underway to address the few remaining identified fish passage issues. See Figure 5.2, a map showing fish passage projects that have been recently completed or are underway.

Projects Completed by SVRCD 2008 - July 2017

NAME OR ID# AND DESCRIPTION	REACH	QUANTITY	FUNDER(S)	YEAR COMPLETE
RIPARIAN FENCING		***linear feet***		
13-01 Riparian Fence	2	2000	SWB IRWM Prop 50	2013
13-02 Riparian Fence	2	5500	SWB IRWM Prop 50	2013
13-03 Riparian Fence	3	2840	RWB 319h #11-099-551	2013
13-04 Riparian Fence	4	180	RWB 319h #11-099-551	2013
13-05 Riparian Fence	4	9500	RWB 319h #11-099-551	2013
13-06 Riparian Fence	4	2700	RWB 319h #11-099-551	2013
14-01 Riparian Fence	6	4800	RWB 319h #11-099-551	2014
11-01 Riparian Buffer/Fence	6	3913	RWB 319h # 06-271-551	2011
RIPARIAN PLANTING		***linear feet***		
Araujo Dam Project Site	2	1000	SWB IRWM Prop 50	2008
Shasta Water Association Dam Project Site	3	1000	SWB IRWM Prop 50	2009
14-02 Riparian Planting	3	1150	RWB 319h #11-099-551	2014
14-03 Riparian Planting	4	100	RWB 319h #11-099-551; USFWS	2014
14-04 Riparian Planting	6	500	RWB 319h #11-099-551	2014
ALTERNATIVE STOCKWATER		***# systems***		
13-07 Stockwater	2	1	SWB IRWM Prop 50	2013
13-08 Stockwater	2	1	SWB IRWM Prop 50	2013
14-05 Stockwater	2	2	RWB 319h #11-099-551, NRCS	2014
13-09 Stockwater	2	1	SWB IRWM Prop 50	2013
15-01 Stockwater	2	2	RWB 319h #11-099-551, NRCS	2015
14-06 Stockwater	3	3	RWB 319h #11-099-551	2014
13-10 Stockwater	4	2	RWB 319h #11-099-551	2013
13-11 Stockwater	4	2	RWB 319h #11-099-551	2013
14-07 Stockwater	4	2	RWB 319h #11-099-551, NRCS	2014
11-02 Stockwater	6	2	RWB 319h # 06-271-551	2011
14-08 Stockwater	6	1	RWB 319h #11-099-551	2014
FISH PASSAGE		***# barriers***		
Araujo Flashboard Dam	2	1	SWB IRWM Prop 50	2008
Shasta River Water Assoc. Flashboard Dam	3	1	SWB IRWM Prop 50	2009
TAILWATER MANAGEMENT		***# projects***		
13-12 Tailwater Re-use Efficiency	2	1	RWB 319h #09-666-551	2013
13-13 Tailwater Re-use Project	2	1	RWB 319h #09-666-551	2013
11-03 Tailwater Re-use Improvement	3	1	RWB 319h # 06-271-551	2011
12-01 SWA Turn-out and Lateral Replacement	3	2	RWB 319h #06-271-551, SWB Prop 50	2012
13-14 SWA Tailwater Ditch Rehabiliation	3	1	RWB 319h #09-666-551; SWB Prop 50	2013
17-01 Tailwater Berm	6	1	RWB 319h #13-501-251	2017
17-02 Spring Connection Pipeline	6	1	RWB 319h #13-501-251	2017
IRRIGATION EFFICIENCY/WATER MANAGEMENT				
11-04 Pipeline Efficiency	2	1	RWB 319h # 06-271-551	2011
13-15 Water Management Efficiency	3	1	RWB 319h #09-666-551	2013
SWA Upper So Ditch Water Measuring Improvr	3	1	SWB IRWM Prop 50	2014
SWA Site 9 Water Measuring Improvmt	3	1	SWB IRWM Prop 50	2014
Big Springs Ranch Head Structure	5	1	RWB 319h #09-666-551	2012
11-05 Pipeline Efficiency	6	1	RWB 319h # 06-271-551	2011
11-06 Pipeline Efficiency	6	1	RWB 319h # 06-271-551	2011
13-16 Ditch Improvement	6	1	RWB 319h #09-666-551	2013
15-02 Flying L Pump/Pipeline	6	1	RWB 319h #13-501-251	2015
BANK STABILIZATION				
16-01 Bank Fine Sediment Reduction	2	1	CDFW FRGP #D1410506	2016

Table 5.1. Completed SVRCD projects by reach and type from 2008 – 2015.

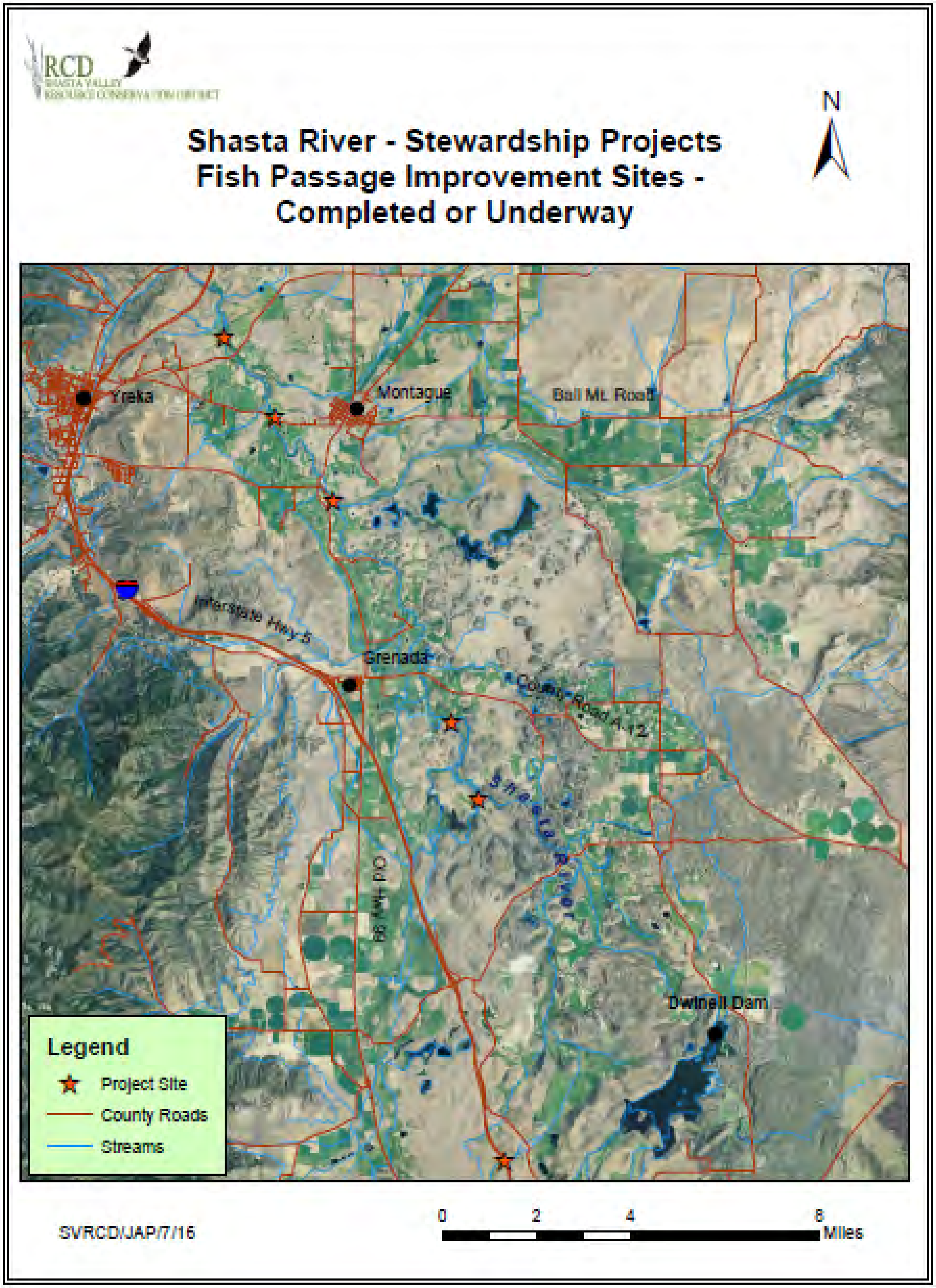

Figure 5.2. Map showing fish passage projects underway or completed by SVRCD since 2006.

5.1.2 Tailwater Management

Tailwater can be defined as run-off from agricultural irrigation practices related to flood irrigation (AquaTerra 2011). When tailwater is delivered to neighboring waterways, it can increase water temperatures and nutrient loading, which indirectly decreases dissolved oxygen. In turn, the poor water quality affects sensitive aquatic species such as coho salmon.

Tailwater management has been a priority in the Shasta River Watershed since 2006. The SVRCD, Natural Resources ConservationService, UC Davis Cooperative Extension, NCRWQCB, AquaTerra Consulting, and others have developed a watershed-wide plan for addressing tailwater, with projects such as those shown in Figure 5.3. The tailwater management plan includes a Tailwater Reduction Plan, a Board-approved project prioritization process, and landowner outreach materials.

The Tailwater Reduction Plan identifies a series of hydrologically defined catchments called "tailwater neighborhoods" that accumulate excess flood irrigation water. The tailwater neighborhoods were identified and prioritized using high resolution aerial remote sensing and a detailed ranking process that took into consideration estimated flow accumulation, proximity to salmon habitat, average tailwater return, temperature effect, available monitoring data, and existing management strategies. For a detailed account of the prioritization process including model limitations, please refer to the Tailwater Reduction Plan http://svrcd.org/wordpress/shasta-river-tmdl/tailwater/.

The resulting Tailwater Reduction Plan targets high-priority tailwater neighborhoods in several key regions of the Shasta River including the Shasta mainstem from Dwinnell Dam to downstream of Big Springs confluence, Parks Creek, and Big Springs Creek (Tailwater Priority Map shown in Figure 5.4). These regions are considered the highest priority for tailwater reduction efforts due to the naturally occurring spring flows found in these sub-areas that contribute to comparatively low and cool river flow (AquaTerra 2011).

The Tailwater Reduction Plan outlines several key management techniques, and extends beyond tailwater management to irrigation water management. Tailwater reduction can be achieved through re-routing tailwater, recycling, and ponding. However, improving and altering irrigation management practices are perhaps the most cost effective methods. Management practices that can greatly mitigate tailwater impacts include education and outreach, irrigation management, and irrigation monitoring.

Figure 5.3. Pump and pipeline projects are designed to manage and reduce tailwater.

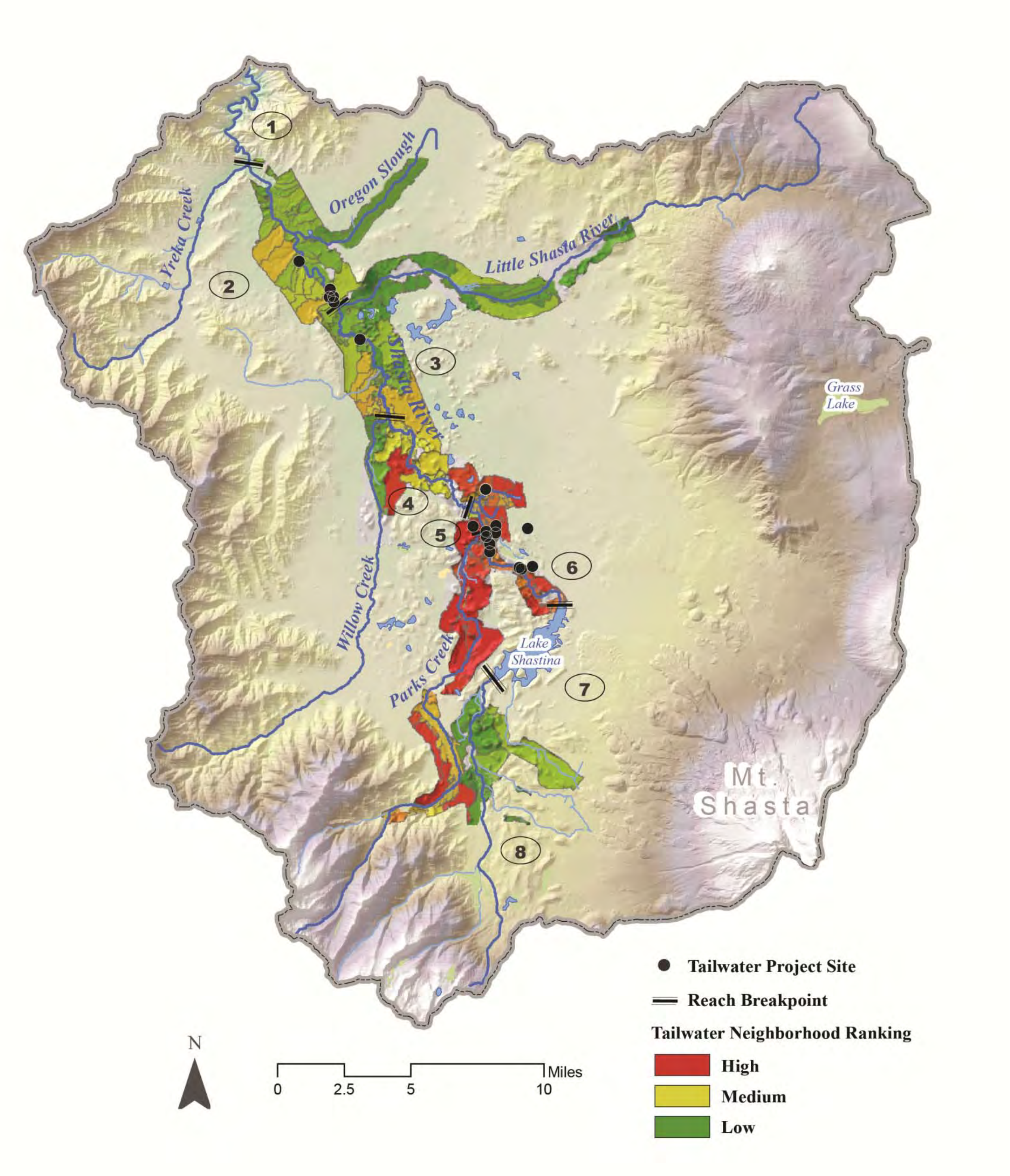

Figure 5.4: Tailwater Neighborhoods and Monitoring by Reporting Reach (AquaTerra and SVRCD 2013)

The Shasta River Irrigation Water Management and Watershed Stewardship Project is a program to improve water quality in the Shasta by decreasing temperature and increasing dissolved oxygen through improved agricultural management. This project involves working with agricultural irrigators to adopt better land management practices and implementing two water management projects in high-priority areas of the watershed. Ultimately, this project aims to reduce the overall diversion quantity utilized from spring sources for irrigation purposes and to reduce the amount of tailwater returning after flooding across pastures.

Several tailwater management projects have been completed in the mainstem Shasta in stewardship reporting reach two and three, which are somewhat low priority. Many irrigation water management projects have been completed in reporting reaches five and six, which are ranked as high priority. Future funding for irrigation water and tailwater management in this area is needed to improve in-stream conditions. Siting of tailwater management projects isn’t simply a matter of following prioritization schedules; of even greater importance is landowner interest and availability of funds for a given site. Figures 5.5 through 5.8 show the locations of completed tailwater and water management projects by reach and the projects are listed in Table 5.1.

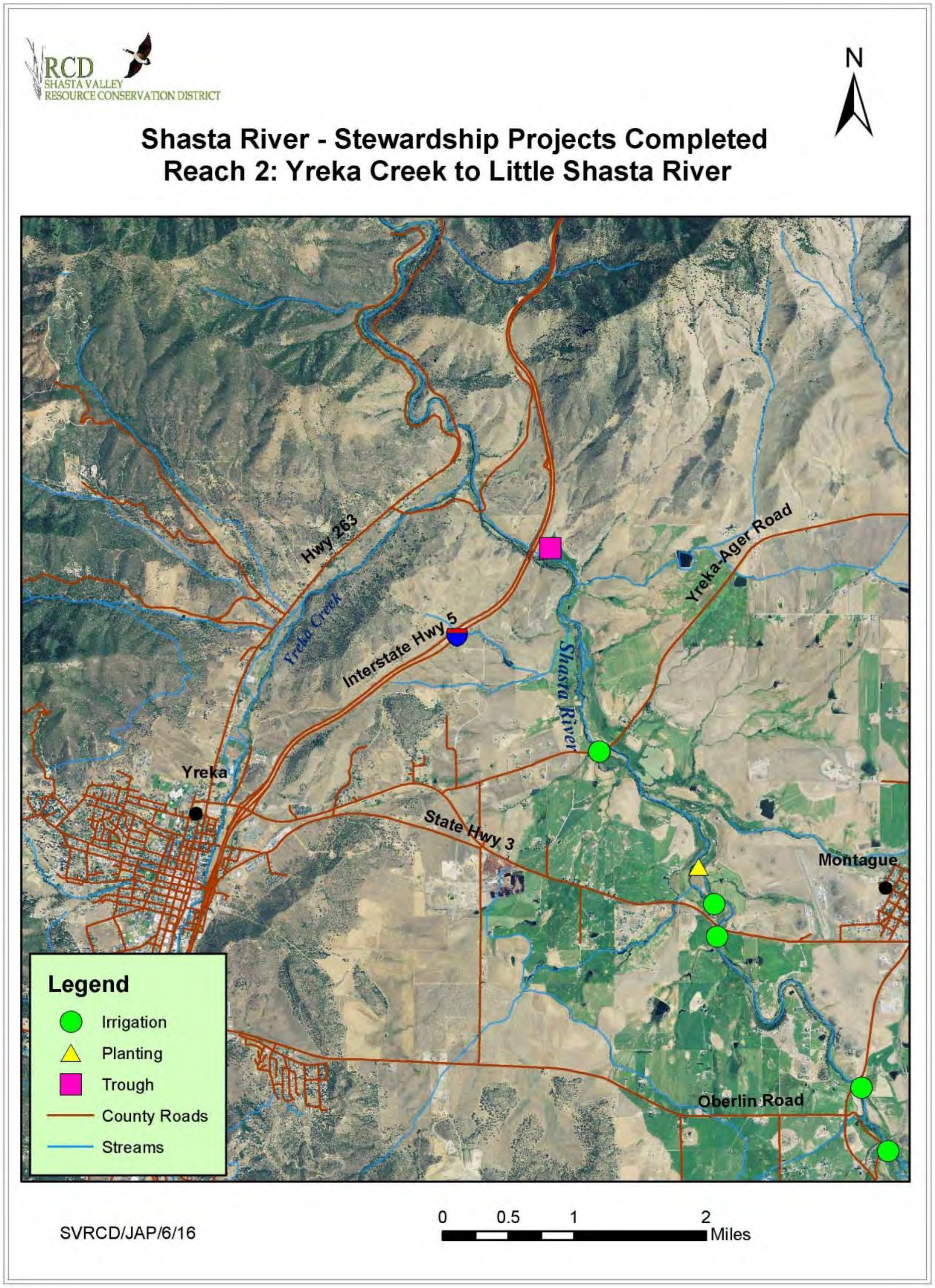

Figure 5.5. SVRCD water management, planting, and stockwater trough projects completed since 2008 in Shasta River Reach 2.

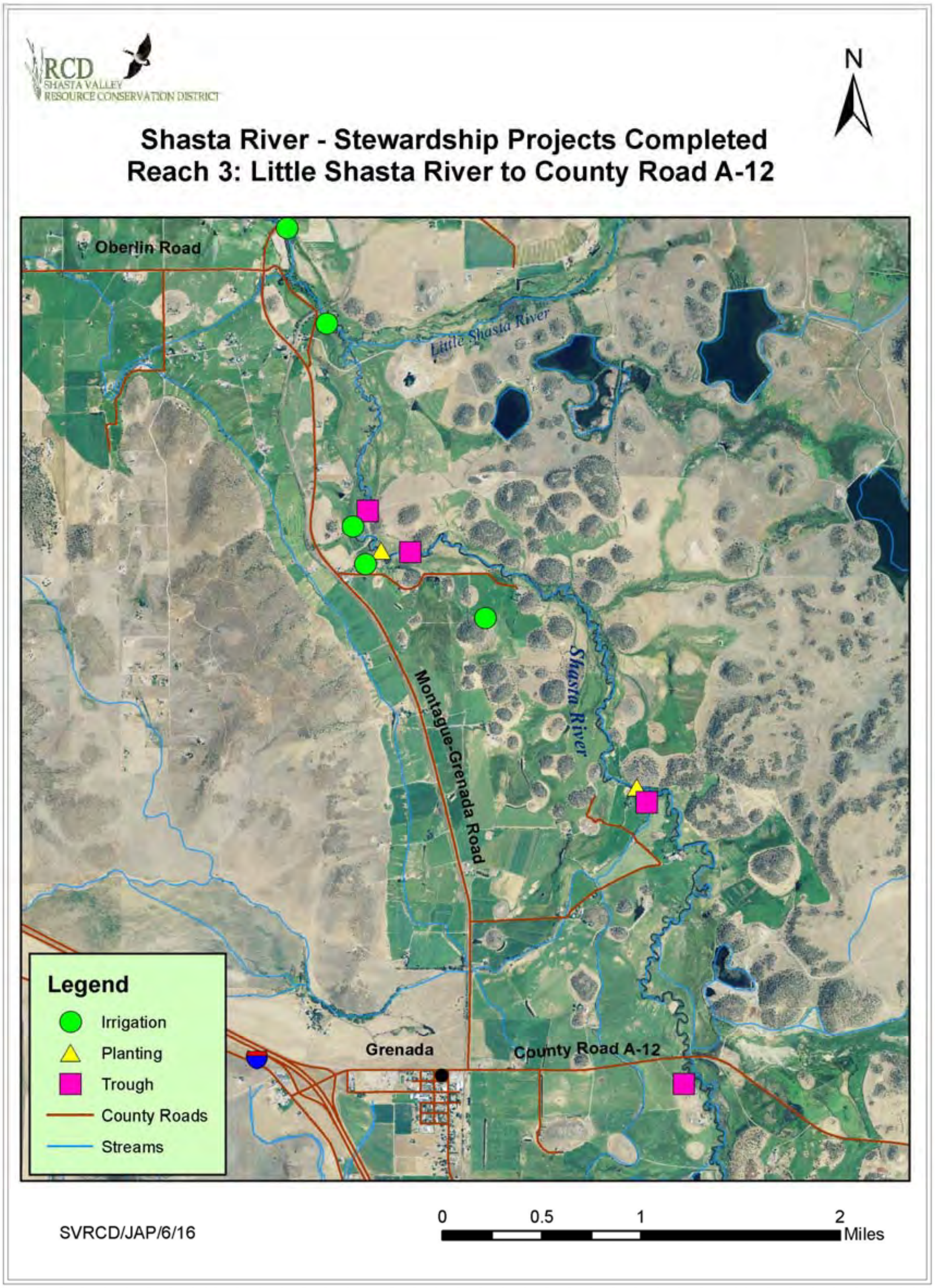

Figure 5.6. SVRCD water management, planting, and stockwater trough projects completed since 2008 in Shasta River Reach 3.

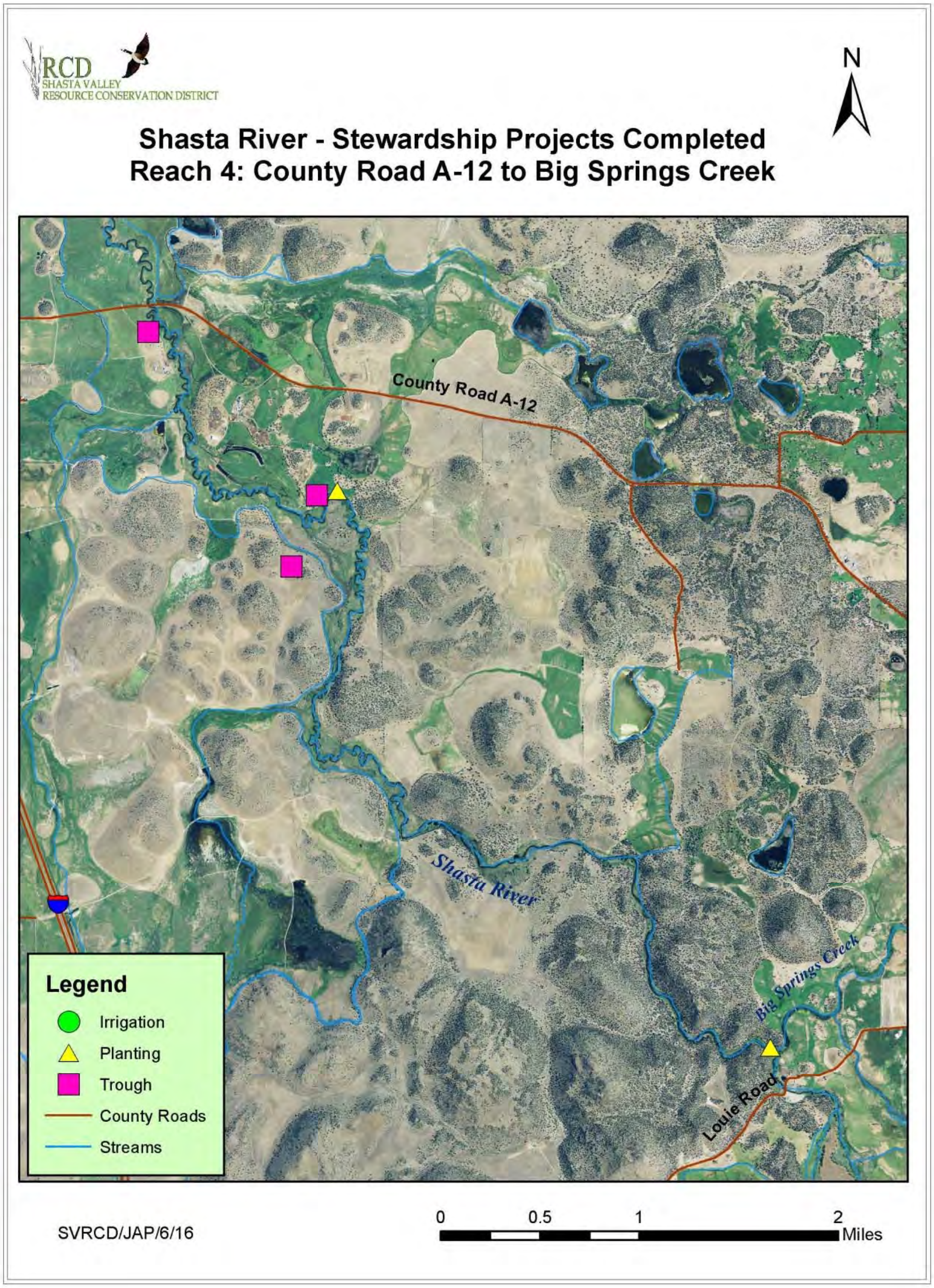

Figure 5.7. SVRCD water management, planting, and stockwater trough projects completed since 2008 in Shasta River Reach 4.

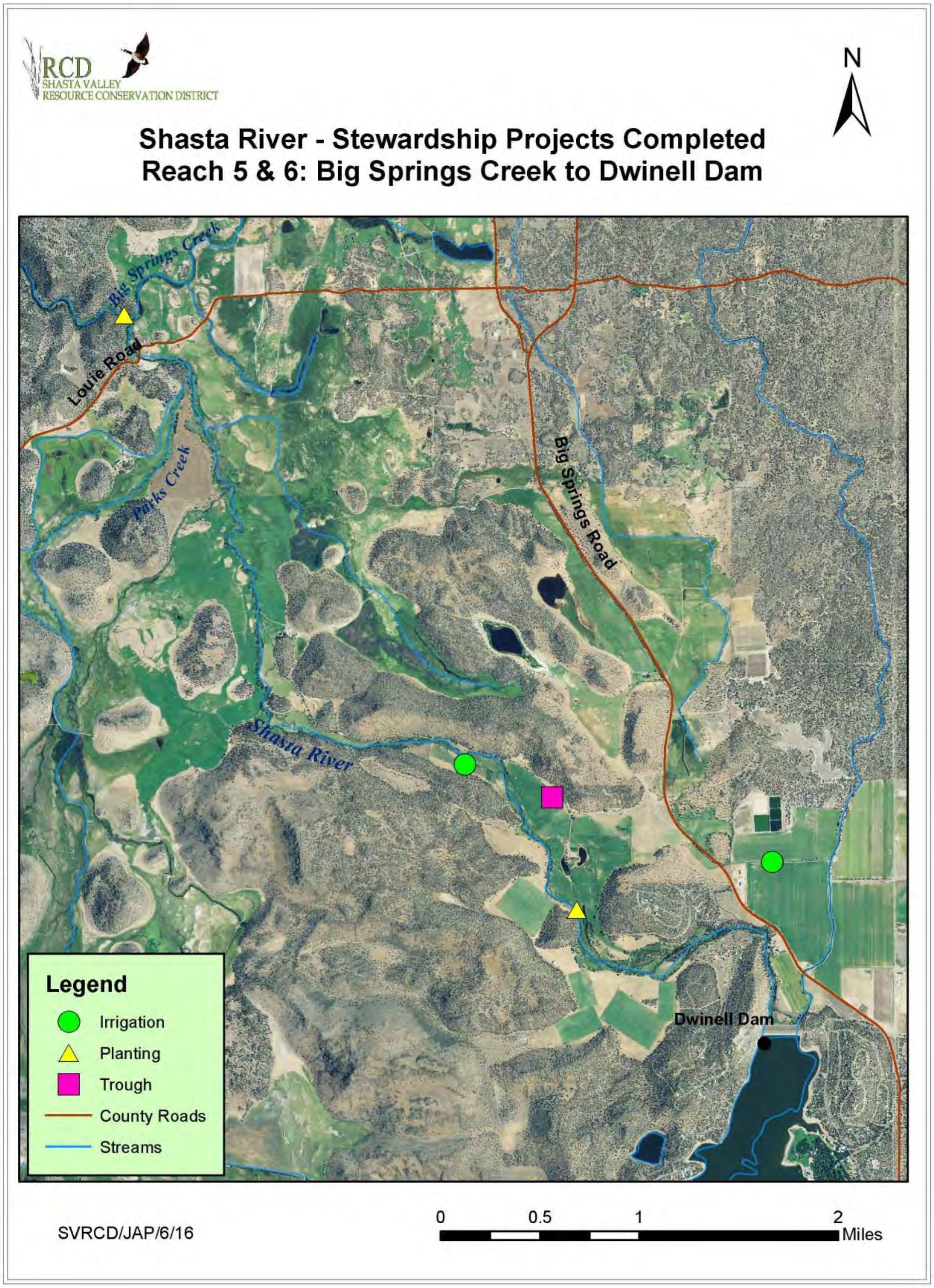

Figure 5.8. SVRCD water management, planting, and stockwater trough projects completed since 2008 in Shasta River Reaches 5 and 6.

5.1.3 Riparian Fencing

Riparian fencing provides protection and enhancement of riparian corridors by allowing management of livestock presence and grazing. This action serves to eliminate overgrazing, bank erosion, and nutrient inputs related to livestock activities within the riparian zone. By protecting the riparian habitat, trees and shrubs can grow to provide stream-side shade which in turn helps to reduce stream temperatures. Ultimately, riparian fencing benefits both terrestrial and aquatic habitats.

The SVRCD and partners have been assisting landowners with riparian fencing for the past twenty-five years. A riparian fencing monitoring project led by SVRCD involved collecting data along the Shasta River and Little Shasta River where riparian zones were already fenced. Comparison of photo points over time indicated that vegetation showed a clear response to riparian fencing; the most obvious responses were increased vegetation and stream channel narrowing (Figure 5.9). The results also showed that fencing was linked to a reduction in grass and a corresponding increase in herbaceous and tree coverage. Monitoring verified an increase in shade, fish cover provided by woody debris, and an increase in habitat complexity (Mattson 2008).

Figure 5.9. Shasta River in Reach 6 during construction of riparian fencing (2011) and later in 2015.

The implementation of riparian fencing has had the most dramatic impact at Shasta Big Springs Ranch, a piece of property that was purchased by TNC in 2009. One of the first stewardship actions was to control livestock access to the creek; instream temperatures were greatly reduced within a season. A key factor was the growth of macrophytes (submerged vegetation) which provided instream shade. The firmly rooted macrophytes also promoted the scouring of fine sediments, deepened the channel, and created a diversity of water velocities (Figure 5.10). The indirect result of the riparian fencing was improved salmonid habitat which was evident by the increased abundance of salmonid populations (Jeffres 2010 https://watershed.ucdavis.edu/pdf/Jeffres-et-al-Big-Springs-2010.pdf). The resulting decrease in temperature is demonstrated by a late summer 5.9 °C drop in Maximum Weekly Maximum Temperature (MWMT) near the mouth of Big Springs Creek from 2008 to 2013 in a temperature analysis conducted by NCRWQCB (See Appendix B).

Figure 5.10. Emergent vegetation response at Big Springs Creek 2008 to 2012 *(Photos courtesy of Ada Fowler, The Nature Conservancy).*

The more typical result following the installation of riparian fencing is to see an herbaceous response in the first season, both instream and along the riparian zone, and a slight narrowing of the channel. A woody response may or may not occur, depending on site characteristics, but has been readily apparent in some areas along the Shasta River after the fence has been in place for about fifteen years. A typical response is shown in Figure 5.11, taken at the upstream end of Reach 2.

Figure 5.11. Response to riparian fencing on Shasta River at Montague-Grenada Rd. Bridge (RM 15.5) in May 1993 and September 2011 (approximately 18 years post-construction).

The SVRCD has conducted an inventory of riparian fencing throughout the Shasta River Watershed as of March 2016. The inventory considers whether the streambank is inherently protected due to inaccessible terrain or a non-agricultural use. The inventory also addresses whether livestock is known to be present or absent and the length of streambank believed to be fenced. Smaller tributaries and tributaries above Lake Shastina have not been fully inventoried. A table of values and percentages is shown in Table 5.2.

Protection From Livestock Impacts - as known by SVRCD

Protection includes fencing, non-agricultural land use, or terrain. Small tributaries not included.

Stream Description	Perennial Stream Length in Miles	Length of Stream Bank (2 times stream length) in Miles	Stream Bank Length Known to be Protected from Livestock in Miles	Stream Bank Length Needing Protection in Miles	% Not Subject to Livestock Impacts
Shasta Mainstem below Lake Shastina	36.33	72.66	65.97	6.69	91%
Little Shasta River	29.53	59.06	35.44	23.62	60%
Parks Creek (including Shasta Springs Creek)	31.89	63.78	31.30	32.48	49%
Yreka Creek (including Greenhorn Creek)	19.32	38.64	23.00	15.64	60%
TOTAL	109.49	218.98	132.71	62.79	61%

Table 5.2: Miles and Percent of Mainstem Shasta River and Larger Tributaries Protected from Livestock Impacts.

5.1.4 Riparian Planting

Riparian habitat provides a host of benefits to the stream ecosystem. Riparian habitat is composed of a diverse community of hydrophilic trees and shrubs that provide habitat for terrestrial species. The aquatic ecosystem also benefits from the riparian zone corridor through reduced stream temperatures from riparian shade; the Shasta TMDL and associated reports suggest that riparian shade is an important factor in reducing stream temperatures of the Shasta River and its tributaries. Additional benefits provided by a healthy riparian zone include reduced evaporation due to reduced wind speed and the dissipation of stream energy as the stream interacts with meandering bends formed by trees and large woody debris. The diversity of stream velocities supports a diverse patchwork of habitat for various life-stages of fish and provides protection from potential predators. Furthermore, a healthy riparian system traps fine sediment, thereby reducing overland sediment and nutrient delivery to the waterbody and improving water quality.

Figure 5.12. Riparian planting project in Reach 6 of Shasta River. Trees are protected from beavers by wire caging supported by a T-post.

Riparian enhancement through planting is shown above in Figure 5.12 at a newly planted site in reach 6. Each tree is protected from beaver damage by a t-post and wire caging. Figure 5.13 shows an example of a riparian planting project implemented in 1994 in Reach 2. In this case, the trees were irrigated for two years. Initial growth was good, but long-term survival of desired tree species is limited. Established trees are often eventually lost due to flooding, beaver damage, or unknown causes that may be site-specific. Continued maintenance is required to maintain proper beaver caging as trees grow and to remove cages where tree mortality has occurred.

Figure 5.13. Upstream of Yreka-Ager Road Bridge at Shasta RM 10.9 in 1994 and 2011. Site was fenced in 1994 and planted in 1996.

Riparian planting is often part of a larger restoration project, as shown below at the Shasta Water Association flashboard dam removal project (Figure 5.14). After the area was disturbed and reconstructed, riparian fencing was installed and several species of willow were planted along both banks.

Figure 5.14. Planting site at SRWA. Shown at pre-construction in 2008, post-planting in 2009, and three years later in 2012. Note the height of vegetation in relation to the white T-post tips across the river in the 2012 photo.

After their extensive riparian fencing effort on Shasta Big Springs ranches, TNC initiated a widespread experimental riparian planting project (Figure 5.15). The plantings included several willow species along with other species such as water birch and hawthorn. Various types of planting stock, stock treatments, planting techniques, and soil types were utilized and recorded. Individual trees were tagged in order to facilitate survival counts and data analysis.

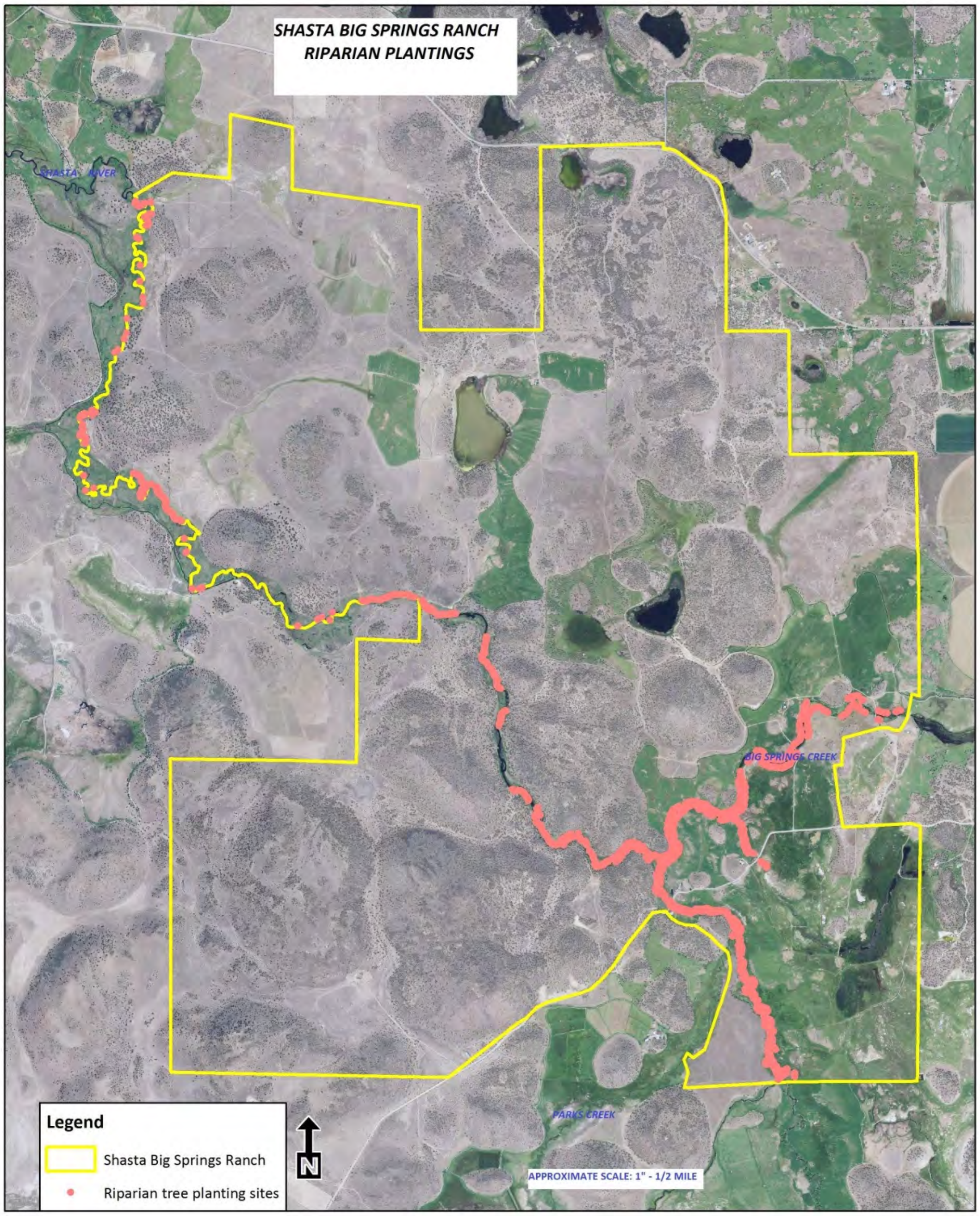

Figure 5.15. Riparian planting sites on Big Springs Ranch implemented by The Nature Conservancy since 2009.

Monitoring of riparian projects begins prior to implementation and continues into the post-implementation phase to measure project effectiveness and as part of the adaptive management process. Monitoring of riparian planting includes river temperature upstream and downstream of the project. Plant survival counts are also taken, particularly when different species and/or planting techniques are used in one project area. A Solar Pathfinder may be used to measure solar radiation changes as shade increases. It can take years for a riparian zone to fully develop after a restoration project.

Given the benefits of riparian corridors to both terrestrial and sensitive aquatic species, local organizations and landowners have been actively promoting the enhancement and preservation of the riparian ecosystem. The Shasta River Riparian Working Group (SRRWG) actively participates in riparian planting projects throughout the watershed. The group was founded to coordinate riparian planting efforts and is dedicated to improving overall riparian system health on the Shasta River. The SRRWG is a mixture of private citizens, non-profits, and local, state, and federal organizations. The mission of the SRRWG is to foster a greater understanding of the riparian ecosystem in the Shasta River. The group's focus is on improved techniques for riparian planting and success to create a functioning riparian ecosystem for the benefit of aquatic and terrestrial species. The SRRWG meets quarterly and has riparian workdays throughout the year.

Several key members of the SRRWG have participated in a riparian restoration prioritization process for the Shasta River as part of the Klamath Strategic Habitat Conservation Program. This effort involved developing a model to improve the identification of suitable habitat for planting new riparian vegetation (Figure 5.16). The model incorporated known survivorship of planted native trees, channel geomorphological features, solar exposure, and hydraulic connectivity and the results provide clear guidance on where native trees are most likely to survive and eventually improve in-stream temperature conditions. Next steps include validating the model's outputs via field testing and addressing factors likely to be limiting the likelihood of success in the marginal sites. Through these efforts, largely contributed by TNC, SVRCD, and U.S. Fish and Wildlife Service, a collaborative, landscape-level riparian planting prioritization tool will serve to increase survivability of plantings and facilitate using limited restoration dollars efficiently.

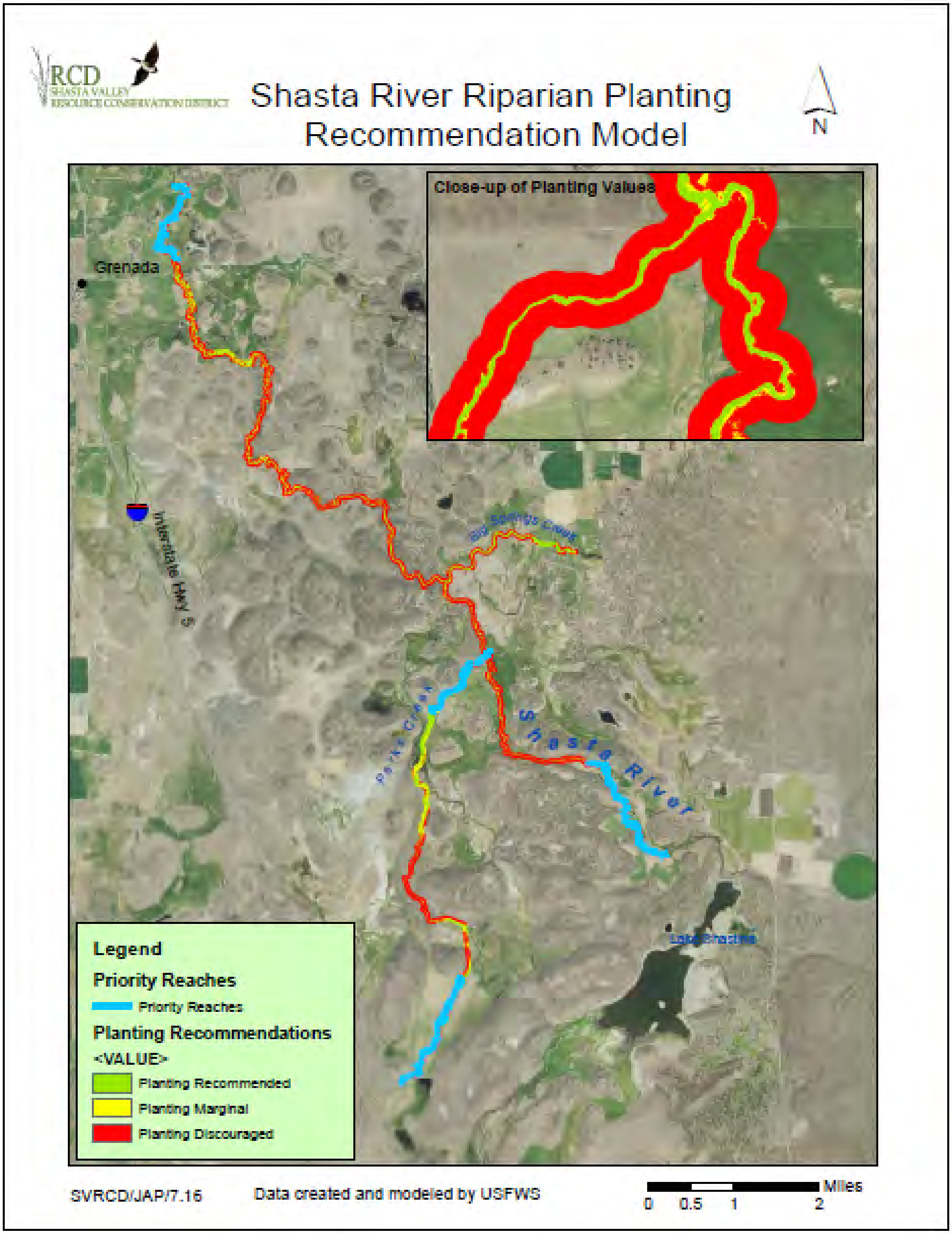

Figure 5.16. Shasta River Riparian Planting Model

5.2 Additional Completed Stewardship Actions

Ranch Planning

Ranch planning is an essential component of watershed stewardship as a means to discuss conservation issues with the landowner, assess issues and needs, and identify potential projects in key areas of the watershed. Conservation strategies that are addressed in a ranch plan may include, but are not limited to, irrigation efficiency, diversion improvements and water measuring devices, bank stabilization, and riparian fencing. The ranch planning process is strictly confidential and the ranch plan belongs to the landowner. SVRCD has made ranch planning a priority for many years, although the effort is often curtailed due to lack of funding. Out of the approximately 60,000 irrigated acres in the Shasta Valley, 11,740 acres or 20% have a ranch plan in place. These 23 ranch plans are on both large and small properties; all but two were conducted by SVRCD. Figure 5.17 shows the approximate areas where ranch planning has occurred, with a symbol provided in lieu of names, and prioritized areas delineated. Information regarding the ranch planning process and approach utilized by the Shasta Valley RCD can be found here: http://svrcd.org/wordpress/shasta-river-tmdl/water-quality-ranch-planning/

Stewardship Actions & Adaptive Management

Planned and completed stewardship actions address both fully implemented projects and future restoration priorities. As part of this report, we documented completed stewardship actions in each reporting reach as a complement to the key stewardship actions identified in the previous section.

Through the collaborative monitoring framework, a holistic understanding of water quality conditions in the Shasta Basin as stewardship actions are implemented can be generated. A holistic understanding implies a mutually agreed upon framework for monitoring and assessing conditions. In addition to a monitoring framework, this process also involves identifying problems and developing solutions so that sources of water quality impairment can be identified. Consensus regarding the sources of water quality and habitat improvement is an essential step toward a collaborative monitoring program in the Shasta River Watershed and beyond. The hope is that through a basin-wide collaborative approach, stewardship actions will be aligned with habitat conservation and resources will be strategically applied toward meeting a collective goal.

Shasta River Watershed Outreach and Communication Plan

An essential component of the Adaptive Management process is transparency and frequent communication. Products of the Shasta River Watershed Stewardship Program are intended to be “living” documents. As the Program Partners move through the Adaptive Management process, we will post updates to the document, monitoring network, and priority actions on the web-links that are currently under development. We also plan to develop outreach materials for stewardship programs and opportunities for landowners to report on stewardship actions in their individual reporting reach.

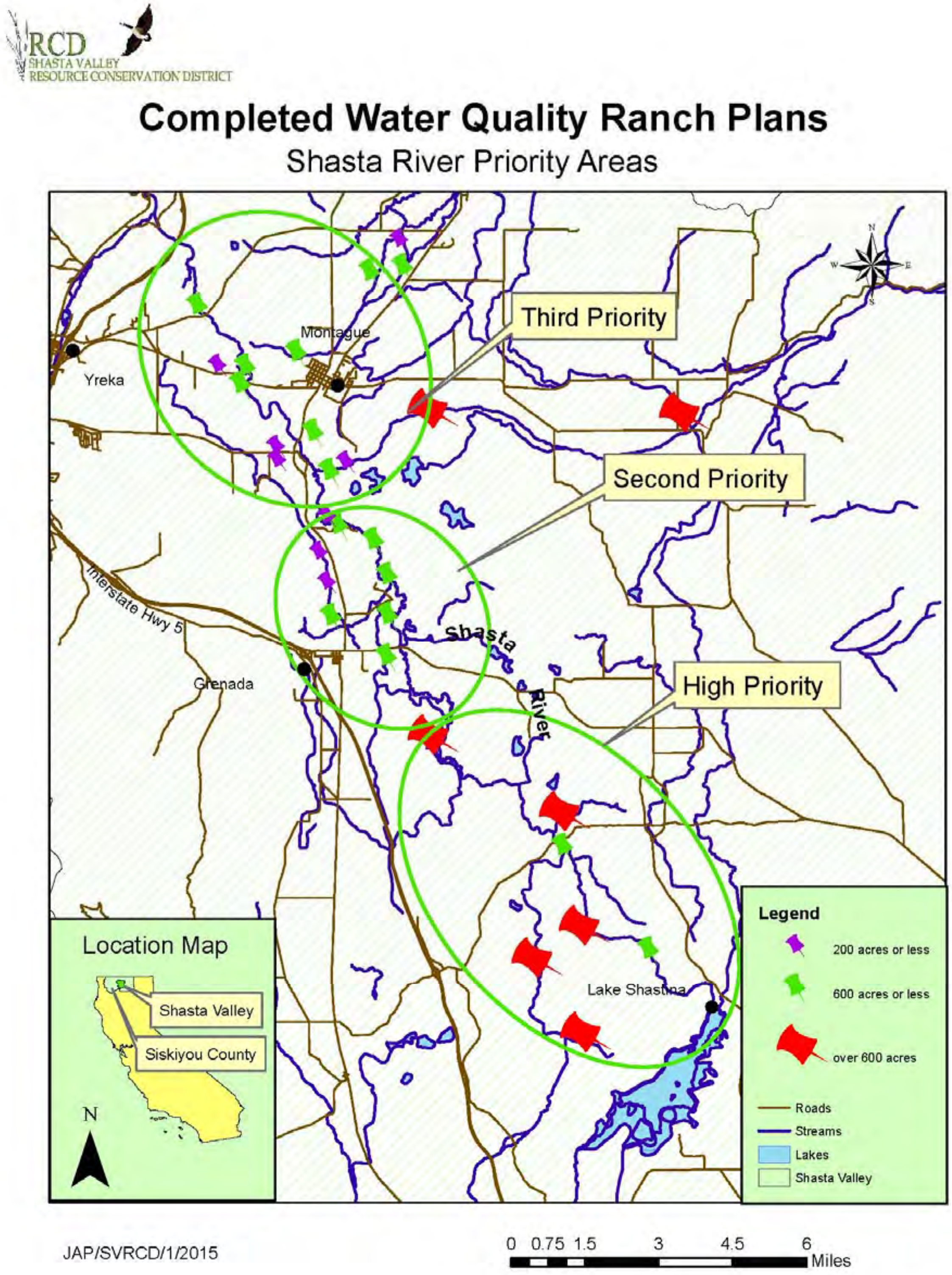

Figure 5.17. Ranches with completed ranch plans conducted by or known to SVRCD.

Stormwater and Municipal Sewer Discharge Improvements

Although there is a small percentage of urbanization in the Shasta River Watershed, impervious surfaces like roads, parking lots, and rooftops still prevent rain and snowmelt from infiltrating into the ground. The resulting runoff from urban landscapes can alter the natural hydrology of the region and carry unwanted nutrients and pollutants into waterways. Urbanized land areas with high percentages of impervious surfaces can have surface runoff even during relatively small rainfall events.

The City of Yreka has actively been improving stormwater runoff during the past decade with the construction of detention ponds and infrastructure upgrades. One example of a community-driven stewardship action is the completion of the Evergreen Bioswale Project (Figure 5.18). Located at an elementary school site, this project directs stormwater runoff into treatment zones prior to entering Yreka Creek.

Figure 5.18. Evergreen Bioswale Project in 2015 before and during construction, and in 2016 after construction.

Following the completion of this project, the resulting increased surface porosity and soil water-holding capacity slow flood waters, which provides biofiltration of parking lot pollutants and traps sediment. This project not only improves water quality in Yreka Creek and protects the school from flooding, it provides ecological benefits and a natural setting for students and increases community awareness and involvement. This project was an outstanding example of partnerships, bringing together Yreka Union School District; USFWS; CDFW; Siskiyou Gardens, Parks, and Greenway Association; the California Conservation Corp's Americorps Watershed Stewards; Landscape Designer Tom Hesseldenz, local contractors, and the City of Yreka.

Water Use and Flow Augmentation

As discussed above, many stewardship actions in the Shasta River address water use by providing some form of water conservation but some actions are directed specifically at water use and flow augmentation. Due to the over-allocated nature of the Shasta River and the importance of summer rearing temperatures to juvenile coho, efforts have been made to identify and reconnect key cold-water springs, increase instream flows through in-stream water rights dedications, and develop voluntary water transactions.

6. Shasta River Watershed Stewardship Action Planning

6.1 Purpose and Goals

The Shasta River Watershed Stewardship Program utilizes a stewardship approach applied by partner organizations and landowners to assist in managing water quality in the watershed. A key component of this approach is a collaborative Stewardship Action Plan developed and maintained within the stewardship adaptive management framework described in Section 2. This Stewardship Action Plan will help guide stewardship in the Shasta River Watershed through 2018.

The Stewardship Report identifies a water quality monitoring and reporting structure using a multi-agency framework with established Reporting Reaches (Table 4.1). Reporting reaches are intended to capture natural breakpoints enabling quantitative tracking of stewardship activities within each reporting reach. The reporting reaches are spatially explicit and can be used to track stewardship activities over time and in association with water quality conditions. Key stewardship activities within the reporting reaches are quantified as part of the Stewardship Action Plan.

While this Stewardship Action Plan focuses on reporting reaches for tracking water quality and quantifying stewardship activities, we plan to apply this framework as the standard for developing a collaborative monitoring program. Specifically, we plan to develop a multi-agency monitoring framework that captures coho abundance, productivity, diversity, and spatial extent, as well as water quality and stewardship actions.

The primary goal of the Shasta River Watershed Stewardship Action Plan is to identify water quality program partner priorities and describe actions that can be taken to address and mitigate existing and future water quality problems within the watershed. The plan identifies responsible parties, inventories past stewardship strategies, and identifies current and planned stewardship actions. Additionally, the Stewardship Action Plan identifies strategic partnerships for water quality monitoring and stewardship actions and presents opportunities for ecosystem rehabilitation.

Access to the stewardship Action Plan will be provided by the Klamath Basin Monitoring Program (KBMP) website at the following link: http://www.kbmp.net/stewardship. The Stewardship Action Plan, and particularly a table of identified potential projects, is intended to be regularly updated by participating organizations in an effort to track stewardship actions needed and completed to date. In addition to up-to-date stewardship activities, plans include providing users access to interactive maps, stewardship stories provided by organizations and local landowners, and resources for participating in stewardship activities, including incentive programs such as KTAP, workshops, and planning sessions.

6.2 Planned Key Stewardship Actions

Six key stewardship actions were identified for the Shasta River Watershed including: riparian fencing, tailwater management, fish barrier removal, riparian planting, flow augmentation, and spring restoration. Tailwater management often falls under the broader category of irrigation water management, which includes many aspects of managing water for irrigation and can be a complex, site-specific process. Several other stewardship actions have also been identified. The key stewardship actions are supported by program partners and several restoration and recovery plans developed for the Shasta River Watershed (NMFS 2012, Shasta CRMP 1997, CDFG 2004). The six key strategies are described as follows:

- **Riparian Fencing** – Track, install, and maintain riparian fencing adjacent to or upstream of salmonid habitat. Implement grazing practices that minimize impacts on riparian vegetation and streambanks.
- **Tailwater Management** – Reduce tailwater input through tailwater management plans. Provide funding support for tailwater management and implement the Tailwater Reduction Plan.
- **Fish Barriers** – Track and maintain fish passage to provide access to spawning habitat, cold water refugia, and migration.
- **Riparian Planting** – Increase stream-side shade through riparian planting. Continue to support the Riparian Working Group planting efforts.
- **Flow Augmentation** – Continue efforts to increase instream flow through voluntary projects. Support minimum flow requirements during upstream migration and outmigration. Work with the landowners and the State Water Resources Control Board to streamline in-stream leasing/conserved water programs. Conduct landowner outreach to participate in conserved water programs and dedication of water rights. Support voluntary water banking.
- **Spring Restoration** – Work to reconnect springs to the Shasta River and tributaries, thereby increasing coldwater refugia and salmonid rearing habitat.

6.3 Additional Stewardship Strategies

- **Ranch Planning** – Continue outreach to landowners to discuss water conservation and water quality issues. Identify potential improvements to their management practices and infrastructure and provide a connection to technical assistance.
- **Basin Planning Actions** – Continue building relationships with partner organizations and develop outreach and education efforts. Emphasize the Stewardship Approach, which includes collaborative problem solving, transparency regarding the evaluation of water quality status and trends, and communication regarding conservation projects with local stakeholders. Maintain interagency collaborative efforts through the Shasta Valley Resource Conservation District, NCRWQCB and KBMP. Some key partners include: NOAA Fisheries, California Trout, U.S. Geological Survey, TNC, CDFW, UC Davis, Montague Water Conservation District, U.S. Forest Service, Karuk Tribe, Yurok Tribe, DWR, USFWS, and the City of Yreka.
- **Water Quality Permit Municipal & Industrial Program Actions** – In a non-regulatory role, improve outreach to cities/communities with aging wastewater infrastructure. Identify opportunities for the beneficial reuse of municipal and industrial bio-solids and municipal wastewater.
- **Water Quality Permit Stormwater, Onsite, & 401 Program Actions** – In a non-regulatory role, support stormwater priority work.
- **Investments with 319** – 319 grant priorities for 2018 and onward will continue to involve working with partners to implement actions that will result in further development of the Klamath Tracking and Accounting Program for quantifying ecosystem benefits related to watershed stewardship projects.

The Stewardship Action Plan includes a list of projects that are currently underway by SVRCD and projects that SVRCD has identified for outreach, assessment, development, or implementation (Table 6.2). These current and future actions have been identified through the Stewardship Program. Many factors are then considered in reviewing and prioritizing projects, including landowner willingness, impact on neighbors, and environmental benefit. Once identified and prioritized, the search for primary funding for design, planning, and implementation is usually the next step. Depending on the magnitude and where in the planning process the project is, coordination of matching funds may be needed.

Continued effort toward implementation of these projects is critical for continued progress towards meeting the goals of the Shasta River Watershed Stewardship Program.

SVRCD SHASTA STEWARDSHIP PLAN 7/31/17

PROJECT DESCRIPTION	REACH or TRIB	PROJECT TYPE	FUNDING	RCD PROJECT #	COMMENTS
UNDERWAY OR FUNDED TO MOVE FORWARD:					
Riparian Planting	6	Riparian Planting	FWS	14-R01	
Riparian Fencing and Stockwater	2	Riparian Fencing & Stockwater	Water Board 2016 319h	TBD	May partner with NRCS
Shasta Water Assn - Water Measuring and Billing Improvements	3	Irrigation Efficiency	BOR (SRWA grantee,SVRCD administer) NCRP IRWM thru SVRCD	15-AD01 16-WC01	
Riparian/WQ Fencing	3	Riparian/WQ fencing	Water Bd 2016 319h	TBD	
Montague-Grenada Weir Improvement	3	Fish Passage		14-P03	
Flashboard Dam/Diversion	4	Fish Passage	NFWF/Pacificorp, FWS, NCRP	15-PA01, 16-HB02, 16-WC01	
Springs Management/Pipeline	6	Water Management	Water Bd 319h Irrig Water Mgmt	14-Q01	Impoundment/Pipeline/Woody Debris
Yreka Ck Post-Restoration Riparian Management	Yreka CK	Post-restoration Mgmt	NFWF/CDFW	14-H01	
Parks Ck Fish Passage Improvement	Parks Ck	Fish Passage	FWS, NFWF/BOR	14-F02, 16-HB01	
NEED DEVELOPMENT/FUNDING:					
Ditch End Water Project	2	Water Management			Outreach and Evaluation needed
Tailwater Capture/Re-use	2	Water/Tailwater Mgmt			
Bank Stabilization	4	Bank Restoration			
Irrigation Efficiency/Pipeline	4	Water/Tailwater Mgmt			Ranch planning and project development needed
Irrigation Efficiency	4	Irrig Efficiency			Various possible projects to be developed
Tailwater Management	4	Tailwater Management			
Water Measuring Improvments	6	Irrigation Efficiency			
Wetland Habitat	6	Wetland Habitat			
Canal Enlargement	6	Water Management/Habitat			
Fish Screen/Pipeline	6	Fish Screen/Water Mgmt			
Tailwater Interception (berm)	6	Tailwater Management			
Diversion Improvements	Parks Ck	Irrigation Management			
Diversion Combining	Parks Ck	Water Management			
Irrigation Eff/Water Management	Parks Ck	Irrig Eff/Water Mgmt			

Table 6.1. Shasta Stewardship Plan: Identified Potential Projects

7. Partner Programs and Activities

7.1 Water Quality Monitoring Activities

In an effort to develop a comprehensive water quality dataset to evaluate the Shasta River Watershed conditions, potential partner programs were contacted. Water quality data requests were sent to each partner program identifying the need for enhanced collaboration regarding the assessment of watershed conditions. This comprehensive approach included an inventory of water quality locations and expanded the monitoring network from a hand full of known locations to over 165 monitoring locations throughout the watershed (Figure 7.1). While the research focus and rationale varied among partner programs, the outreach effort yielded an up-to-date inventory of water quality monitoring, a comprehensive dataset for watershed evaluation, and an opportunity for future collaboration regarding water quality monitoring and stewardship activities.

This data outreach effort signifies the first step in the Stewardship Approach, which is intended to be an on-going effort to bring partner programs together to establish a collaborative monitoring framework. The long term goal of the Stewardship Approach is that once the framework is established, the partner programs can work together to identify problems and develop solutions. The Stewardship Approach is also intended to provide a transparent forum to evaluate water quality status and trends, identify gaps in monitoring, and reduce duplication of efforts. This comprehensive approach is dependent upon data-sharing and collaboration among partner programs to forge a holistic understanding of water quality conditions.

Water quality monitoring data were acquired from several organizations to determine the extent of water quality monitoring in the Shasta River Watershed. The NCRWQCB collaborated with KBMP and the SVRCD to conduct outreach to the following organizations in an effort to develop a comprehensive inventory of water quality monitoring activities.

- California Department of Fish and Wildlife
- California Department of Water Resources
- City of Yreka
- Karuk Tribe
- McBain and Trush
- Montague Water Conservation District
- North Coast Regional Water Quality Control Board
- Shasta Valley Resource Conservation District
- The Nature Conservancy
- UC Davis – Center for Watershed Sciences
- U.S. Bureau of Reclamation
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Geological Survey

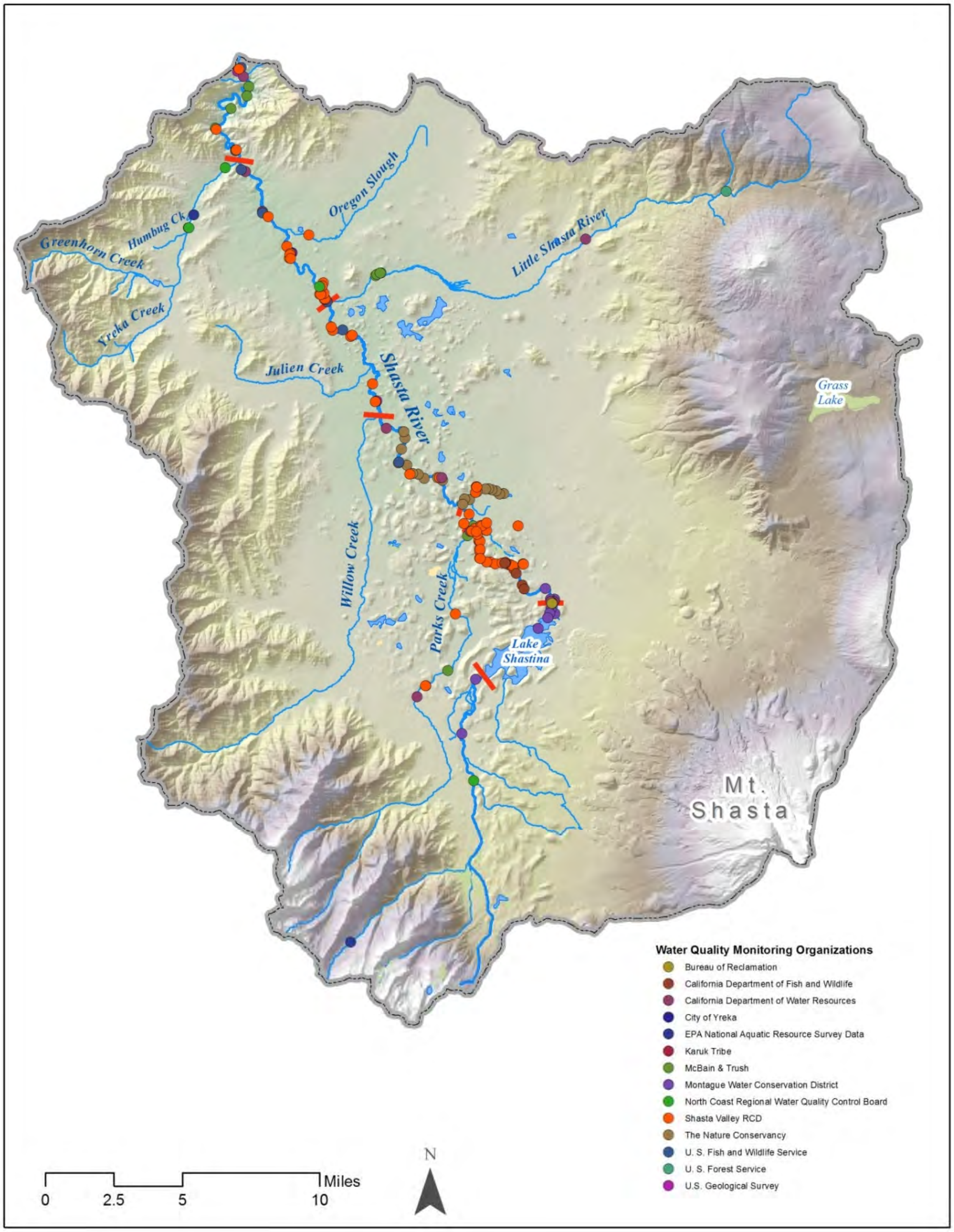

Figure 7.1: Water quality monitoring locations and partners programs 2013

Water quality monitoring occurs throughout the watershed, with the highest monitoring density occurring on the Shasta River mainstem. Water quality monitoring typically occurs at road junctions due to limited access to private property. The most commonly monitored parameter was water temperature, followed by dissolved oxygen, nutrients, and sediment. Limited information was available on sediment oxygen demand and biochemical oxygen demand.

Overall, there are very few long-term (15+ years) datasets from which to establish long-term water quality status and trends. Over space and time, the water quality data is a patchwork that appears to be driven by an intermittent funding environment, coupled with the need for project-specific monitoring. While long-term data are limited, short-term datasets were useful in identifying status and trends on a shorter timeframe. The data were evaluated based on water quality conditions to support sensitive beneficial uses, namely salmonids. The results are discussed in detail in Section 8 of this report, Data for Adaptive Management.

7.2 Shasta River Watershed Stewardship Partners and Stakeholders

Thirty-one organizations have been identified that are affiliated with monitoring, research, and stewardship in the Shasta River Watershed. Watershed partner programs consist of a variety of federal, state, local, and non-profit organizations, as well as consulting firms. Below is a brief description of each of the partner programs:

AquaTerra Consulting – Local consulting firm based in Mt. Shasta. AquaTerra Consulting specializes in project management, resource vulnerability analysis, erosion protection planning, and implementation/management of water quality improvement projects. AquaTerra has an on-going involvement in the Shasta Valley RCD’s tailwater reduction program and manages the construction of associated implementation projects, as well as monitoring in association with SVRCD staff. AquaTerra also manages fish passage improvement projects, facilitates stakeholder groups, and serves as a liaison between landowners and agencies.

California Department of Fish and Wildlife (CDFW) – State agency with a field office in Yreka, CA. CDFW maintains native fish, wildlife, plant species, and natural communities for their intrinsic and ecological value, as well as their benefits to people. This includes habitat protection and maintenance in a sufficient amount and quality to ensure the survival of all species and natural communities. The department is also responsible for the diversified use of fish and wildlife including recreational, commercial, scientific, and educational uses. CDFW manages the Shasta Valley Wildlife Area located on the Little Shasta River near Montague and monitors flow and temperature in salmonid habitat throughout the watershed, as well as adult/juvenile salmonid counts.

California Department of Water Resources (DWR) – State agency with a field office in Red Bluff, CA. DWR manages and protects California’s water and works with other agencies to benefit the state’s people and to protect, restore, and enhance the natural and human environments. DWR has an established rotational monitoring program for flow, temperature, dissolved oxygen, nutrients, turbidity, minerals, and metals in the watershed.

California Department of Transportation (CalTrans) – The mission of The California Department of Transportation (CalTrans) is to improve mobility across California. CalTrans is responsible for CalTrans properties, facilities, and activities including construction regarding stormwater discharge under a National Pollution Discharge Elimination System (NPDES) permit. CalTrans has oversight over Interstate 5 and Highway 97 within the watershed.

California Trout (CalTrout) – Non-profit organization with a field office in Mt. Shasta, CA. CalTrout's mission is to protect and restore wild trout, steelhead, salmon, and their waters throughout California. CalTrout supports projects that reduce in-stream temperatures and improve flows for salmonids during critical times of the year. Additionally, CalTrout supports projects that remove fish migration barriers, and restore habitat throughout the watershed. CalTrout invests in education and policy analysis and supports research regarding spring vulnerability analysis throughout the Mt. Shasta Region, which includes the Shasta River Watershed.

City of Yreka – Local municipality (population 7,697) located along Yreka Creek, a tributary to the Shasta River. The City of Yreka Public Works Department manages runoff from storm drains and impervious surfaces, provides water, and manages the sewer service. Additionally, the department manages the Yreka Creek Greenway and other parks and recreation areas. The City of Yreka conducts water quality monitoring in accordance with the Regional Board's wastewater treatment facility monitoring and reporting program.

City of Weed – Local municipality located above Lake Shastina with a population of 2,943. The City of Weed Public Works Department manages runoff from impervious surfaces and provides wastewater services to the residents and businesses of the community.

City of Montague – Local municipality located east of Yreka in the Shasta River with a population of 1,443. The City of Montague relies on the Shasta River for domestic water. The City of Montague Public Works Department manages runoff from impervious surfaces including streets, sidewalks, curbs and gutters. The City of Montague also provides wastewater services to the residents and businesses of the community.

Community of Edgewood – Local community three miles north of Weed with a population of 43. Community manages runoff from impervious surfaces. The community does not provide wastewater treatment services, but a sewer system has been proposed.

Community of Lake Shastina – Local community located on the east side of Lake Shastina with a population of 2,836. Community manages runoff from impervious surfaces and the community's wastewater treatment system is located north of the Lake Shastina area.

Klamath Basin Monitoring Program (KBMP) – Many of the organizations within the Shasta River Watershed are members of KBMP, a multi-agency water quality monitoring organization dedicated to implementing, coordinating, and collaborating on water quality monitoring and research throughout the Klamath Basin. KBMP provides a collaborative framework through bi-annual membership meetings, maps water quality monitoring activities, and provides an open forum for data sharing and information dissemination.

Klamath Tracking and Accounting Program (KTAP) – Several member organizations of the Klamath Basin Monitoring Program have worked together to develop a collaborative approach to document watershed stewardship activities in the Klamath Basin. The Klamath Tracking and Accounting Program

(KTAP) provides a system to record stakeholder's stewardship actions towards water quality improvement. Participation in KTAP is voluntary and the project developer determines the level of project information to be included in the KTAP registry. The primary benefit of KTAP is to provide information that can be used to continually improve our knowledge on refining stewardship practices, help establish project priorities, and provide the basis for modifying stewardship practices in response to water quality improvements or ongoing impacts. KTAP is a key component of practicing adaptive management. The adaptive management process is intended to be transparent and inclusive, involving Shasta River Watershed partner programs and local stakeholders. KTAP can also be a source of good news as implementation milestones are met and progress can be documented. KTAP has registered pilot projects in the Shasta Watershed in collaboration with the Shasta Valley Resource Conservation District. However, not all stewardship projects described in this report have been registered into KTAP.

Karuk Tribe – Klamath Basin Tribe with ancestral territory extending from Seiad Creek on the Klamath to upstream of Weitchpec and within the Salmon Watershed up to Sawyer's Bar. The mission of the Karuk Tribe is to establish equality and justice for the tribe, to restore and preserve Tribal traditions, customs, language and ancestral rights, and to secure the power to exercise the inherent rights of self-governance. The Karuk Tribe conducts water quality monitoring near the mouth of the Shasta River using a data sonde, which conducts real-time monitoring for temperature, dissolved oxygen, conductivity, and pH. Nutrient and algae samples are collected intermittently.

McBain and Trush – Consulting firm located in Arcata, CA which specializes in landscape consulting and planning. The firm has conducted extensive flow and temperature monitoring to better characterize salmonid habitat needs throughout the Shasta River Watershed.

Montague Water Conservation District (MWCD) – The MWCD provides water to ranchers within the irrigation district located in the Shasta Valley and the City of Montague. The MWCD oversees Dwinnell Dam operations and water quality monitoring. Additionally, the MWCD conducts surface and vertical profile monitoring in Lake Shastina for temperature, pH, dissolved oxygen, and nutrients. The MWCD has monitoring locations above and below Lake Shastina.

National Oceanic and Atmospheric Administration (NOAA) / Fisheries – Federal agency with a field office in Arcata, CA. NOAA Fisheries supports the stewardship of living marine resources for the benefit of the nation through science-based conservation and management programs. NOAA Fisheries supports projects that improve salmonid habitat and works with landowners regarding incidental take permits and proposed coho supplementation.

North Coast Regional Water Quality Control Board (NCRWQCB) – State agency with a field office in Santa Rosa, CA. The NCRWQCB's mission is to preserve, enhance, and restore the quality of California's water resources and to ensure their proper allocation and efficient use for the benefit of present and future generations. The NCRWQCB is responsible for TMDL implementation, permits, and waivers associated with certain land and water uses. The NCRWQCB conducts monitoring at select locations throughout the Shasta River Watershed and has an established rotational monitoring program for temperature, dissolved oxygen, nutrients, pH, turbidity, minerals, metals, and emerging contaminants.

Shasta River Riparian Working Group –The Shasta River Riparian Working Group is a committee made up of local agencies and groups with a focus on riparian fencing and planting projects. Formed in 2009, the Working Group oversees prioritization, funding acquisition, and implementation of riparian fencing projects throughout the Shasta River Watershed.

Shasta Valley Resource Conservation District (SVRCD) – Special District of the County of Siskiyou located in Yreka, CA. The mission of the SVRCD is to work with interested landowners on a voluntary basis to enhance the management and sustainable use of natural resources in order to ensure the long term economic viability of the community. The SVRCD provides project and technical assistance to local landowners in areas such as riparian projects, irrigation efficiency, tailwater management, and livestock watering tanks. Additionally, the SVRCD conducts monitoring throughout the Shasta River Watershed, focusing on temperature, dissolved oxygen, nutrients, and flow.

State Water Resources Control Board - Division of Water Rights – The mission of the State Water Board is to preserve, enhance and restore the quality of California's water resources and ensure their proper allocation and efficient use for the benefit of present and future generations. The mission of the Division of Water Rights is to establish and maintain a stable system of water rights in California to best develop, conserve, and utilize public interest in the water resources of the State while protecting vested rights, water quality, and the environment. The Division of Water Rights oversees allocation of the state's water resources to various entities and its use for various activities ranging from agricultural irrigation and hydroelectric power generation to municipal water supplies. The water rights program is administered to protect the public trust resources of the state and to serve the public interest. The Division of Water Rights is committed to working with landowners and organizations interested in the voluntary Instream Flow Dedication Program.

The Nature Conservancy (TNC) – Nonprofit organization with a field office in Mt. Shasta, CA. The mission of TNC is to conserve the lands and waters on which all life depends. TNC owns and manages the Big Springs Ranches and aims to illustrate that farming and ranching can coexist with healthy salmonid populations. TNC supports projects geared toward salmonid habitat restoration, tailwater management, and spring connectivity and management. Additionally, TNC also conducts water temperature, nutrient, and flow monitoring on the Big Springs Ranch property.

University of California Davis – Center for Watershed Science – State research institution located in Davis, CA. UC Davis's Center for Watershed Sciences is dedicated to the interdisciplinary study of critical issues in watershed science with a focus on the sustainable and cost-effective restoration and management of stream, lake, and estuarine ecosystems. The center has conducted extensive research in Big Springs, examining the interplay among physical processes that create ideal conditions for a productive food web. Monitoring includes sampling water quality, evaluating hydrologic conditions, and identifying primary producers, invertebrates, and fish.

U.S. Bureau of Reclamation (BOR) – Federal agency with offices located outside the watershed. The BOR's mission is to assist in meeting the increasing water demands of the western United States while also protecting the environment and the public's investment in these structures.

U.S. Bureau of Land Management (BLM) – Federal agency with a field office located in Redding, CA. The BLM's mission is to sustain the health, diversity, and productivity of America's public lands for the use and enjoyment of present and future generations. The BLM manages grazing on federal lands and implements best management strategies for riparian management and wetland areas within the Shasta

River Watershed. The U.S. Forest Service is currently managing BLM lands in the Shasta River Watershed.

U.S. Environmental Protection Agency (EPA) – Federal agency with a field office in San Francisco, CA. The EPA's mission is to protect human health and the environment. The EPA conducts periodic monitoring at select locations in the Shasta River Watershed, focusing on water temperature, dissolved oxygen, pH, conductivity, turbidity, nutrients, metals, and minerals.

U.S. Fish and Wildlife Service (USFWS) – Federal agency with a field office in Yreka, CA. The USFWS's mission is to work with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. The USFWS conducts research in the Shasta River Watershed in support of salmonid habitat and monitors water temperature and stream flow in key habitat areas throughout the watershed.

U.S. Forest Service (USFS) – Federal agency with a field office in Yreka, CA. The USFS's mission is to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. The USFS currently conducts monitoring for turbidity and water temperature at one location in the Shasta River Watershed.

U.S. Geologic Survey (USGS) – Federal agency with a field office in Redding, CA. The USGS's mission is to provide the nation with reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect quality of life. The USGS has several real-time gaging stations in the Shasta River Watershed that record discharge and gage height. Additionally, the USGS conducts periodic monitoring of temperature, dissolved oxygen, pH, conductivity, turbidity, nutrients, metals, and minerals.

Watercourse Engineering – Consulting firm based in Davis, CA that specializes in water quality monitoring, riparian shade estimates, and thermal profiling and modeling. Monitoring is typically conducted in collaboration with other partner programs.

7.3 Expanding on Current Stewardship Activities

This report is intended to define a transparent and collaborative process that helps identify and support successful stewardship actions. Several partner programs have already implemented stewardship actions at a local scale. For example, individual partner programs such as TNC, SVRCD, and the City of Yreka have successfully implemented projects focusing on stream restoration, effective landowner outreach, and enhanced public involvement and education. While each organization has been successful, the implementation of stewardship actions at the watershed level has been a challenge. By creating a collaborative basin-wide stewardship effort, partner programs will be able to share successful stewardship actions and expand beyond traditional boundaries to encompass the entire Shasta River Watershed.

The Stewardship Approach proposed here is intended to build on successful stewardship actions. Through a collaborative framework, goals and objectives are identified for addressing water quality concerns. The proposed monitoring framework was developed by several partner programs for tracking water quality concerns and sensitive beneficial uses. From the proposed monitoring framework, the status and trends may be evaluated and potential sources of impairment may be identified. Given this holistic view, actions taken to address impairments may be evaluated collectively at a larger spatial scale. As progress is made, successful stewardship actions may be implemented throughout the Shasta River Watershed and beyond.

8. Data for Adaptive Management

8.1 Temperature

Stewardship activities within the Shasta River Watershed have been predicated on the hypothesis that increasing riparian vegetation, restoring stream channel integrity, reducing tailwater return flows, and increasing the inflow of cold water to the mainstem of the Shasta River will result in a decreasing trend for temperature in the Shasta River. These changes are also expected to result in dissolved oxygen improvements. In order to test that hypothesis, a combination of assessment strategies were employed to form a comprehensive understanding of water temperature conditions in the Shasta Watershed. These strategies were primarily divided into two categories: performing trend analysis on yearly water temperature values and assessing water temperature conditions for Cold Freshwater Habitat beneficial uses in 2016.

Trend analysis was performed for the maximum weekly maximum water temperatures (MWMT) and the maximum daily maximum water temperatures (MDMT). The MWMT is the maximum seasonal or yearly value of the seven-day running average of daily maximum temperatures. The MWMT describes the maximum temperatures in a stream, but the value is not overly influenced by the maximum temperature of a single day. The MDMT is the maximum seasonal or yearly value of the daily maximum temperature and provides a measure of acutely high water temperatures

Date ranges were selected based on instrument deployment and retrieval dates to capture as much of the data record as possible. Data was also bracketed into shorter “windows” to examine in closer detail the effects of emergent vegetation on water temperatures. The “Early Summer” window refers to the time period before emergent vegetation has grown large enough to provide effective shade. The “Late Summer” window refers to when emergent vegetation has fully set in. The “Whole Summer” window includes both the “Early Summer” and “Late Summer” windows. The beginning of the MWMT “Early Summer” and “Whole Summer” windows differ from the MDMT “Early Summer” and “Whole Summer” windows because weekly averaging requires reporting to start on April 21st. Exact dates for these windows can be found in Table 8.1.1. The monitoring sites assessed for the temperature analysis are listed in Appendix B. Note the monitoring sites located at Shasta River at mid-canyon and Shasta River at Highway 263 were excluded from the trend analysis due to insufficient data records (see Appendix B for details):

Table 8.1.1. Study Windows and Associated Date Ranges

Metric	Window	Begin Date	End Date
MWMT	Early Summer	April 21	June 15
MWMT	Late Summer	June 16	August 15
MWMT	Whole Summer	April 21	August 15
MDMT	Early Summer	April 16	June 15
MDMT	Late Summer	June 16	August 15
MDMT	Whole Summer	April 16	August 15

Additional metrics were generated to supplement assessment of cold freshwater beneficial uses. The primary function of these supplemental stewardship metrics is to identify cold water habitat and displacement behavior of coho rearing salmon during critical summer months (Stenhouse, 2012). Analysis included review and categorization of daily maximum temperatures and results are reported for further context.

Table 8.1.2. Supplemental Stewardship Metrics and Associated Temperature Ranges

Categories	Temperature Range
Optimal	≥10°C and ≤15.5°C
Suboptimal	>15.5°C and ≤20.3°C
Detrimental	>20.3°C or <4°C

Trend Analysis

Statistically significant decreasing MWMT trends of 0.48 and 0.46 ˚C per year were detected at Big Springs Creek near the mouth for the previously defined Late Summer and Whole Summer windows, respectively. Additionally, a statistically significant decreasing trend of 0.64 ˚C per year was detected at the same location for the MDMT during the Late Summer window.

A statistically significant increasing trend of approximately 0.1 ˚C per year was identified for the MDMT and MWMT at both Shasta River RM 0.6 and Shasta River RM 13.09 for the Late Summer window, while a statistically significant increasing trend of 0.10 ˚C per year was identified for the MWMT only at Shasta River RM 15.51. While the direction of this trend is consistent with yearly increasing ambient air temperatures (Figure 8.1.1), the trends at the Shasta River monitoring sites indicates that water temperatures have increased at approximately three times the rate of the long term average of air temperature increase. It must also be noted that the trend is less than the reported accuracy of the measurement equipment (+/- 0.2 ˚C). All other stations had no detectable trend. Trend results are presented in Figures 8.1.2 – 9. A complete listing of the trend results and associated methods are outlined in Appendix B.

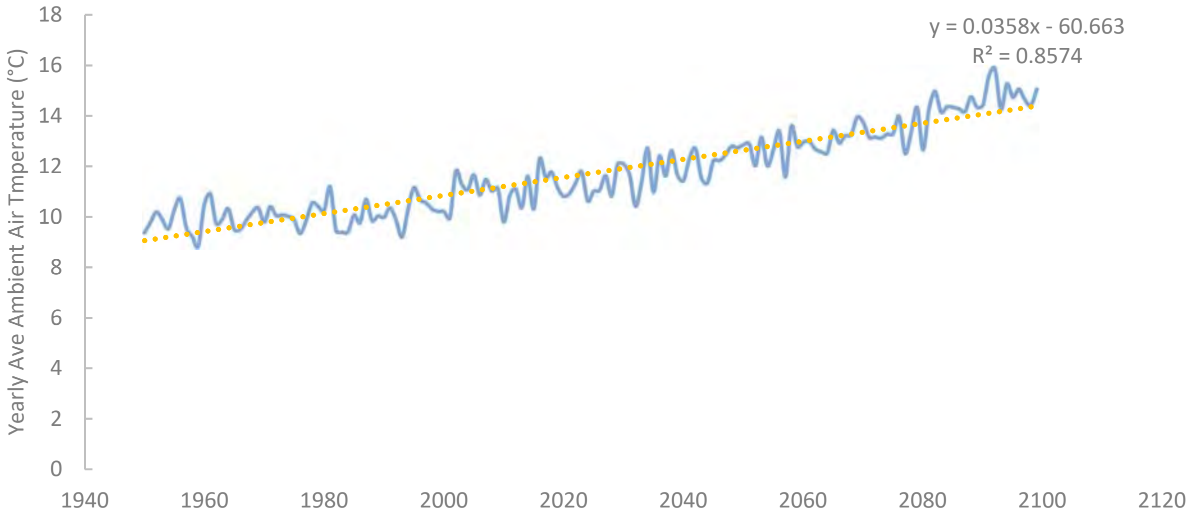

Figure 8.1.1. Increasing trend of approximately 0.04 °C per year for ambient temperatures for Shasta Valley at latitude 41.7844 and longitude -122.5907. (Modeled average temperatures – ccsm3 model; low carbon emissions scenario). Source: Public Interest Energy Research, 2011. Cal-Adapt (http://cal-adapt.org)

The linkage between air temperature and water temperature has been explored in previous analyses. One example analyzes data from the mouth of the Shasta River in years 2001 – 2011 and shows statistically significant correlations between monthly mean air temperature and monthly mean water temperature for the months of June, July, and September (Asarian and Kann, 2013). It is expected that the temperature recorded at the mouth of the Shasta River reflect the river approaching equilibrium temperature. Equilibrium temperature is the temperature a body of water will reach if given enough time to come into balance with its surroundings (Bogan et al. 2003, Mohseni et al. 2002). The strongest driver of equilibrium temperature is air temperature, whereas shade, groundwater inputs, and wind sheltering are the greatest modifiers of the relationship of air temperature to equilibrium temperature (Morrill et al. 2005). The data presented below shows monitoring sites at different reaches along the Shasta River, where factors like shading, cold spring water influence, and localized microclimatic dynamics drive water temperature. This can be seen in the decreasing trend in MWMT and MDMT at Big Springs Creek, where there is localized cold spring water influencing instream temperatures andthe exclusion of cattle in the stream channel has allowed emergent aquatic macrophytes to shade approximately 52% of the stream channel at the end of the growing season (Willis et al., 2012). The influence of aquatic macrophytes on reducing solar radiation reaching the water surface has been quantified at 84-93%. Aquatic macrophytes also impact flow, decreasing flow within aquatic macrophyte patches while increasing flow between patches, thus decreasing travel time of surface water exposed to direct solar radiation.

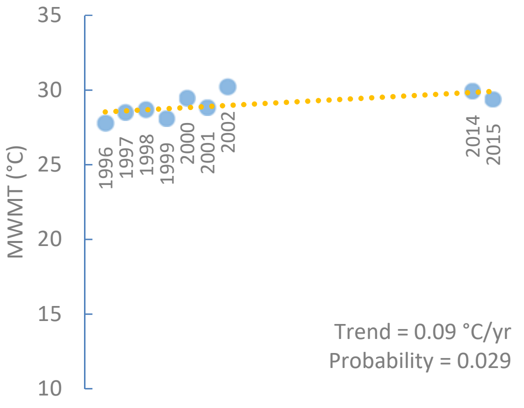

Figure 8.1.2. Trend results for Shasta River near the mouth (RM 0.6) for seasonal MWMT during Late Summer, June 16 – August 15

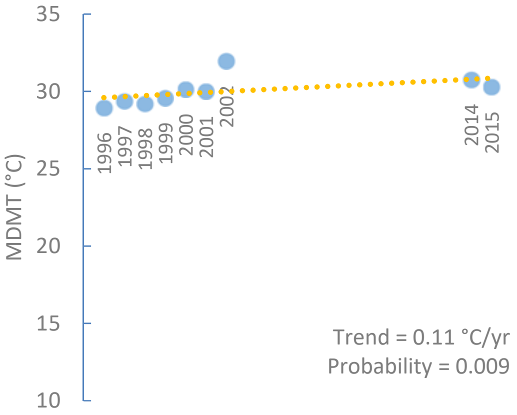

Figure 8.1.3. Trend results for Shasta River near the mouth (RM 0.6) for seasonal MDMT during Late Summer, June 16 – August 15

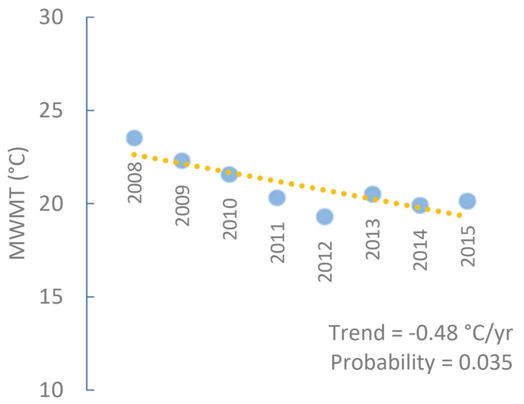

Figure 8.1.4. Trend results for Big Springs Creek near the mouth for seasonal MWMT during Late Summer, June 16 – August 15

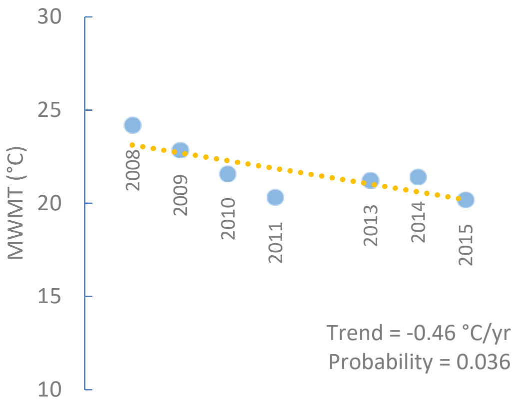

Figure 8.1.5. Trend results for Big Springs Creek near the mouth for seasonal MWMT during Whole Summer, April 16 – August 15

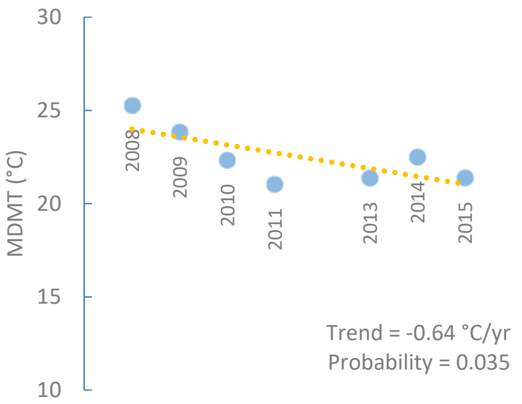

Figure 8.1.6. Trend results for Big Springs Creek near the mouth for seasonal MDMT during Late Summer, April 16 – June 15

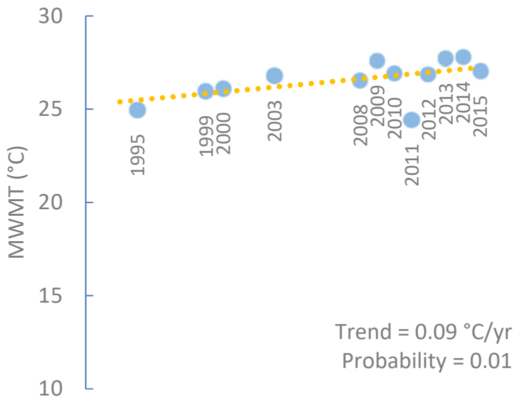

Figure 8.1.7. Trend results for Shasta River at Highway 3 (RM 13.09) for seasonal MWMT during Late Summer, June 16 – August 15

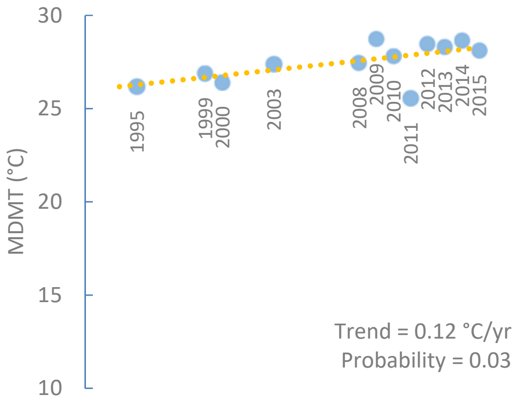

Figure 8.1.8. Trend results for Shasta River at Highway 3 (RM 13.09) for seasonal MDMT during Late Summer, June 16 – August 15

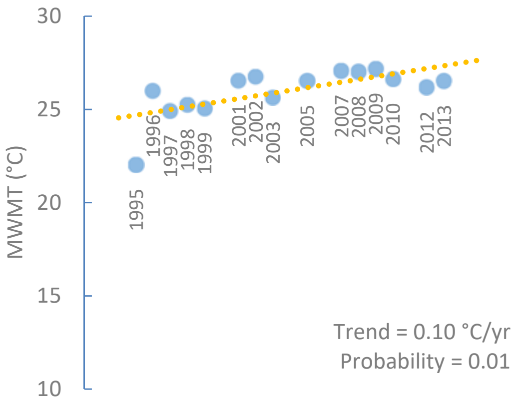

Figure 8.1.9. Trend results for Shasta River at Montague-Grenada Road (RM 15.51) for seasonal MWMT during Late Summer, June 16 – August 15

Assessing 2015 Conditions

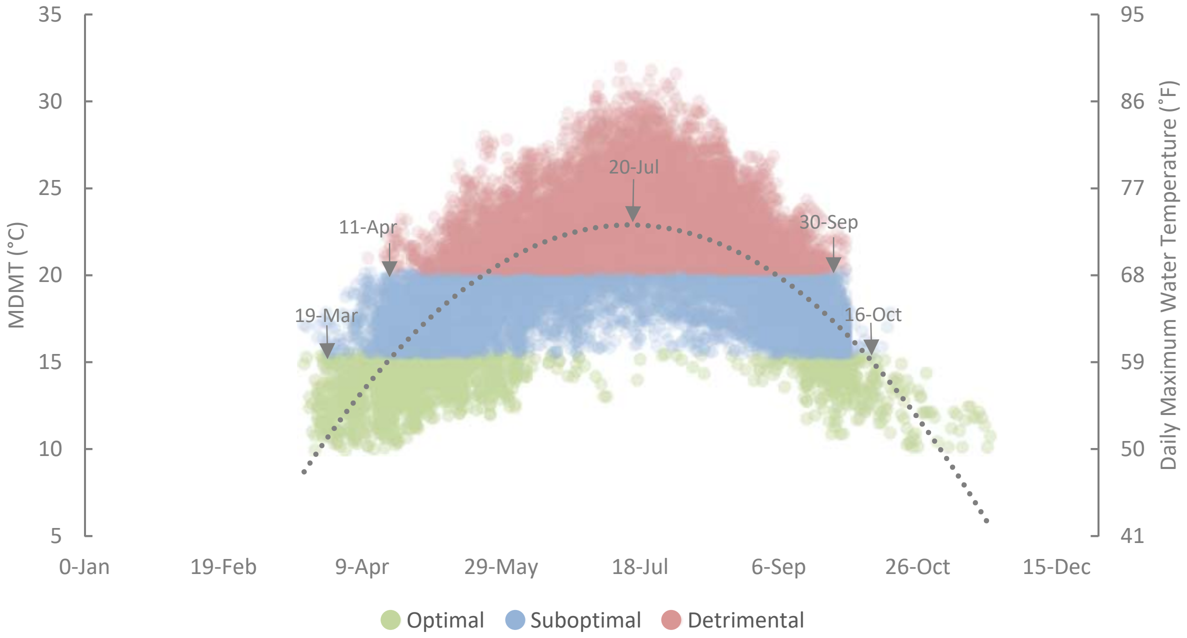

Figure 8.1.10. Seasonality record of daily maximum water temperatures for Shasta Watershed, years 1994 – 2015

Daily maximum water temperatures are represented in Figure 8.1.10 and are categorized by the previously defined supplemental stewardship metrics in Table 8.1.2. The MDMT in the Shasta Watershed was 31.97 ˚C, recorded July 11th, 2002. The minimum recorded MDMT was 9.02 ˚C, recorded April 8th, 1999. The peak of the fitted polynomial trend line occurs at July 20th with a MDMT value of 23.9 ˚C.

The first and last recorded detrimental daily maximum water temperatures occur on April 11th and September 30th, respectively. The first and last recorded suboptimal daily maximum water temperatures occur on March 19th and October 16th, respectively. During the previously defined Whole Summer window of April 16th to August 15th, the daily maximum water temperatures were 8.8% optimal, 32.1% suboptimal, and 59.1% detrimental.

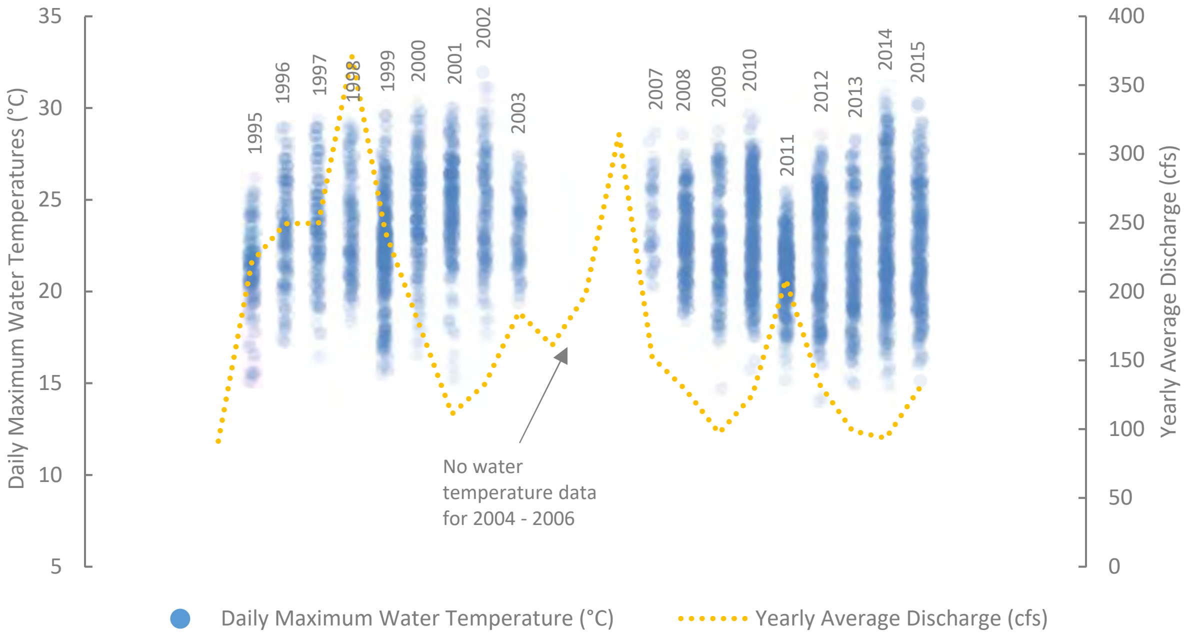

Figure 8.1.11. Yearly record of daily maximum water temperatures for Shasta Watershed for all locations, years 1995 – 2015 (Late Summer Window, June 16 – August 15), and recorded yearly average discharge for USGS 11517500 SHASTA R NR YREKA CA, years 1994 – 2015

Daily maximum water temperatures are organized yearly and plotted against yearly average flows in Figure 8.1.11. Noticeable drops in daily maximum water temperatures occur in 2003 and 2011, dropping to 27.4 and 25.57 ˚C, respectively. For comparison, the average daily maximum water temperatures for 2007 – 2010 and 2012 – 2015 are 28.9 and 29.5 ˚C, respectively. Although not consistent in all years, lower daily maximum water temperatures seem to correspond with higher flow years, while higher daily maximum water temperatures seem to correspond with lower flow years. This correlation has been documented in other analyses, for example an analysis of 2001-2011 data found statistically significant correlations between monthly mean flow and monthly mean water temperature at the mouth of the Shasta River for September, but not June, July, and August (Asarian and Kann, 2013).

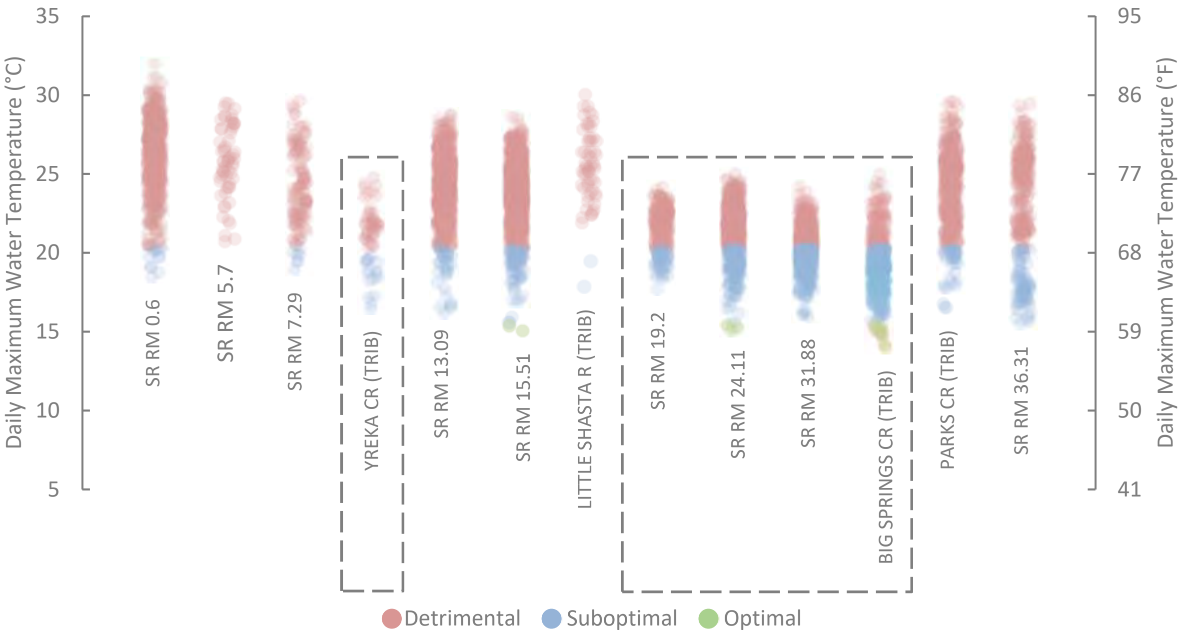

Figure 8.1.12. Longitudinal record of daily maximum water temperatures for Shasta Watershed, years 1995 – 2015 (Late Summer Window, June 16 – August 15)

Daily maximum water temperatures are represented in Figure 8.1.12 and categorized according to the supplemental stewardship metrics. Noticeably present are colder trending areas in Yreka Creek near the mouth with an average daily maximum temperature of 21.1 ˚C, while Shasta River RM 19.2, Shasta River RM 24.11, Shasta River RM 31.88, and Big Springs Creek near the mouth have average daily maximum temperature of 23.7 ˚C.

Comparatively, the lower Shasta River mainstem sites (Shasta River RM 0.6, Shasta River RM 5.7, and Shasta River RM 7.29) have an average daily maximum temperature of 25.8 ˚C, while the mid-reach (Shasta River RM 13.09, Shasta River RM 15.51, and Little Shasta River near the mouth) and upper reach sites (Parks Creek near the mouth and Shasta River RM 36.31) have average daily maximum temperatures of 23.7 and 21.4 ˚C, respectively.

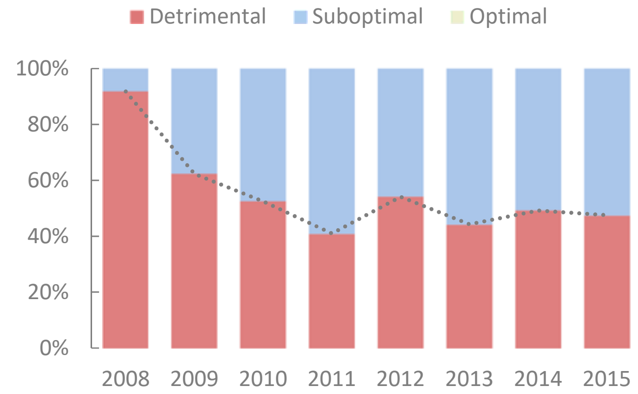

Figure 8.1.13. Percent of daily maximum temperatures in classified ranges per year at Shasta RM 31.88 (Late Summer Window, June 16 – August 15)

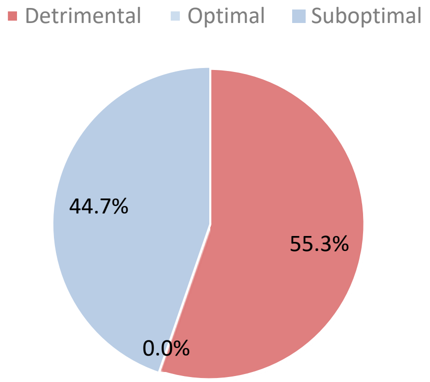

Figure 8.1.14. Cumulative percentage of daily maximum temperatures in classified ranges for all years at Shasta RM 31.88 (Late Summer Window, June 16 – August 15)

While no statistically significant trend was detected at Shasta River RM 31.88 during the trend analysis, the supplemental stewardship metric analysis revealed a noticeable decrease in detrimental daily maximum water temperatures from 2008 – 2015, from 91.8% detrimental to 47.5% detrimental. Comparative to other sites analyzed, Shasta River RM 31.88 consistently held the lowest temperatures in mainstem Shasta, with a cumulative percentage of 44.7% of days during June 16 – August 15 with temperatures not in the detrimental range (for those years listed in Figure 8.1.13).

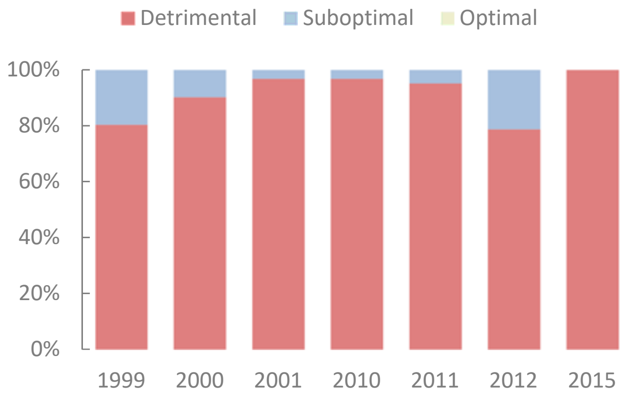

Figure 8.1.15. Percent of daily maximum temperatures in classified ranges per year at Parks Creek (Late Summer Window, June 16 – August 15)

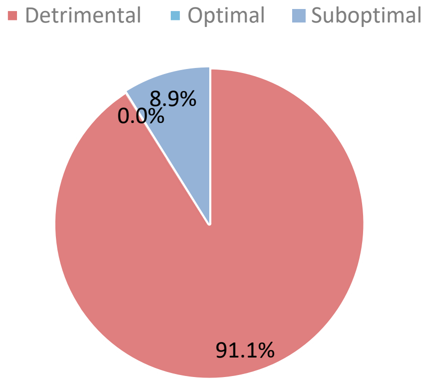

Figure 8.1.16. Cumulative percentage of daily maximum temperatures in classified ranges for all years at Parks Creek (Late Summer Window, June 16 – August 15)

Among tributaries with adequate water temperature data for analysis, Parks Creek stands out as one of the most critical tributaries in the Shasta Watershed with recent temperatures in 2015 reaching 100% detrimental for days during June 16 – August 15 and a cumulative percentage of 91.1% detrimental (for those years listed in Figure 8.1.15).

A complete listing of the 2015 conditions for all sites and associated methods are outlined in Appendix B.

Temperature Findings

Results from the completed water temperature analysis have revealed:

- Protection of cold water supplies (springs) during warm summer months is the most critically important attribute to work towards improving stream temperature conditions. This is perhaps most evident in Figure 8.1.12, where average daily maximum temperatures are noticeably lower in locations downstream of cold water springs, such as Big Springs Creek.
- The cooling influence of these springs is evident downstream on the mainstem Shasta River at Shasta River RM 19.2, Shasta River RM 24.11, and Shasta River RM 31.88.
- With some exceptions, lower flow years corresponding with drought have noticeable increases of watershed-wide MDMT's and average daily maximum water temperatures. However, further analysis is required to quantify the relationship of flow to water temperatures.
- Since TNC acquired ownership of the Big Springs Creek property, both restoration activity and flow strategies have been employed with a noticeable effect on water temperatures, with a Whole Summer window decreasing MWMT trend of 0.46 ˚C, and a marginally larger Late Summer window decreasing MWMT trend of 0.48 ˚C.
- Supplemental stewardship metric analysis revealed a noticeable decreasing trend (but not statistically significant) in the percent of days experiencing detrimental daily maximum water temperatures from 2008 – 2015 at Shasta RM 31.88 (Nelson Ranch).
- Supplemental stewardship metric analysis revealed consistently high percentages of detrimental temperatures in Parks Creek.

8.2 Dissolved Oxygen

Stewardship actions within the Shasta River Watershed have been predicated on the hypothesis that reducing inputs of warm tailwater laden with nutrients, sediment, and organic matter, while increasing the amount of cold spring water allowed to flow into the Shasta River, will result in improved dissolved oxygen conditions. The table below demonstrates the potential efficacy of this activity, showing monitoring data collected during the 2016 irrigation season (SVRCD, 2016).

Table 8.2.1. Tailwater Monitoring Results from 2016

Site ID	TKN (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)	NH3_NH4-N (mg/L)	TP-P (mg/L)	Notes
07-174TW	0.3	0.59	<0.01	0.03	0.24	Tail Water + Spring Water
Shasta River	0.3	0.16	<0.01	0.02	0.16	Downstream of 07-174TW
06-074TW2	1.0	<0.02	<0.01	0.03	0.32	Tailwater
Shasta River	0.2	0.07	0.01	0.01	0.19	Downstream of 06-074TW

TKN = Total Kjeldahl nitrogen, NO3-N = nitrogen as Nitrate, NO2-N = nitrogen as nitrite, NH3_NH4-N = nitrogen as ammonium plus unionized ammonia, TP-P = total phosphorous.

While only one sampling event occurred for nutrients in 2016, some general statements about the data can be made. The tailwater samples were equal or higher in concentrations than the Shasta river samples for TP-P, NH3-N, and TKN, indicating a flow of nutrients from tailwater to the Shasta River. TKN and TP were higher in the tailwater sample collected at 06-074TW2 than in any other sample collected. TKN is a combined measure of NH3_NH4-N and organic nitrogen. The corresponding NH3_NH4-N nitrogen value for this sample was relatively low, indicating the resulting concentration of TKN is predominantly from organic matter. These results confirm tailwater as a source of organic matter above Shasta River's concentrations. The overall lower TKN and TP-P values indicated in the results for sample 07-174TW could reflect dilution by the spring water. Overall, the data shows that tailwater is a continuing source of nutrients to the Shasta River that likely increases biological and sediment oxygen demand. To understand the impact of stewardship activities to date, an analysis of dissolved oxygen data collected in the Shasta River system was conducted.

Analysis of dissolved oxygen included assessing both data for 2016 across the monitoring network established by the stewardship monitoring program and long-term trends at three monitoring sites. The intent of this analysis is to present data collected from the stewardship monitoring program network and seek to understand water quality trends as they relate to stewardship actions implemented throughout the Shasta River Watershed. Including data from monitoring programs external to the stewardship monitoring program is beyond the scope of this assessment, however such an analysis should be performed in the future. The long-term monitoring sites selected from the stewardship monitoring program network include Shasta River at the Araujo Dam Site, Shasta River at Montague-Grenada Road, and Shasta River below Big Springs. These sites were selected based on location and data set completeness during the selected time period. These sites are also representative of different tailwater neighborhoods, have different tailwater neighborhood priority assignments, and have experienced varying degrees of stewardship actions.

Analyses were focused on the time period between June 22 and September 1 to understand the dissolved oxygen conditions during the time of highest impact from tailwater return flows and primary production of aquatic vegetation. A full description of data sets for 2016 conditions and long-term trends, including the criteria utilized to exclude years from long-term analysis, is presented in Appendix B. The criterion used for this analysis to identify the level of impact to dissolved oxygen concentrations is 6 mg/L, which represents the basin plan objective for dissolved oxygen adopted by the NCRWQCB in 2015 for Cold Freshwater Habitat.

2016 Conditions

Conditions for the Shasta River in 2016 are presented in Figure 8.2.1, showing the percentage of days in the selected time period where the daily minimum value for dissolved oxygen falls below 6 mg/L. The sites are ordered by location along the reach of the Shasta River, with the most upriver station on the left side of the figure and the most downriver station on the right side of the figure.

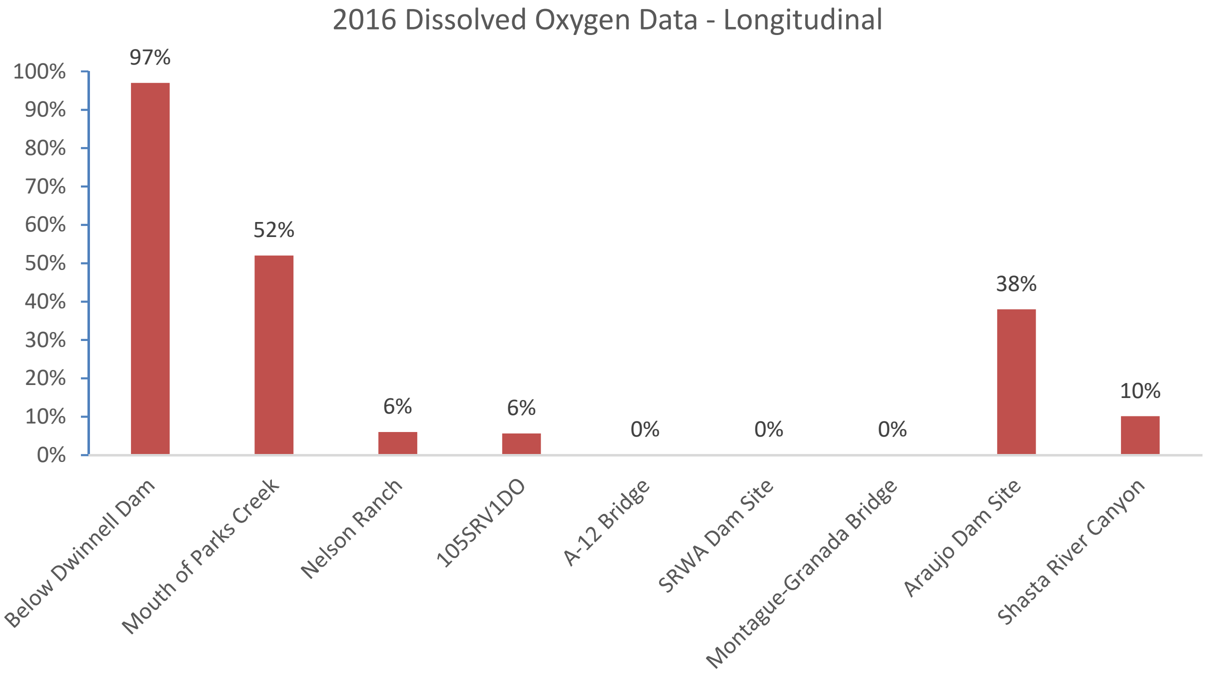

Figure 8.2.1 - Percent Days with a Minimum DO value below 6 mg/L in 2016.

Based on this analysis, monitoring locations located within and immediately downstream of tailwater neighborhoods ranked “high priority” by the Tailwater Reduction Plan (reaches 5 and 6 – See Figure 5.4) show more than 50% of days experience minimum dissolved oxygen levels below 6 mg/L. Monitoring locations within reach 2, 3, and 4 show fewer days with dissolved oxygen levels below 6 mg/L, ranging from 1% to 16% of the days considered. Monitoring location 105SRA1DO, located at the site of the former Araujo flashboard dam stands out as an exception to this. Station 105SRA1DO shows 38% of the days within the selected period with minimum dissolved oxygen concentrations below 6mg/L.

Trend Analysis

Long term trends for the selected sites are presented in figures 8.2.2, 8.2.3, and 8.2.4, showing the percentage of days where the minimum value for dissolved oxygen drops below 6 mg/L. *Shasta River Below Big Springs*

The monitoring site on the Shasta River below Big Springs is the most upstream dissolved oxygen monitoring point with sufficient data to identify trends. It is located downstream from the confluence of Big Springs Creek and the Shasta River, immediately downstream of reach 5 and 6. Tailwater management and irrigation efficiency project completed upstream of this monitoring site include, but may not be limited to:

- The Big Springs Ranch Head Structure Project (2011),
- Hidden Valley Bunkhouse and Westside Pipeline Efficiency Project (2011),
- Hole in the Ground Ditch Maintenance Project (2013), and
- the Flying L Pump and Pipeline Project (2015).

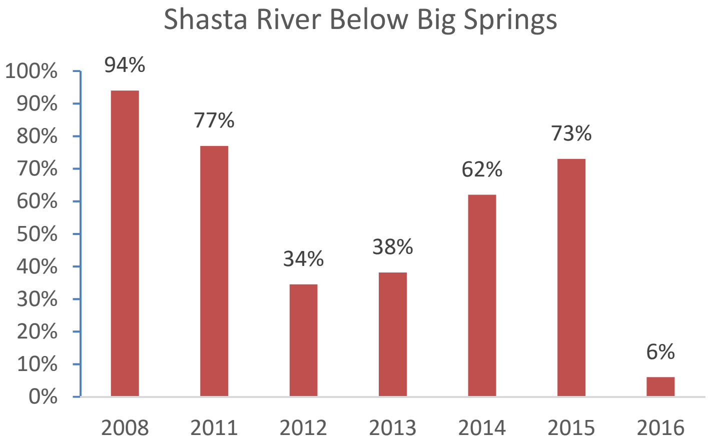

Figure 8.2.2 Percent Days with a Minimum DO value below 6 mg/L

This monitoring site captures the influence of several high-priority tailwater neighborhoods identified in the 2011 Shasta River Tailwater Reduction Plan. No significant trend is apparent at this site, however an unacceptably high percentage of days during the analysis period fall below the desired criteria value and water quality objectives.

Shasta River at Montague-Grenada Road

The monitoring site on the Shasta River at the Montague-Grenada Road bridge is located downstream of the confluence of the Little Shasta River and the Shasta River mainstem, just downstream of reach 3. Tailwater management and irrigation efficiency projects conducted upstream of this monitoring site include:

- the Meamber Tailwater Re-use Efficiency Project (2013),
- the Meamber Pipeline Efficiency Project (2011),
- the Kuck Tailwater Re-use Project (2013),
- the Freeman Efficiency Project (2013),

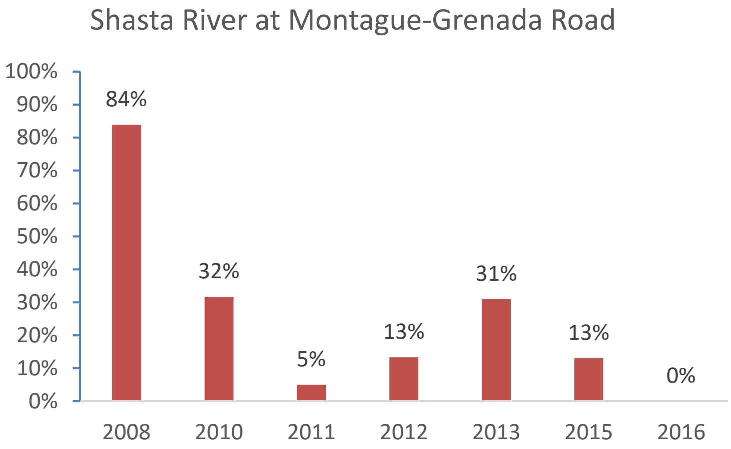

Figure 8.2.3 Percent Days with a Minimum DO value below 6 mg/L

- the Shasta Water Authority (SWA) Upper South Ditch Water Measuring Improvement Project (2014),
- the SWA turn-out and Lateral Replacement Project (2012),
- the SWA Tailwater Ditch Rehabilitation, and
- the SWA Site 9 Water Measuring Improvement Project (2014).

This monitoring site captures the influence of medium and low priority tailwater neighborhoods identified in the 2011 Shasta River Tailwater Reduction Plan. There appears to be a decline in days below 6 mg/L dissolved oxygen at this location, however more data is needed to identify a statistically significant trend.

Shasta River at Araujo Dam Site

This monitoring site is on the Shasta River at the location of the former Araujo flashboard dam. The site is downstream from the confluence of the Little Shasta River and upstream of the confluence of the Oregon Slough. Tailwater management and irrigation efficiency projects conducted upstream of this monitoring site are limited, and include:

- Lemos Tailwater Re-use Improvement Project (2011);
- Araujo Dam Removal (2008).

This monitoring site captures the influence of medium and low priority tailwater neighborhoods identified in the 2011 Shasta River Tailwater Reduction Plan. No significant trend is apparent at this site, and the percentage of days falling below the criteria value remains higher than at other sites included in this analysis.

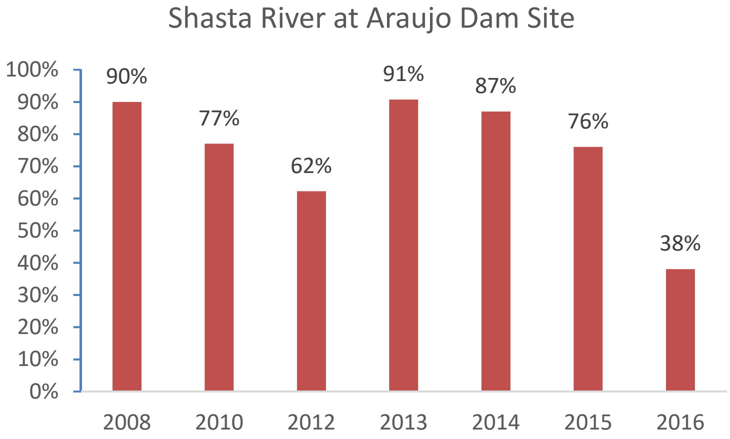

Figure 8.2.4 Percent Days with a Minimum DO value below 6 mg/L

Dissolved Oxygen Findings

Conditions within the Shasta River in 2016 indicate spatial variability in dissolved oxygen concentrations.

- Reach 5 and 6, located in high priority tailwater neighborhoods, show high degrees of impairment with over 75% of days falling below the 6 mg/L basin plan objective.
- Relatively lower levels of impairment are seen in reaches 2, 3, and 4, with fewer than 15% of days falling below the basin plan objective. The exception to this is 105SRA1DO, which is located at the site of the former Araujo flashboard dam. This site shows consistent impairment with 38% of days falling below the basin plan objective.

These results justify the level of priority for river reaches 5 and 6, but also show potential for land use practice improvements between the Montague-Grenada Bridge and the former Araujo dam site, which are located in reaches considered low to medium priority tailwater neighborhoods.

Historical data analysis conducted at three monitoring locations provides the following insights into ongoing dissolved oxygen trends:

- No conclusive trend is visible at the monitoring site located in the Shasta River below Big Springs. It appears dissolved oxygen conditions were improving from 2008 to 2013, then showed a marked increase in the number of days with dissolved oxygen values below 6 mg/L from 2013 to 2015, only to improve substantially in 2016. While some tailwater management and irrigation efficiency projects have been completed in this reach, it is possible that the completed projects were not of sufficient scale to address the magnitude of tailwater inputs. However, tailwater is not the only factor impairing water quality; the drought during 2014-15 reduced both surface water and spring flows.
- The monitoring site at the Montague-Grenada bridge shows a potential downward trend in dissolved oxygen impairment, with 84% of days falling below the basin plan objective in 2008 and 0% of days falling below the basin plan objective in 2016. The tailwater neighborhoods that drain into the Shasta River immediately upstream of this location are considered low to medium priority, and have also experienced the highest density of tailwater management and irrigation efficiency projects since 2011. These results provide a line of evidence for the effectiveness of these management practices to improve water quality. The potential success of these restoration and efficiency projects could be partially attributable to their cumulative impact being of appropriate scale relative to the magnitude of tailwater impacts. Is it notable that the largest decrease in concentrations is seen between 2008 and 2010, prior to the implementation of the projects listed in this report. The reason for this drop is unclear, however the sustained improvement in conditions in subsequent years is not seen at the other monitoring sites, and is indicative of an improvement in conditions that support beneficial uses.
- The monitoring site at the former Araujo dam site shows a consistently high level of impairment with no discernable trend across the data record. This result is not surprising, as few tailwater management and irrigation efficiency projects have been completed in the medium to low priority tailwater neighborhoods that drain into this reach of the Shasta River. Results could also indicate legacy sediment oxygen demand from the former dam impoundment influencing dissolved oxygen conditions, or it is possible the cumulative effect of general heating in the river becomes apparent within this reach. Further data is required to understand the drivers behind the consistently high level of impairment.

Overall, these results provide insight into the application of management measures within the Shasta Valley. Areas with a medium to low priority tailwater neighborhood, but with a high density of tailwater and irrigation efficiency projects seem to have responded well, with dissolved oxygen conditions potentially improving over time. Areas with high priority tailwater neighborhoods, but with low to moderate changes to land use practices have shown little change over time with respect to dissolved oxygen conditions, and a high number of days with values below the minimum criteria. It is also important to note that localized site conditions are highly variable. Processes including reaeration from riffles, increased biological oxygen demand from low-velocity reaches with high organic matter, dense aquatic macrophytes can have site-specific impacts on dissolved oxygen conditions.

8.3 Adaptive Management Recommendations

There is evidence that managing tailwater inputs and encouraging riparian vegetation growth has beneficial effects on both temperature and dissolved oxygen. Big Springs Creek received significant changes to management practices following purchase by the Nature Conservancy to encourage recovery of riparian and emergent aquatic vegetation and a general reduction of the amount of cold water diverted from Big Springs Creek. Big Springs Creek is the only monitoring site where temperature shows a significant decreasing trend, providing evidence that these management practices have been successful. However, the presence of a stronger trend in the late summer than through early summer or whole summer indicates early summer heat loading when emergent riparian vegetation is not fully established. The data also indicates that flow could have an influence on temperature, with lower flow years showing notable increases in MDMTs and average daily maximum water temperatures across the watershed.

Dissolved oxygen data showed a compelling long-term trend of improvement in days where the daily minimum dissolved oxygen concentrations failed to meet the basin plan objective at the Montague-Grenada bridge. This is an area where a large number of tailwater management and irrigation efficiency projects have been conducted, and those activities likely play a key role in the observed reduction. It is possible that the improvement seen is a function of the size and scope of these projects relative to the scale of tailwater impacts influencing the Shasta River at that location. The spatial variability in 2016 dissolved oxygen concentrations shows that the oxygen balance in the Shasta River is complex and the dominant source of oxygen consuming material is not known with certainty.

Several watershed stewardship report reviewers commented that a higher priority needs to be placed on water quality improvement and restoration projects that focus on improving flow and temperature conditions in the Shasta River. Tailwater return flow projects that have been completed were undertaken with the intent to both reduce non-point source pollutants (e.g., sediment, organic matter, temperature) and increase flows. These tailwater return flow projects have not always met their flow improvement objectives. However, through our adaptive management analysis, we believe that changes can be made in future project design and implementation that can increase their potential to improve flow conditions. In addition, several spring restoration projects are under consideration that could also contribute to putting more cold water into the river.

Following the analysis of the data collected to date, the following management questions are apparent:

- What management measures can be applied to improve early summer temperatures before emergent vegetation has set in?
- Which processes dominate dissolved oxygen conditions at different reaches of the Shasta River?
- Do former dam sites still contribute significantly to sediment oxygen demand, and if so, how long will those impacts persist in the water column?
- How has dissolved oxygen demand from various sources changed since the adoption of the Shasta River TMDL Action Plan? How does this compare to the Water Quality Compliance Conditions described in the Action Plan?
- How can management measures be applied commensurate to the scale of site-specific tailwater influence to ensure efficient and effective mitigation?

- How can tailwater projects be designed to assure that net flow instream is not reduced as a result of the project?

The following restoration actions and monitoring activities are recommended to answer these questions:

- Continue to implement riparian protection strategies, spring reconnection and rehabilitation, and tailwater management projects.
- Work to remove the remaining flashboard dams on the mainstem Shasta, as well as tributaries.
- Continue ongoing dissolved oxygen and temperature monitoring as well as photo documentation. Continuous monitoring of water quality conditions is crucial to understanding which restoration actions are successful, efficient, and suitable to site-specific conditions. Additionally, ongoing analysis of water quality and restoration data is crucial to guiding TMDL action plan implementation and understanding the dynamics and trends of the overall system. Ensure projects are implemented with appropriate pre- and post-implementation monitoring to assess the effectiveness of projects at addressing the scale of impacts.
- Improvements in data collection and study can be made by collecting meteorological data and other important data at locations in close proximity to the waterbodies of interest to understand dominant drivers of water temperature loading. This includes at least ambient air temperature, relative humidity, solar radiation, and wind speed. These added parameters would prove more representative of conditions adjacent to the Shasta River and its tributaries than existing CDEC weather stations, while also providing boundary conditions for water temperature modeling efforts.
- An updated comprehensive temperature modelling study may prove the most effective means to assess spatial and temporal variability in heat loading to the Shasta River.

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Appendix A

Shasta River Monitoring Plan

Shasta River Watershed Water Quality Monitoring Plan

Shasta River watershed program partners have conducted water quality monitoring at various locations throughout the Shasta River watershed. Overall, there are numerous data gaps at many of the sites. Based on the water quality monitoring location inventory conducted as part of developing the stewardship report, a clear need to establish and maintain a basin-wide water quality monitoring network was identified. The need has been echoed by several program partner organizations as a critical step toward supporting beneficial uses and developing long-term water quality management strategies. Local monitoring entities, referred to as the Shasta River Water Quality Monitoring Network, identified monitoring locations and water quality constituents that will allow continued assessment of instream conditions and trends. This *Shasta River Watershed Water Quality Monitoring Plan (Monitoring Plan)* was prepared by the North Coast Water Board staff, in collaboration with the Shasta Valley Resource Conservation District (SVRCD) and the Shasta River Water Quality Monitoring Network. The monitoring elements are presented in a prioritized approach in an effort to build in flexibility while maintaining a consistent long-term monitoring network in an intermittent funding climate.

In addition to providing protocols and tools for conducting monitoring, this Monitoring Plan provides direction for how monitoring will be utilized in the Shasta River Watershed that will maintain landowner privacy and confidentiality in addition to documenting success and performance of projects and programs. This important task to appropriately honor individual privacy rights is critical to encourage further stewardship planning and actions. This will be done by collecting and reporting data at a landscape and reach scale larger than any one farm, ranch or property.

Basin-wide Monitoring Collaboration

Along with the monitoring network, some of the program partners participated in the collaborative development of a formal Klamath Basin monitoring plan. Through a facilitated effort beginning in 2007, Klamath Basin Monitoring Program (KBMP) member organizations developed guiding goals and objectives for the program as well as a Klamath Basin-wide monitoring plan. The goal of the monitoring plan was to develop and maintain a long-term monitoring network of sites that capture status and trends of selected indicators throughout the Klamath Basin. The KBMP provides a forum for on-going collaboration and coordination by hosting a twice a year membership meeting and research conference, hosts important information about water quality monitoring on their website, and assists organizations with uploading data to a state-supported water quality data clearing house, such as the California Environmental Data Exchange Network (CEDEN).

There are plans to connect stewardship and restoration actions, tracked by the Klamath Tracking and Accounting Program (KTAP) database, with water quality monitoring data by linking the water quality database system to the KTAP database. The product will be an integrated network of water quality monitoring data and restoration actions. The benefit of linking the two systems will be the enhanced ability to track restoration benefits to water quality. The results will also play an important role in the stewardship adaptive management process, since the effectiveness of restoration activities may be quantified and evaluated as part of this process.

Types of Monitoring

Four types of monitoring of stewardship efforts are commonly applied at various scales to understand impacts of restoration projects using conservation practices and water quality improvement programs such as waivers and TMDL’s. These four types are listed and described below.

1. Implementation Monitoring – Assess whether the environmental protection and restoration measures detailed for each ranch water quality plan, conservation practice, and restoration project have been fully and properly implemented according to the original project design. Assessment is usually carried out via visual observation and anecdotal accounts of the completed plan or project. Implementation monitoring is conducted for all projects and will be the primary method for early detection of potential water-quality improvements or problems that may occur following initiation and installation. Implementation monitoring often follows ground-disturbing activities, prior to the beginning of the winter period following project initiation, and at the completion of the project. This monitoring is completed early enough to allow corrective action to be taken, if needed, prior to the release of contractors or the onset of the first winter period.

2. Effectiveness Monitoring – Assess whether each of the implemented environmental protection and restoration measures are adequately responding to be protective of water quality. This is not water quality sampling. Effectiveness monitoring may be as simple as conducting a visual inspection of the project site and adjacent area. Effectiveness monitoring is typically performed after conservation practices have gone through one year or one winter period to evaluate project function during winter rain events and resiliency following disturbance. Effectiveness monitoring addresses project specific questions such as the following examples: was shade created over time as expected? Did pools maintain adequate depth? Was warm tailwater surface runoff reduced by the project? Did water secured for instream flow augmentation achieve the water quality improvement goal?

3. Validation Monitoring – This type of monitoring is the actual collection of water quality samples. It assesses the impacts to water quality or habitat use from multiple projects over time. Important questions may include: are the fish using the restored habitat in greater abundance or as healthier populations than pre-project? How did water quality parameters change since the implementation of stewardship activities? Quantitative numerical approaches are preferred.

4. Compliance Monitoring – This is not the focus of the Watershed Stewardship Plan. It is the job of the Water Board or other regulatory agency staff to ascertain if specific requirements are being followed according to the law. This is also used to determine if specified water-quality criteria or stream conditions are being met and may be numerical or descriptive approaches.

Other terms often used include trend and project monitoring, but these focus on methods of analysis and can be applied at various scales across the four types described above. Another common term is photopoint monitoring – taking a series of photographs over time, from the same point and orientation. Photographs are well-suited for project implementation, effectiveness and compliance monitoring types such as erosion and sediment control, streambank stabilization, fish migration barrier removal, and riparian planting conservation practices. The specific objectives for each project guide how to monitor and parameters to measure over time.

The collection of adequate baseline data is critical to measure changes, performance and success over time. Implementation and effectiveness monitoring are expected for all projects. The minimal level of monitoring includes checklists for implementation of on-the-ground prescriptions to protect water quality, and environmental protection and conservation measure effectiveness evaluations for recent projects.

Scientific Certainty

Management of water quality requires information, usually in the form of data. Effective management depends on the quality of the data that is collected. For the purposes of a management decision, data quality depends on the following conditions:

1. Asking the right management questions
2. Defining measures that provide the answers to those questions
3. Creating a monitoring design that collects the measures to answer the questions
4. Achieving the level of certainty needed by decision makers
5. Controlling quality of the collection of data

Management decisions are made using the information gained from data collection. If all fish are counted or all habitat is measured, there is no uncertainty because a complete sample has been obtained, often called a census. However, this is seldom possible or cost effective. Therefore, sampling is the accepted approach to determining the answer to a desired question. Sampling provides an estimate of the true value sought. While sampling may focus on the quantification of water quality constituents such as temperature, effective decision-making is dependent on an appreciation of the uncertainty associated with the measurement of these constituents.

The goal of water quality monitoring is to provide an accurate and precise estimate of the constituents needed by decision makers. Questions and concerns with sampling estimates include:

- How reliable are the estimates?
- Is the decision correct, based on estimates?
- What is the chance that the decision is wrong?

Uncertainty introduced in monitoring will depend on the accuracy (or bias) of the measures and the reliability (or precision) of the estimates of those measures. An accurate or unbiased estimate is an estimate that does not have systematic error. Bias is not generally a quantity that can be measured, so typically bias can only be minimized by careful consideration of assumptions and methods of data collection in the monitoring design. Precision or reliability is measured by the variation between repeated measurements of the same sample. A reliable estimate has a relatively small variation in replicate measurements. Imprecision is introduced when samples are measured instead of conducting a census of the whole population. The precision of a measurement depends on factors that include the underlying sample variability and the numbers of samples collected.

Shasta River Watershed Water Quality Monitoring Questions

To identify locally appropriate questions related to water quality monitoring in the Shasta River, below are questions that can help guide an effective water quality monitoring program:

1. What are the baseline trends?
2. Does water quality support beneficial uses?
3. How could the water quality be affected by climate change?
4. How can local private property and privacy rights be protected while partnering with landowners as part of voluntary water quality improvement projects?

What are the baseline trends?

There are very few long-term datasets from which to assess Shasta River water quality trends, as an intermittent funding environment has resulted in a patchwork of data. Water temperature measurements were compiled and assessed for temporal trends where adequate data existed in the Shasta River. The statistical evaluation assessment of trends was conducted at locations where at least eight years span of water temperature measurements were available. Years with large data gaps through the season were not included in the trend analysis so as to not bias the results. Water temperature trend analysis was conducted on available data from six (6) Shasta River locations. No statistically significant trends were observed at any of the locations assessed. Meteorological factors that influence water temperature also did not have any effect on the trend results. Additional long-term monitoring is needed to gather adequate information to detect any temporal trends.

Does water quality support beneficial uses?

The *Water Quality Control Plan for the North Coast Region* (*Basin Plan*) designates the specific beneficial uses of water to be protected. The *Basin Plan* applies to both existing and potential beneficial uses of these waters. The most impacted beneficial use in the Shasta River Watershed is aquatic life. Historically the Shasta River Watershed supported fall and spring-run Chinook salmon, coho salmon and steelhead trout. Today, spring Chinook salmon are extinct, fall chinook and Steelhead trout return in diminished but growing numbers, and coho salmon are listed as threatened under the federal Endangered Species Act and the California Endangered Species Act. Assessment of water quality measurements show that acute water temperature thresholds are met most of the time, but that water temperature conditions that can create chronic sub-lethal effects exist for most life stages and species. Dissolved oxygen concentrations are also not meeting standards for the protection of aquatic life. In addition, biostimulatory conditions may exist at many locations. These water quality impacts to beneficial uses need to be monitored to assess the potential for salmon recovery efforts, as river rehabilitation projects will continue into the future. Ongoing fishery monitoring, which gives us production estimates per spawner, provide information on the successful utilization of the river by salmonids, which is linked to water quality and habitat improvements.

How could the water quality be affected by climate change?

Natural variables may influence the results of the trend analyses. For example, a trend in air temperature over the measurement period may correlate to a trend in water temperature, even if other factors have not changed over time. The same effect may be observed with other factors that influence water temperature (e.g. cloud cover, smoke cover, flow volumes, etc.). The positive effects on water temperature from restoration activities may be masked by changing conditions of these influencing factors. Statistical analyses were conducted to investigate which factors most influence maximum daily water temperatures in the Shasta River. Daily mean air temperature was found to be the most influential factor related to daily maximum water temperature at all locations assessed. The Shasta River Watershed Monitoring Plan includes the compilation of these ancillary data sources to help evaluate any climatic influences on water quality.

How can local private property and privacy rights be protected while partnering with landowners as part of voluntary water quality improvement projects?

It can be challenging to document water quality improvements from any particular project designed to improve water quality. Privacy and access are always issues with this type of project-specific monitoring, and decisions will have to be made regarding data collection and sharing. Landowners may not want their specific areas and data identified in public reports, and privacy in this regard needs to be considered. The issues of privacy and access are important, and need to be addressed so that information on projects can be presented to assist in future decisions regarding similar project funding and implementation.

The Shasta River Water Quality Monitoring Network will avoid identifying specific properties or individuals in presenting data, such as grouping data by reach and a specific project type. For example, one could present data on a number of tailwater return projects as ranges and percentiles, and discuss the relative advantages and disadvantages without identifying participants. Such a presentation needs to account for the relative effectiveness and importance of each project to overall objectives of a program. Since not all tailwater projects are the same, specifics that explain successful attributes and future challenges can be included in presentations of overall program effectiveness.

Monitoring Location Selection

Many parties have collected water quality data in the Shasta River Watershed over the years and for many different reasons. Over 2 million water quality data records were compiled from measurements collected from 1991 through 2012 at 160 locations in the Shasta River watershed. However, continuing routine monitoring at the locations identified in this monitoring plan should remain the focus. The intent of selecting fewer locations is to focus limited funding and staff resources to provide consistent long-term monitoring on a small subset of which data is collected continuously and consistently to minimize location bias, and to better inform trend analyses.

Monitoring locations were selected to provide access for water sampling that reasonably represents the range of surface waters in the watershed. The approach was to segment the main stem Shasta River into reaches based on hydrologic and geomorphic characteristics, as well as the knowledge of influencing sources (Figure 1). The following assessment reaches were identified for the Shasta River:

1. Mouth to Yreka Creek
2. Yreka Creek to Little Shasta River
3. Little Shasta River to Willow Creek
4. Willow Creek to Big Springs Creek
5. Big Springs Creek to Parks Creek
6. Parks Creek to Dwinnell Outlet
7. Lake Shastina
8. Lake Shastina inflow to Headwaters

In addition, the major tributaries that influence the Shasta River were identified for monitoring:

1. Big Springs / Little Springs Creek
2. Little Shasta River
3. Oregon Slough
4. Parks Creek
5. Willow Creek
6. Yreka Creek

Figure 1- Map of Shasta River Watershed Monitoring Reaches

The selected water quality monitoring locations are listed and described in Table 1. Monitoring locations were selected for a number of reasons, also described in Table 1. For example, temperature TMDL compliance locations (River Miles 5.6, 15.5, and 24.1) were selected largely due to ease of access. Selection of monitoring locations was also guided by locations that provide supporting information.

Table 1 - Selected Water Quality Monitoring Locations in the Shasta River Watershed

Location	River Mile	Selection Rationale
Shasta River near mouth	0.61	● Downstream end of Reach 1 ● USGS stream flow gage ● Existing monitoring location, easy access
Shasta River at "Salmon Heaven"	5.60	● Temperature TMDL Compliance Point ● Easy access
Shasta River at HWY 263	7.29	● Downstream end of Reach 2 ● Downstream of anthropogenic impacts ● Upstream of TMDL compliance point at RM 5.6 ● Easy access
Shasta River at Montague Grenada Road	15.51	● Downstream end of Reach 3 ● Temperature TMDL Compliance Point ● USGS stream flow gage ● Easy access
Shasta River at Highway A-12	24.11	● Downstream end of Reach 4 ● Temperature TMDL Compliance Point ● Site likely to show beneficial temperature effects of rehabilitation work completed in the primary cold water source areas upstream. ● Existing monitoring location, easy access
Shasta River below Big Springs	33.66	● Downstream end of Reach 5 ● Existing monitoring location, easy access.
Shasta River below Parks Creek	34.92	● Downstream end of Reach 6 ● Existing monitoring location.
Shasta River below Dwinnell Dam	39.94	● Downstream end of Reach 7 ● Represents the water quality released from Lake Shastina.
Shasta River at Edgewood Road	47.52	● Downstream end of Reach 8 ● Montague Water Conservation District stream flow station. ● Represents water quality entering Lake Shastina.
Big Springs Creek near Mouth	0.04	● Temperature TMDL Compliance Point ● Most downstream point easily accessible
Oregon Slough at Ager Road	2.33	● Most downstream point easily accessible
Little Shasta River Below DFG diversion	6.43	● Most downstream point easily accessible
Parks Creek near mouth	0.03	● Temperature TMDL Compliance Point ● Most downstream point accessible
Willow Creek at West Louie Road	8.72	● Most downstream point accessible
Yreka Creek near mouth at Anderson Grade Road	0.59	● Most downstream point accessible ● Existing monitoring location, easy access

The monitoring locations selected represent considerably fewer sites than have been historically sampled throughout the watershed. Additional locations could be added if resources become available. For example, only one downstream location has been selected on each of the major tributaries. If additional resources become available, additional monitoring locations can be added and used to track tributary stewardship activities over time and in association with water quality conditions.

Monitoring Priorities

The monitoring elements are presented in a priority approach in an effort to build in flexibility while maintaining a consistent long-term monitoring network with intermittent funding. The intent of selecting a small number of key locations is to ensure limited funding and staff resources can provide consistent long-term monitoring. The priority approach allows additional locations and constituents to be added as additional resources become available. See Table 2 for the Annual High Priority and Low Priority monitoring locations and constituents.

Annual High Priority monitoring includes the Monitoring Plans developed in conjunction with current SVRCD projects. This plan uses existing staff and equipment resources to collect temperature and/or dissolved oxygen, pH, or other constituents in support of each respective project. Currently, this monitoring includes some funding for laboratory analyses of water samples including nitrogen, phosphorus, and biological oxygen demand. Other annual project effectiveness or validation monitoring can include tailwater flow volumes and temperatures, streambank stability assessments, and photo point monitoring, among others.

Low Priority monitoring is the recommended expansion of the existing monitoring. Combined these represent the minimum monitoring needed for an adequate assessment of water quality status and trends. Resources are expected to be provided through a coordinated partnership contribution. This increases the number of locations for continuous monitoring of dissolved oxygen, pH, and other constituents. It also recommends collecting water samples for laboratory analyses of water quality constituents of concern. This does not increase the locations selected, but increases the information collected at each representative location.

Extended Monitoring, Research, and Special Studies will be required to answer specific questions, beyond status and trends and adaptive management. Research and studies could be conducted to provide additional information to support water quality monitoring. Additional monitoring that is not conducted every year or season (e.g. physical habitat and riparian condition assessments) can provide a snapshot of river conditions over time. Increasing the number of monitoring locations from those identified as the minimum for annual High Priority monitoring should also be considered.

Table 2 - Water Quality Monitoring of the Shasta River Watershed

Location	River Mile	Annual High Priority	Low Priority
Shasta River near mouth	0.61	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Shasta River at "Salmon Heaven"	5.6	Water and Riparian Air Temperature	DO, pH
Shasta River at HWY 263	7.29	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Shasta River at Montague-Grenada Road	15.51	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Shasta River at Highway A-12	24.11	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Shasta River below Big Springs	33.66	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Shasta River below Parks Creek	34.92	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Shasta River below Dwinnell Dam	39.94	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Shasta River at Edgewood Road	47.52	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Big Springs Creek near Mouth	0.04	Water and Riparian Air Temperature, DO	pH, TP, TN, NH_3
Oregon Slough at Ager Road	2.33	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Little Shasta River below DFG diversion	6.43	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Parks Creek near mouth	0.03	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Willow Creek at West Louie Road	8.72	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3
Yreka Creek at Anderson Grade Road	0.59	Water and Riparian Air Temperature	DO, pH, TP, TN, NH_3

Quality Assurance Planning

Consistency in collection of water quality samples is critical to answering the identified management questions. Quality assurance is the overall process that ensures that procedures are being followed and appropriate actions taken to address data quality issues. Quality control is the set of procedures and criteria to check that measurements conform to accuracy and precision limits. The Shasta River Watershed Water Quality Monitoring Plan is guided by the Quality Assurance Program Plan (QAPrP) of the Klamath Basin Monitoring Program. It applies to the generation and use of surface water quality data by the KBMP and its individual Member Organizations. The primary purpose of the QAPrP is to provide KBMP members with documented procedures to assist and ensure comparability; specify the quality systems to the KBMP members; and serve as a guidance document for projects that are required to be or desire to be KBMP-comparable.

The KBMP QAPrP needs to be supplemented with a watershed-specific QA Project Plan (QAPP) which would provide additional detailed information regarding organizational staffing, assignment of available resources to specific tasks, and information on supporting measurements such as stream flow and meteorological data. The purpose of preparing a QAPP is to ensure that all necessary steps are taken to acquire data of the type and quality needed. The information in the QAPP must be sufficiently detailed to allow those responsible for review, approval, and implementation of the monitoring plan to understand what is to be done and the reasons for doing so.

A QAPP currently exists for the Irrigation Water Management and Watershed Stewardship Project (Water Management Project) currently conducted by the SVRCD. The current QAPP describes monitoring the effectiveness of projects designed to reduce warm tailwater return flows. The QAPP identifies the need to develop a collaborative monitoring plan under a watershed stewardship framework. Beyond project specific monitoring of tailwater return flows, the current QAPP also includes limited receiving water monitoring. These include continuous (quarter-hourly) temperature and dissolved oxygen concentrations measured at nine (9) mainstem and one tributary location; and continuous water temperatures measured at a minimum of two (2) additional mainstem locations. Monitoring under this funding is scheduled to be complete by late 2016, although an extension through 2017 has been requested. The current QAPP does not discuss how the continuous water temperatures and dissolved oxygen concentration receiving water monitoring measurements will be used in assessment of project effectiveness.

In addition to the Water Management Project QAPP which is currently being implemented and addresses the Annual High Priority monitoring, a QAPP as also been developed for the Low Priority monitoring. These QAPPs are combined into one document and describe the details, responsibilities, and resources for conducting this Monitoring Plan from year to year (See Appendix). The QAPP describes how the information currently being collected will be used for assessing status and trends. Elements from the Low Priority monitoring are shown in the QAPP in blue font. As future collaborations with monitoring partners participate in the Shasta River Watershed Stewardship Program, the QAPP will need to be updated if monitoring expands to include additional constituents or procedures in the Extended Monitoring, Research, and Special Studies of this Monitoring Plan.

Constituents to be Measured: Annual High Priority and Low Priority

Water Temperature

Water temperature is the most important water quality constituent that needs long-term monitoring in the Shasta River Watershed. In 2007, as part of the Shasta River TMDL development, water temperature was assessed and it was found that standards established for the protection of salmonid beneficial uses were not being met. The Shasta River TMDL established water temperature targets that reflect “natural receiving water temperatures” and aim to achieve the narrative water quality objective in the *Basin Plan*. A review of 2010-2013 water temperature data demonstrated that Chinook salmon, coho salmon, and steelhead trout continued to be impaired from sub-lethal effects throughout the watershed and that TMDL targets had not yet been achieved.

A continuous record of water temperature is essential to observe the daily maximum water temperature. Since water temperature probes are relatively inexpensive, continuous temperature monitoring should be implemented throughout the watershed. Both water temperature and riparian air temperature should be measured at each location. The frequency interval should be short enough to record the maximum values for any one day. Half-hour readings are commonly recommended, but 1-hour intervals are acceptable. Sampling dates should begin in mid-April and continue until mid-October of each year.

Dissolved Oxygen Concentration

In 2007, the Shasta River TMDL established load allocations for oxygen consuming substances from nonpoint sources. In 2007, as part of the development of the Shasta River TMDL, dissolved oxygen concentrations were assessed and it was found that the Basin Plan water quality objective was not being met during the summer season. The TMDL established load allocations for oxygen consuming substances from nonpoint sources. A review of 2010-2013 dissolved oxygen data demonstrated that the Basin Plan water quality objective was not being met.

Dissolved oxygen (DO) concentrations fluctuate diurnally. The ability to observe these daily swings is important in characterizing conditions in the stream. Therefore, the use of continuous recording equipment (e.g. YSI data sondes, ZebraTech D-Opto Loggers) is essential to assess impacts from impaired dissolved oxygen concentrations. The collection interval should be short enough to record both the minimum and maximum values for any one day. Quarter-hour intervals are commonly recommended, but 1-hour intervals are acceptable. Rigorous quality control as described in the QAPP is essential since fouling of certain DO probes is common and can affect the measurements. Determining the frequency of servicing is based on experience for a given site and conditions, but is recommended to be between two to four weeks. Sampling dates should begin in mid-April and continue until mid-October of each year.

pH (Hydrogen ion concentration)

Mathematically, pH is a logarithmic measure of the hydrogen ion concentration in water. The Basin Plan sets the acceptable pH value range between 7.0 and 8.5 for the protection of aquatic life. The pH values may rise above 8.5 due to biostimulatory conditions. When algae and aquatic plants remove carbon dioxide from the water during photosynthesis (day time), the level of hydroxide and the pH value increases. The opposite is true when respiration occurs without photosynthesis (night time); more carbon dioxide is released to the water and pH decreases. Therefore, high pH values during the day can be an indicator of photosynthesis by large quantities of algae and aquatic plants, whose growth can be driven by high nutrient concentrations and sufficient light conditions. The California Nutrient Numeric Endpoint criteria for potential impairment from biostimulatory conditions occurs when the pH reaches 9.0 or above. The pH values presented in the Shasta TMDL show pH values reach 9.0, indicating possible impairment from biostimulatory conditions.

A continuous record of pH values is essential to capture these diurnal fluctuations and observe the daily maximum pH value. The collection interval should be short enough to record the maximum values for any one day. Quarter-hourly is generally recommended, but 1-hour intervals are acceptable. Rigorous quality control as described in the QAPP Plan is essential since fouling of the pH probes is common and can affect the measurements. Sampling dates should begin in mid-April and continue until mid-October of each year.

Nutrient Concentrations

Biostimulatory conditions can be observed when nutrient concentrations are high, and when light and other physical conditions are not limiting growth. Nutrients provide cells with the necessary ingredients for growth. Specifically, macronutrients such as nitrogen, phosphorus, and carbon are consumed in larger quantities than others. Therefore, nutrient concentrations are a primary indicator of biostimulatory conditions. Due to the geology, the Shasta River watershed has naturally high concentrations of inorganic nitrogen and inorganic phosphorus relative to other areas in California. Secondary indicators such as pH, benthic algal biomass, planktonic chlorophyll, dissolved oxygen, dissolved organic carbon, macrophyte cover, and clarity can be measured to assess whether nutrient concentrations are leading to biostimulatory conditions. These secondary indicators provide a more direct risk-based linkage to beneficial uses than the nutrient concentrations alone.

For assessment of beneficial uses, total phosphorus (TP) and total nitrogen (TN) concentrations should be measured at a minimum. Ammonia (NH_3) concentrations should also be measured for assessment of possible toxicity. Dissolved and organic forms are only needed for more advanced model development, but not for status and trends. Water samples should be collected monthly at a minimum between May and October when biostimulatory conditions are of concern.

Extended Monitoring, Research and Special Studies

The following monitoring has been identified as important to answer specific questions and may or may not be currently underway, as it is dependent on available funding. When funding is secured, the following types of monitoring are recommended to be added to the Annual High Priority and Low Priority monitoring efforts.

Benthic Algal Biomass

Biostimulatory conditions can be observed when benthic algal biomass increases in streams. The recreational beneficial use categories affected include aesthetics, fishing, and wading activities. High levels of benthic biomass are aesthetically displeasing and may present a hazard during instream foot travel for fisherman, hikers, etc. Several species of filamentous greens represent a risk to invertebrate communities as well. The California Nutrient Numeric Endpoint criteria presume that impairment from biostimulatory conditions occurs when the benthic algal biomass reaches 150 mg chl-*a*/m^2.

The methods for collecting and determining the biomass of the aquatic plants and algae varies depending on the community (i.e. periphyton-dominated, macrophyte-dominated, or phytoplankton-dominated) at a given river location. Representative sampling of benthic biomass can be complex and should be conducted found in *Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California* (SWAMP 2010).

Meteorological Information

Data compilation from other sources should include hourly measurements for air temperature and relative humidity. Currently, known continuous meteorological information is being collected at Brazie Ranch (wind speed, wind direction, air temperature, solar radiation, precipitation, and relative humidity) and Weed Airport (wind speed, wind direction, atmospheric pressure, air temperature, solar radiation, precipitation, and relative humidity), both operated by CAL FIRE. These stations are not close to the mainstem Shasta River and may not be representative of conditions near the river. Additionally, precipitation data is collected at Shasta River below A-12 road (Department of Water Resources) and in Yreka (US Forest Service). Establishment of an improved meteorological data collection site more representative of the Shasta River watershed conditions should be pursued. However, the ratio of ambient temperature to stream temperature is often important to interpret annual variations and statistically compare changes over time during trend analysis and the CAL FIRE gage will be needed to analyze the long-term data.

Stream Flows

Data compilation from other sources should include measurements for stream flow. Currently continuous stream flows are measured at 3 locations: near the mouth (RM 0.61), at Montague-Grenada Road (RM 15.51), and below Dwinnell Dam (RM 39.94). Flow gauges help resource managers respond to unforeseen situations, coordinate with the watermasters, and work with the water transaction program. Stream flows are difficult to measure at many locations in the watershed due to difficulty in finding adequate cross sections to develop a stream flow rating curve. However, efforts should be made to measure continuous stream flow in the Shasta River below Big Springs Creek (RM 33.66) and from the Big Springs Creek complex.

Shade and Riparian Vegetation

The Shasta River temperature TMDL identified the need to increase riparian shade to achieve site potential riparian conditions on a river-reach scale. Compliance with the TMDL is based on achieving adjusted potential effective shade in the riparian corridor. Potential effective shade represents the shade equivalent to that provided by topography and potential vegetation conditions on a reach. Adjusted potential effective shade is equal to 90% of site potential shade, to allow for natural riparian disturbance such as floods, wind throw, disease, landslides, and fire.

The Shasta River temperature TMDL for the mainstem Shasta River downstream of Dwinnell Dam is expressed as potential percent solar radiation transmittance, but is based on adjusted potential effective riparian shade. Big Springs Creek and Parks Creek are high priority tributaries for assessing riparian shade since the Shasta River TMDL identified required water temperature reductions in these streams. However, emergent vegetation in response to recent restoration efforts has significantly reduced the stream temperature of Big Springs Creek. As a result, monitoring methods and models will need to be improved to account for and describe the importance of emergent vegetation to the instream habitat and salmonid production of the Shasta River.

Stream shade is measured as solar radiation with the solar pathfinder at a minimum of three locations, further divided within each subsection of a project site, but not less than 30-50 feet apart. Other approaches can correlate spatial analysis to field measurements using LIDAR and/or aerial photos. As the canopy grows, solar radiation can be measured every 3-5 years at riparian restoration project sites. The appropriate modeling of stream temperature using shade measurement is currently being researched by the Klamath Basin Rangeland Trust to integrate with TMDL-referenced values of reach scale adjusted potential effective shade.

Riparian habitat improvement objectives commonly involve increasing the abundance and diversity of native woody vegetation along streams at historically grazed project sites. Harris et al. (2005) consolidated existing protocols into an efficient method to assess plant species cover over time using the Riparian Line Intercept Transect. This method is used for any practice intended to improve or protect riparian vegetation, such as control fencing and other indirect passive approaches, in addition to direct planting. This common transect approach measuring canopy structure and species composition is being compared to plot-based protocols to assess the natural recovery potential of riparian vegetation and establish target conditions. Other important attributes being considered are riparian corridor width, invasive weed species, grazing management plans, and other reforestation approaches within floodplain pastures along the mainstem and high priority tributaries.

Instream Physical Habitat

Aquatic habitat improvements often target factors that may be limiting to specific populations in the area, such as water depth, cover, shade, etc. Improvements often include riparian control fencing practices which indirectly affect aquatic habitat by allowing woody vegetation to colonize passively, in addition to practices directly improving the stream channel.

Spawning gravels in the Shasta River have been recently assessed, focusing on spawning gravel availability and quality for coho salmon and Chinook salmon. The study recommended additional gravel quality sampling in the Big Springs Reach and Dwinnell Reach to better quantify overall gravel quality in the reaches.

Fish Studies

Fish studies including rotary screw trapping, adult counts, and PIT tagging have been conducted in the Shasta River and provide important data. However, this monitoring is dependent on intermittent funding that should be pursued whenever possible.

APPENDIX

Quality Assurance Project Plan

- Annual High Priority monitoring elements are shown in a black font text.
- Low Priority monitoring elements are shown in blue font text.

Appendix B

Assessment of Water Quality in the Shasta River Watershed

Assessment of Water Quality in the Shasta River Watershed

The watershed stewardship process relies on an understanding of existing conditions, including the identification of informational needs and water quality problems. This understanding supports project priority assessment, evaluates the effectiveness of stewardship actions, and informs the development of future monitoring activities. Water quality data have been collected in the watershed by a variety of parties spanning several decades, and available water quality information has been compiled and assessed for impacts to beneficial uses. When adequate data existed, temporal and spatial trends in water quality were also evaluated in the Shasta River and its tributaries.

Many parties have collected water quality data in the Shasta River Watershed. Over 2 million water quality data records were compiled from measurements collected from 1991 through 2015 at 160 locations throughout the watershed. The data were collected by several different entities, including:

- California Department of Fish and Wildlife
- The Nature Conservancy
- Shasta Valley Resource Conservation District
- Shasta Valley Coordinated Resource Management Planning Group
- Montague Water Conservation District
- North Coast Regional Water Quality Control Board
- California Department of Water Resources
- U.S. Geological Survey
- U.S. Fish and Wildlife Service
- Karuk Tribe
- McBain and Trush Consultants
- Various researchers, including the University of California at Davis

These water quality data were collected under varying monitoring designs and locations. Some of these data were collected to characterize conditions over a select number of years. Other data were collected for a portion of a year or season to document conditions around a specific study area associated with an identified or perceived problem, with a specific interest (like a spring) or for a specific project (like a tailwater reduction project).

Measurements of water temperature collected since 1994 were used in this assessment of COLD beneficial use impairment. Trend analysis on water temperature measurements was conducted for those locations when an adequate length of record existed.

Assessment results are presented for Chinook, Coho and steelhead for each life stage for both acute and chronic water temperatures (see Attachment 1 – Temperature Assessment Results). The assessment results present the percentage of samples that exceed the assessment thresholds. Colored table cells (Attachment 1) have adequate number of samples to assess the support of the life stage: green cells meet the threshold while red cells do not meet the threshold. Table cells that are not colored do not have adequate number of measurements to assess the support of the life stage according to the State of California Water Quality Control Policy (SWRCB 2004).

Supplemental stewardship metrics were also generated from water temperature measurements to characterize displacement behavior of Coho rearing and are presented in Table E1 (Stenhouse et al. 2012). The primary function of these supplemental stewardship metrics is to identify cold water habitat and displacement behavior of Coho rearing salmon during critical summer months. Analysis including review and categorization of daily maximum temperatures and results are reported as informational.

Table E1. Supplemental Stewardship Metrics and Associated Temperature Ranges

Category	Temperature Range
Optimal	≥10°C and ≤15.5°C
Suboptimal	>15.5°C and ≤20.3°C
Detrimental	>20.3°C or <4°C

Processed and raw data are housed in the Regional Water Board office and are available upon request.

Quality Assurance

Water quality data were collected at sites with varying deployment and retrieval dates. Some locations included measurements throughout the entire calendar year, whereas other locations only had measurements collected during the summer months. Data analysis limitations in this review are related to unknown quality assurance/quality control procedures, data quantity, data type, and staffing resources.

This analysis was conducted with minimal contact from the original data collectors. However, the analysis is not necessarily hindered by unknown data quality. The assessment assumes that differences in data collection would not significantly affect the assessment conclusions. This assumption is generally reasonable for water temperature data due to monitoring instrument accuracy and precision. However, dissolved oxygen concentration measurements can be influenced by instrumentation that does not function properly (i.e. fouling of the membrane on electronic probes, inaccurate calibration with air, etc.). Data were reviewed, suspected quality issues identified, and anomalous data were removed from use in this assessment.

Water Temperature

A small percentage of the water temperature data was determined to be anomalous and was removed before beginning data analysis. Exact percentages can be found in Table E2.

Table E2. Classification and Applied Corrective Action for Water Temperature Data

Classification	Applied Corrective Action	Percentage of Total Record
Pre-deployment	Trimmed	0.04
Post-deployment	Trimmed	0.01
Other	Trimmed	0.44
Good	None	99.51

Classification of the water temperature data can be described most accurately as either “Pre-deployment”, “Post-deployment”, “Other”, or “Good”. “Pre-deployment” or “Post-deployment” refers to when the sensor is recording data, but the sensor is not placed in water. “Other” may refer to anomalous behavior during deployment; an example might include temporary dewatering of the sensor or equipment malfunctioning. “Good” refers to data that accurately reflects water quality conditions.

The only corrective action applied to the water temperature data was “Trimmed”, which refers to removing anomalous data prior to data analysis.

Examples for classification of water temperature data and applied corrective action can be found in Figures E1, E2, and E3.

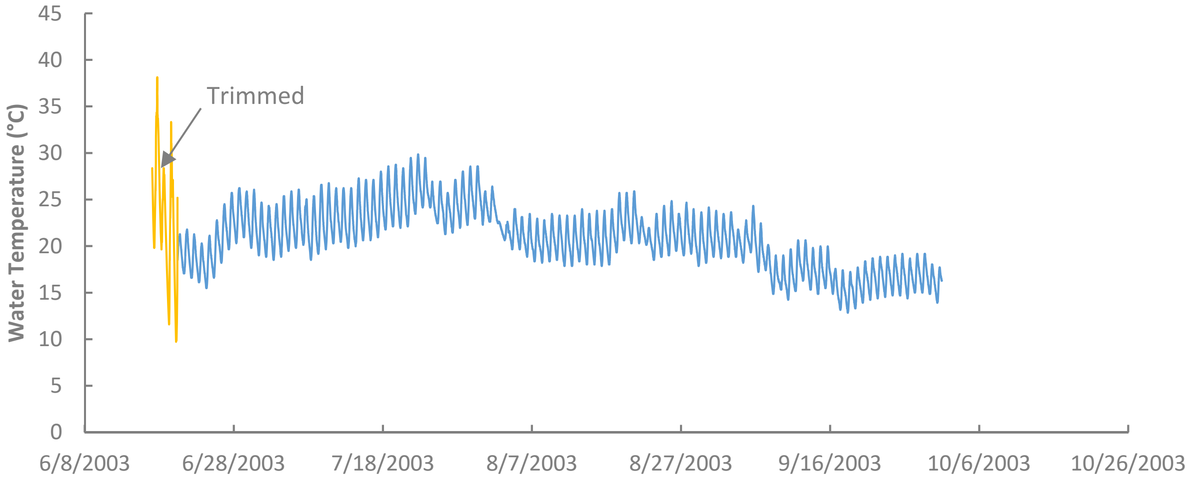

Figure E1: Pre-deployment Classification of Water Temperature Data

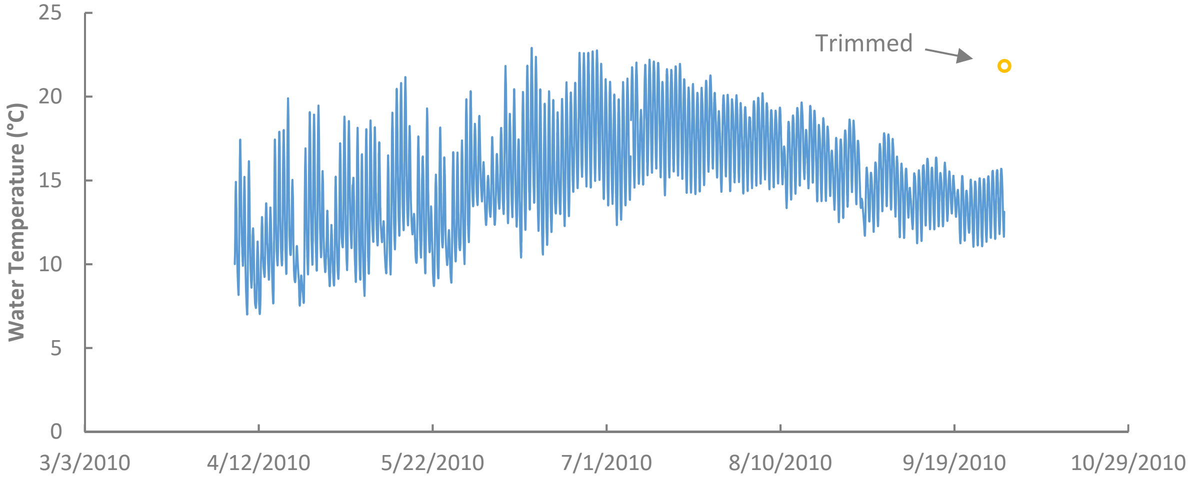

Figure E2: Post-deployment Classification of Water Temperature Data

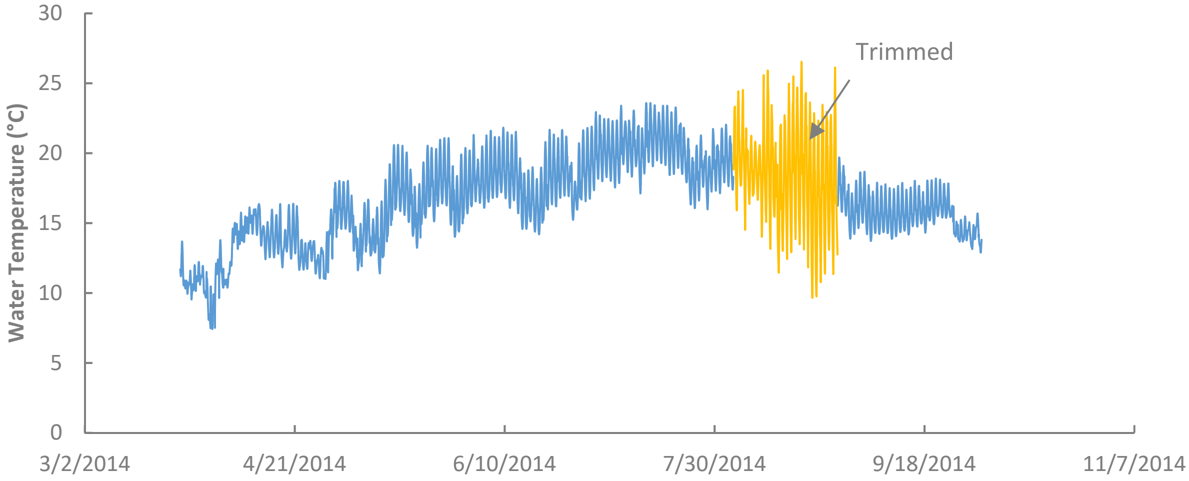

Figure E3: Other Classification of Water Temperature Data

Dissolved Oxygen

Owing to varying deployment and retrieval dates, as well as the general timing of irrigation season, analysis of dissolved oxygen data was limited to measurements recorded between June 22nd and September 30th. A small percentage of the dissolved oxygen data was determined to be anomalous and was removed before beginning data analysis. Exact percentages can be found in Table E3.

Table E3. Classification and Applied Corrective Action for Dissolved Oxygen Data.

Classification	Percentage
Spikes	0.15
Small gaps	0.17
Large gaps	0.36
Other	0.28
Good	99.04

Classification of the dissolved oxygen data can be most accurately described as “Spikes”, “Small gaps”, “Large gaps”, “Other”, or “Good”. “Spikes” refer to anomalous or sudden changes in the data, usually within the span of 1 to 2 time steps. “Small gaps” or “Large gaps” refer to missing data in the provided time series. The most likely explanation for this missing data could be attributed to processing and removal of anomalous data by the original data providers. “Other” may refer to anomalous behavior in the data during deployment; an example might include temporary dewatering of the sensor or equipment malfunctioning. “Good” refers to data accurately reflecting water quality conditions.

For analysis, years of data that contained large gaps were excluded. To calculate this, first a time period was selected that included the height of the irrigation season, where conditions that support over-summer rearing are critically important (June 22 through September 1). For current conditions, all 9 sites in the Stewardship Monitoring Network were utilized. For long-term trends, three sites were selected based on the extent of their historical record: Shasta River below Big Springs, Shasta River at the Montague-Grenada Bridge, and Shasta River at the Araujo Dam Site. At every site, each year of data was inspected visually to ensure the minimum value for each day represented the trough of the diurnal trend in dissolved oxygen. The daily minimum value for each day in the time period was then compiled. The total number of daily minimum data points were compared to the total size of the data set; years with less than 85% of days represented were disregarded. For the Montague-Grenada Bridge site this included 2009 and 2014. For Shasta River below Big Springs this included 2009 and 2010. For the Araujo Dam Site this included 2009 and 2011.

After the final data set was selected each year was analyzed to see what percentage of daily minimum values fell below the Basin Plan water quality objective of 6 mg/L. An in depth discussion of the results of this analysis is presented in Chapter 8.2 of the accompanying text.

Trend Analysis of Water Temperature Measurements

The statistical trend assessment was conducted at locations where at least three years of water temperature measurements were available. Years with large data gaps through the season were not included in the trend analysis to not bias the results. Water temperature trend analysis was conducted on available data at the following locations:

- Big Springs Creek near the mouth (RM 0.96)
- Shasta River near the mouth (RM 0.6)
- Shasta River at Highway 3 (RM 13.09)
- Shasta River at Montague-Grenada Road (RM 15.51)
- Shasta River at Freeman Lane (RM 19.2)

- Shasta River at Highway A-12 (RM 24.11)
- Shasta River at Nelson Ranch (RM 31.88)
- Shasta River at Hole in the Ground (RM 36.31)

Water quality data possess distributional characteristics that generally require specific approaches to evaluating trends. Water quality data sets can contain censored values, outliers, missing values, and serial correlation. These characteristics present problems when using conventional parametric statistics that assume normally distributed data sets. Since water quality data often show a non-normal data distribution, these data sets generally require the use of non-parametric statistical procedures for analysis. Nonparametric statistical tests are more powerful when applied to non-normally distributed data and are almost as powerful as parametric tests when applied to normally distributed data (Helsel and Hirsch, 2002).

Trend analysis was performed for the maximum weekly maximum water temperatures (MWMT) and the maximum daily maximum water temperatures (MDMT). The MWMT (also known as the seven-day average of the daily maximum temperatures (7-DADM)) is the maximum seasonal or yearly value of the daily maximum temperatures averaged over a running seven-day consecutive period. The MWMT describes the maximum temperatures in a stream, but the value is not overly influenced by the maximum temperature of a single day. The MDMT is the maximum seasonal or yearly value of the daily maximum temperature.

The Mann-Kendall test was selected for trend analysis of the water temperature data (Helsel et al. 2006). This nonparametric test was used to evaluate whether water temperatures have increased or decreased significantly since the first year of available monitoring data. The test is non-parametric, based on rank, and insensitive to missing values.

Sen's slope estimator was used to estimate the magnitude of change over time when a significant trend was observed (Sen, 1968). Sen's slope estimator is a non-parametric method that is insensitive to outliers and can be used to infer the magnitude of a trend in the data. Sen’s slope estimator is not greatly affected by gross data error or outliers and it can be computed when data are missing. The Sen’s slope estimator was used to estimate the slope for the statistical tests.

Date ranges were selected based on mode deployment and retrieval dates to capture as much of the data record as possible. Data was also bracketed into shorter “windows” to examine in closer detail the effects of emergent vegetation on water temperatures. The “Early Summer” window refers to the time period before emergent vegetation has grown large enough to provide effective shade. The “Late Summer” window refers to when emergent vegetation has fully set in. The “Whole Summer” window includes both the “Early Summer” and “Late Summer” windows. The MWMT and MDMT windows differ slightly because of differing mode deployment dates. Exact dates for these windows can be found in Table E4.

Table E4. Study Windows and Associated Date Ranges

Metric	Window	Begin Date	End Date
MWMT	Early Summer	April 21	June 15
MWMT	Late Summer	June 16	August 15
MWMT	Whole Summer	April 21	August 15
MDMT	Early Summer	April 16	June 15
MDMT	Late Summer	June 16	August 15
MDMT	Whole Summer	April 16	August 15

Results

Statistical analysis was conducted to investigate long-term trends on a site-specific basis. “Trend” refers to Sen’s slope, which describes the rate at which water temperatures are either decreasing or increasing on an interannual basis. “Probability” describes the significance of the relationship between water temperatures and time, with probabilities below 0.05 considered to be statistically significant. Whether a trend is detectable (statistically significant) is clarified by either a “Yes” or “No” indicator. The number of years analyzed at each site is described under “Number of Years”. The results of the statistical trend test used to evaluate the MWMT values are provided in Tables E5, E6, and E7.

Table E5. MWMT Early Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.4642	0.2296	No	7
Shasta River near the mouth (RM 0.6)	0.1218	0.1329	No	6
Shasta River at Highway 3 (RM 13.09)	0.1351	0.3865	No	8
Shasta River at Montague-Grenada Road (RM 15.51)	0.04014	0.4434	No	14
Shasta River at Freeman Lane (RM 19.2)	-0.2281	1	No	3
Shasta River at Highway A-12 (RM 24.11)	0.03903	0.3865	No	8
Shasta River at Nelson Ranch (RM 31.88)	-0.3398	0.2207	No	5
Shasta River at Hole in the Ground (RM 36.31)	0.3785	0.4624	No	5

Table E6. MWMT Late Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.4812	0.0354	Yes	8
Shasta River near the mouth (RM 0.6)	0.09419	0.0286	Yes	9
Shasta River at Highway 3 (RM 13.09)	0.09058	0.0112	Yes	12
Shasta River at Montague-Grenada Road (RM 15.51)	0.1009	0.0133	Yes	15
Shasta River at Freeman Lane (RM 19.2)	-0.02073	0.7341	No	4
Shasta River at Highway A-12 (RM 24.11)	0.05328	0.2105	No	10
Shasta River at Nelson Ranch (RM 31.88)	-0.1469	0.1331	No	7
Shasta River at Hole in the Ground (RM 36.31)	0.557	0.2207	No	5

Table E7. MWMT Whole Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.4642	0.0355	Yes	7
Shasta River near the mouth (RM 0.6)	0.06805	0.2597	No	6
Shasta River RM 13.09 /RKM 21.07	0.09571	0.0635	No	8
Shasta River at Montague-Grenada Road (RM 15.51)	0.08836	0.0769	No	13

Shasta River RM 19.2 /RKM 30.9	0.02507	1	No	3
Shasta River at Highway A-12 (RM 24.11)	0.03651	0.7545	No	9
Shasta River at Nelson Ranch (RM 31.88)	-0.3247	0.0864	No	5
Shasta River at Hole in the Ground (RM 36.31)	0.513	0.3082	No	4

The results of the statistical trend test used to evaluate the MDMT values are provided in Tables E8, E9, and E10.

Table E8. MDMT Early Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.4605	0.2296	No	7
Shasta River near the mouth (RM 0.6)	0.04429	0.7071	No	6
Shasta River RM 13.09 / RKM 21.07	0.08423	0.3865	No	8
Shasta River at Montague-Grenada Road (RM 15.51)	0.001852	1	No	15
Shasta River at Freeman Lane (RM 19.2)	-0.413	1	No	3
Shasta River at Highway A-12 (RM 24.11)	0.09	0.1524	No	10
Shasta River at Nelson Ranch (RM 31.88)	-0.3225	0.2597	No	6
Shasta River at Hole in the Ground (RM 36.31)	0.3283	0.8065	No	5

Table E9. MDMT Late Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.643	0.0354	Yes	8
Shasta River near the mouth (RM 0.6)	0.1183	0.0091	Yes	9
Shasta River at Highway 3 (RM 13.09)	0.1152	0.0335	Yes	12
Shasta River at Montague-Grenada Road (RM 15.51)	0.1006	0.0791	No	16
Shasta River at Freeman Lane (RM 19.2)	-0.02411	0.7341	No	4
Shasta River at Highway A-12 (RM 24.11)	0.03856	0.4743	No	10
Shasta River at Nelson Ranch (RM 31.88)	-0.12	0.5362	No	8
Shasta River at Hole in the Ground (RM 36.31)	0.5723	0.2207	No	5

Table E10. MDMT Whole Summer Trend Results

Location	Trend (°C·yr-1)	Probability	Significant Trend?	Number of Years
Big Springs Creek near the mouth	-0.4605	0.2296	No	7
Shasta River near the mouth (RM 0.6)	0.05556	0.0603	No	6
Shasta River at Highway 3 (RM 13.09)	0.09975	0.2655	No	8
Shasta River at Montague-Grenada Road (RM 15.51)	0.08154	0.2284	No	14
Shasta River at Freeman Lane (RM 19.2)	-0.1572	1	No	3
Shasta River at Highway A-12 (RM 24.11)	-0.0067	0.917	No	9
Shasta River at Nelson Ranch (RM 31.88)	-0.3225	0.2597	No	6
Shasta River at Hole in the Ground (RM 36.31)	0.5081	0.3082	No	4

Assessment of COLD Beneficial Use Support

The assessment of beneficial use impairment was conducted at the following locations along the mainstem Shasta River, downstream of Dwinnell Dam:

- Shasta River near the mouth (RM 0.6)
- Shasta River at mid-canyon (RM 5.7)
- Shasta River at Highway 263 (RM 7.29)
- Shasta River at Highway 3 (RM 13.09)
- Shasta River at Montague-Grenada Road (RM 15.51)
- Shasta River at Freeman Lane (RM 19.2)
- Shasta River at Highway A-12 (RM 24.11)
- Shasta River at Nelson Ranch (RM 31.88)
- Shasta River at Hole in the Ground (RM 36.31)

The following locations on major tributaries were also assessed for impairment to COLD beneficial uses:

- Big Springs Creek near the mouth
- Little Shasta River near the mouth
- Parks Creek near the mouth
- Yreka Creek near the mouth

Acute and Chronic Water Temperature Thresholds

Regional Water Board staff conducted a literature review and have recommended both acute (lethal) and chronic (sub-lethal) water temperature thresholds for evaluation of Klamath River Basin streams (Carter 2006). Acute water temperature thresholds were assessed using the daily maximum temperature (Table E11). Although salmonids may survive brief periods at these temperatures, these thresholds represent a protective level against lethal conditions. Chronic water temperature thresholds are based on the MWMT (Table E12).

Table E11. Lethal Temperature Thresholds

Life Stage	Lethal Threshold for Steelhead (˚C)	Lethal Threshold for Chinook (˚C)	Lethal Threshold for Coho (˚C)
Adult Migration	24	25	25
Juvenile Growth and Rearing	24	25	25
Spawning, Egg Incubation, and Fry Emergence	20	20	20

Table E12. MWMT Chronic Effects Temperature Thresholds

Life Stage	MWMT (˚C)
Adult Migration	20
Adult Migration plus Non-Core Juvenile Rearing	18
Core Juvenile Rearing	16
Spawning, Egg Incubation, and Fry Emergence	13

The water temperature thresholds were assessed during the time of year when the life stage of each species is present at each stream location assessed. The periodicity of salmonid fish life cycles in the Shasta River were identified and are demonstrated in Figure E4 (Chesney 2016). Assessment results are presented for Chinook, Coho and steelhead for each life stage for both acute and chronic water temperatures (see Attachment 1 – Temperature Assessment Results). The assessment results present the percentage of samples that exceed the assessment thresholds (15%). Colored table cells (Attachment 1) have adequate number of samples to assess the support of the life stage: green cells meet the threshold while red cells do not meet the threshold. Table cells that are not colored do not have adequate number of measurements to assess the support of the life stage according to the State of California Water Quality Control Policy (SWRCB 2004).

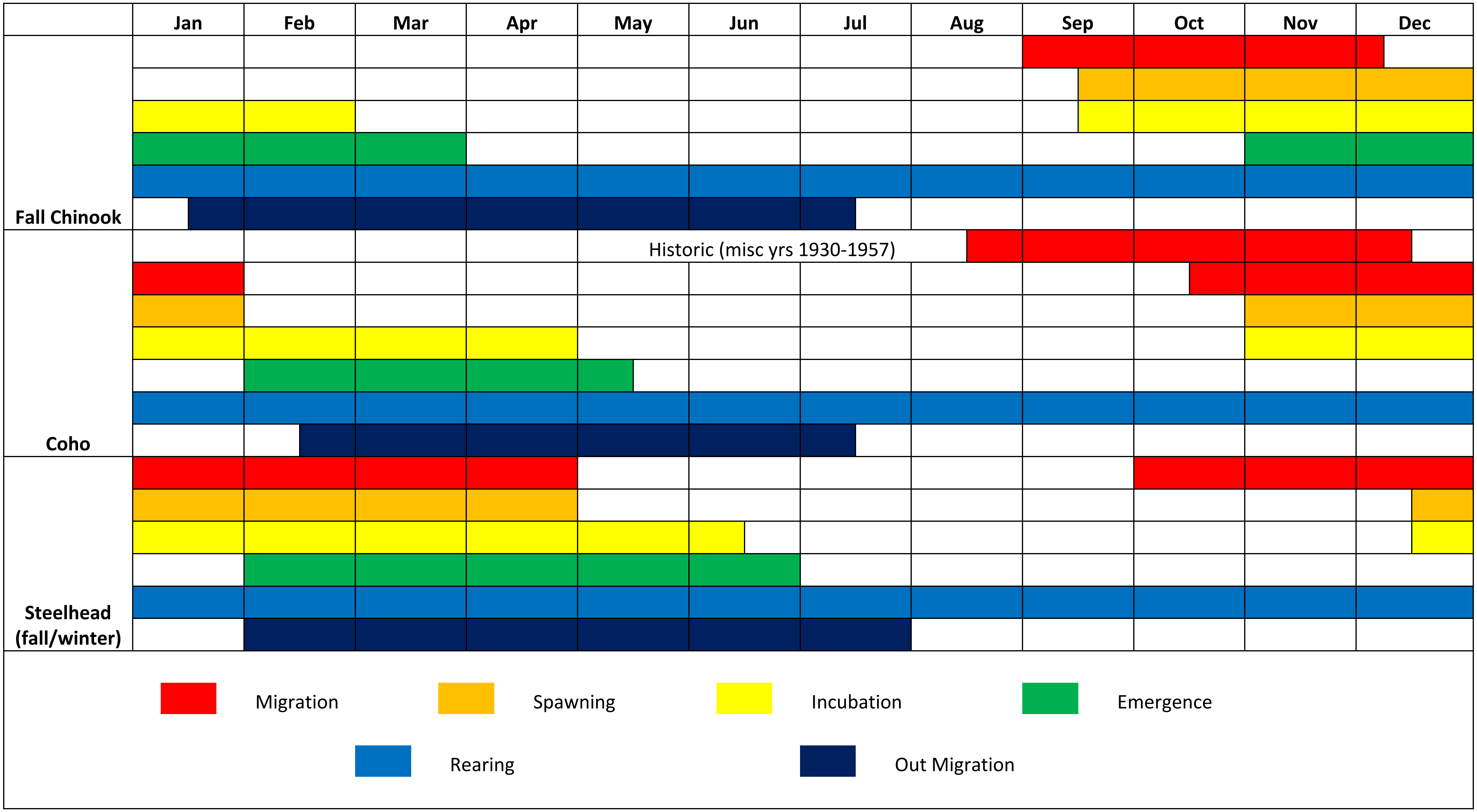

Figure E4. Periodicity for Fall Chinook, Coho, and Steelhead in the Shasta River Watershed

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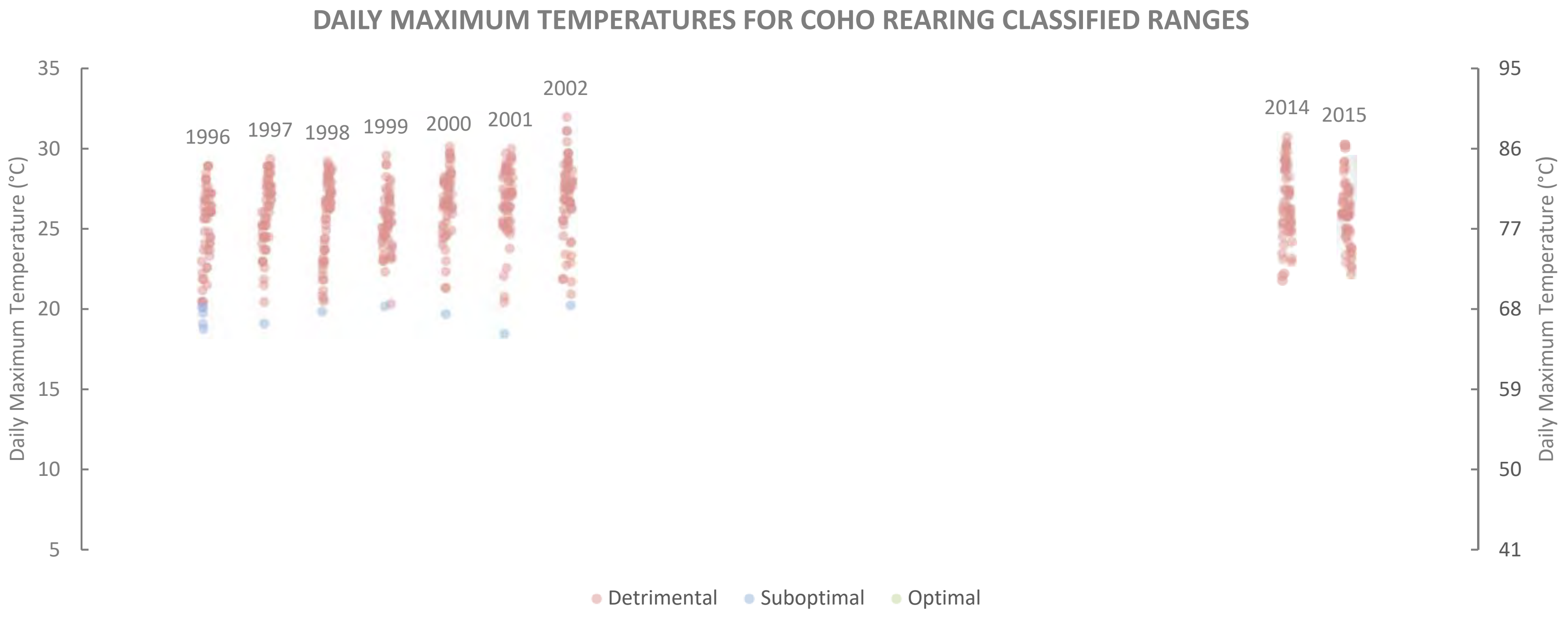
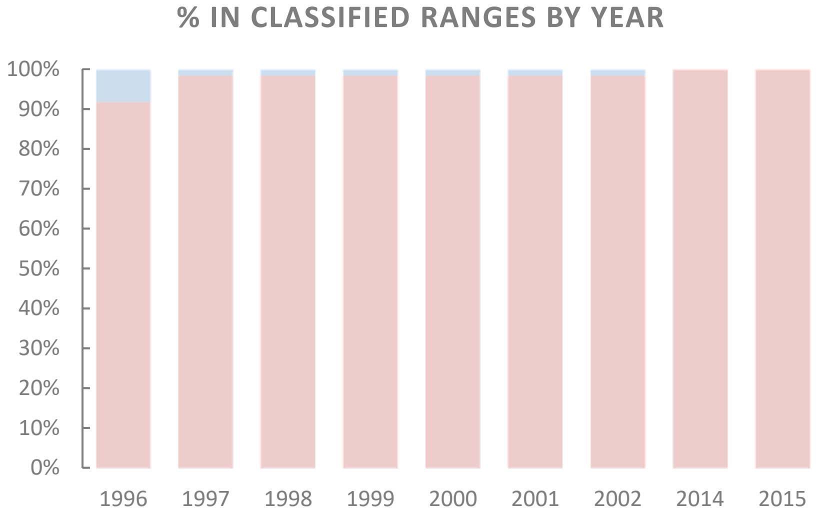
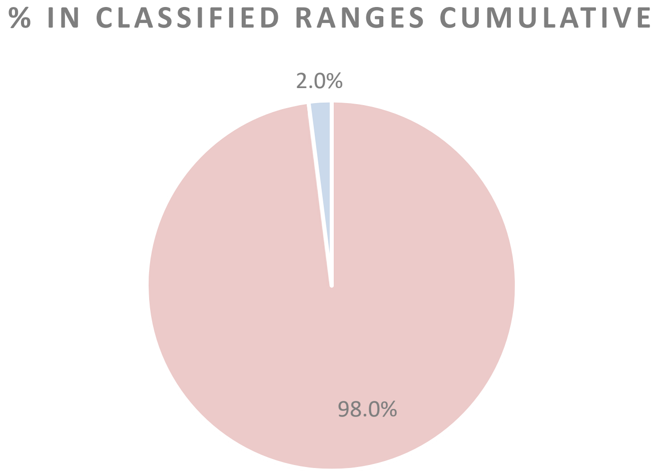
Attachment 1

Temperature Assessment Results

Shasta River near the Mouth (RM 0.6)







Shasta River near the mouth (RM 0.6)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1994			5.88%	25.81%	7.00%	9.21%
1995					0.00%	
1996					31.82%	29.09%
1997			0.00%	25.00%	28.40%	14.12%
1998					35.82%	15.79%
1999			0.00%	0.00%	27.22%	18.48%
2000			0.00%	0.00%	34.91%	23.91%
2001					58.39%	65.00%
2002	0.00%		0.00%	12.50%	35.88%	37.66%
2003			0.00%	3.23%	25.31%	24.71%
2011					23.46%	0.00%
2012					24.00%	11.11%
2013					48.81%	60.87%
2014			5.13%	13.21%	28.35%	22.81%
2015			0.00%	9.43%	27.23%	29.82%

Shasta River near the mouth (RM 0.6)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1994	0.00%	37.50%	37.50%		7.00%	9.21%
1995	0.00%				0.00%	
1996	0.00%	0.00%	0.00%		31.82%	29.09%
1997	0.00%	0.00%	0.00%		28.40%	14.12%
1998	16.67%	18.75%	18.75%		35.82%	15.79%
1999	0.00%	62.50%	62.50%		27.22%	18.48%
2000	0.00%	43.75%	43.75%		34.91%	23.91%
2001	6.67%	50.00%	50.00%		58.39%	65.00%
2002	4.35%	25.00%	25.00%	0.00%	35.88%	37.66%
2003	0.00%	0.00%	0.00%		25.31%	24.71%
2011	0.00%	6.25%	6.25%		23.46%	0.00%
2012	0.00%	25.00%	25.00%		24.00%	11.11%
2013	0.00%	12.50%	12.50%		48.81%	60.87%
2014	0.00%	36.84%	36.84%	0.00%	28.35%	22.81%
2015	0.00%	0.00%	0.00%	0.00%	27.23%	29.82%

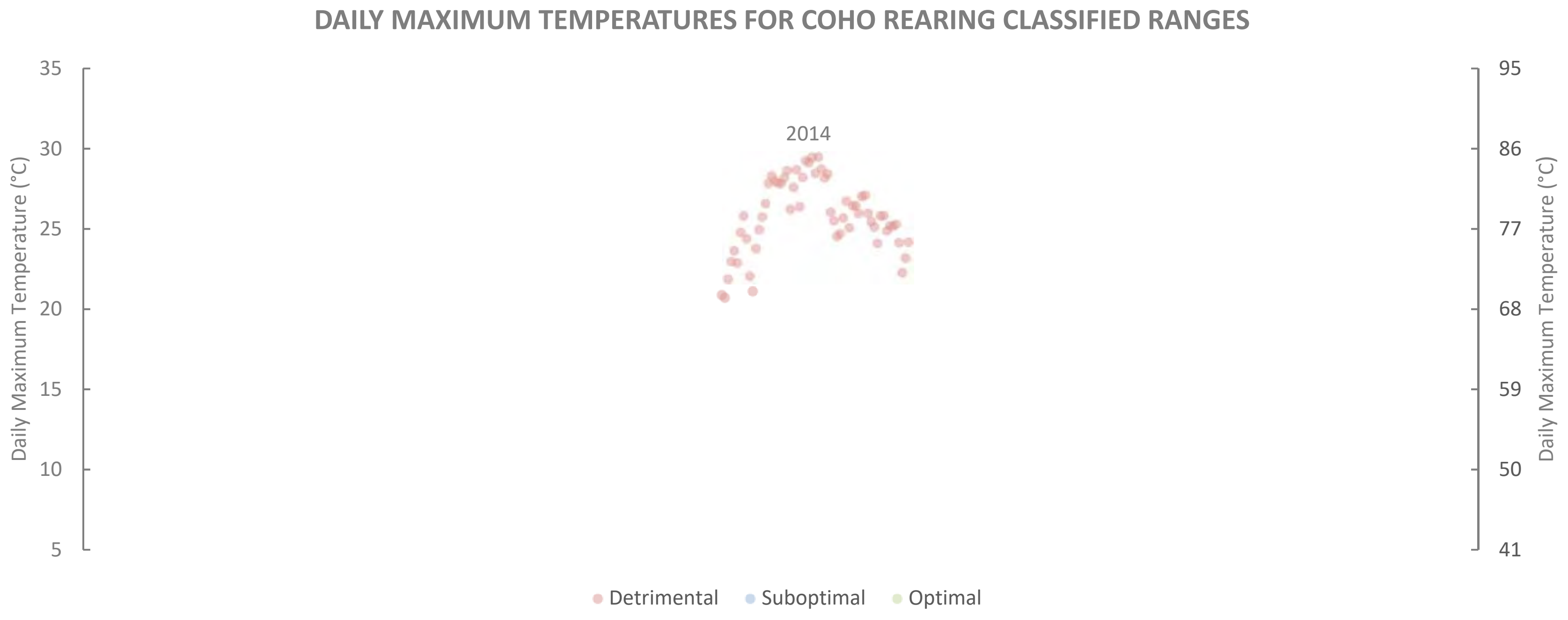
Shasta River near the mouth (RM 0.6)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1994	0.00%	6.25%	48.39%	57.33%	14.00%	18.42%
1995	0.00%				0.00%	
1996	0.00%		64.00%	70.00%	43.94%	46.48%
1997	0.00%	0.00%	52.73%	61.43%	35.80%	37.62%
1998	20.00%		40.74%	59.52%	47.76%	39.73%
1999	0.00%	0.00%	24.19%	38.96%	37.87%	38.89%
2000	0.00%	0.00%	40.32%	51.95%	45.56%	43.52%
2001	13.33%		96.67%	95.56%	65.69%	75.00%
2002	5.00%	0.00%	53.19%	64.52%	44.12%	55.91%
2003	2.17%	0.00%	45.16%	55.84%	36.42%	43.56%
2011	0.00%				43.21%	50.00%
2012	0.00%		50.00%	60.47%	30.00%	36.07%
2013	0.00%		100.00%	88.89%	57.14%	79.49%
2014	0.00%	2.63%	44.05%	52.53%	36.08%	37.69%
2015	0.00%	0.00%	32.14%	42.42%	35.08%	41.54%

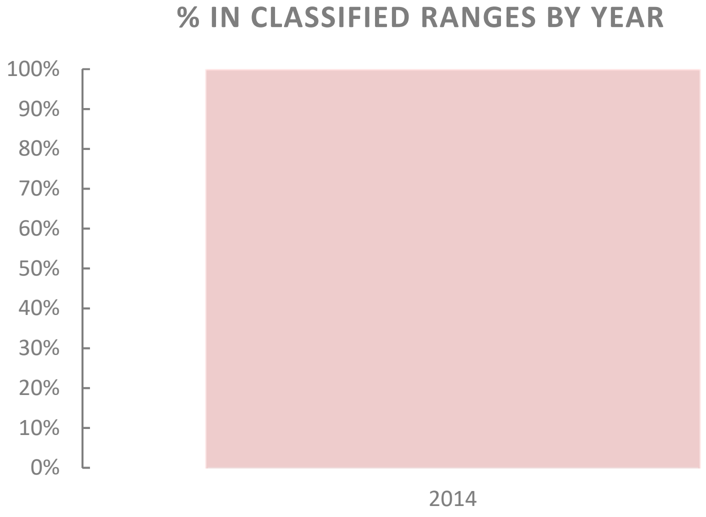
Shasta River near the mouth (RM 0.6)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994			18.86	22.17	25.28	25.28
1995					22.01	
1996					27.80	27.80
1997			17.04	22.23	28.51	25.69
1998					28.70	25.97
1999			14.91	15.76	28.11	28.11
2000			16.66	17.72	29.47	27.85
2001					28.84	28.33
2002	13.15		17.51	17.51	30.23	29.31
2003			13.93	17.30	29.20	26.97
2011					26.10	
2012					27.15	24.45
2013					28.94	28.58
2014			18.61	19.69	29.95	29.62
2015			18.50	20.16	29.39	29.39

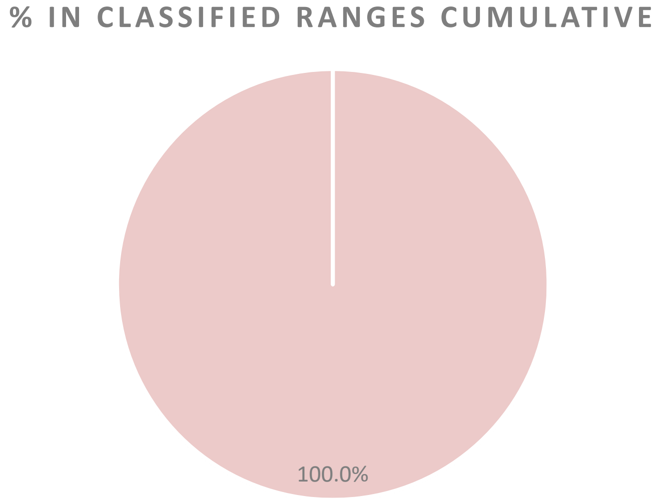
Shasta River near the mouth (RM 0.6)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994	20.05	20.05	20.05		25.28	25.28
1995	21.87				22.01	
1996	24.18	19.05	19.05		27.80	27.80
1997	23.00	19.80	19.80		28.51	25.69
1998	26.02	22.19	22.19		28.70	25.97
1999	22.81	21.15	21.15		28.11	28.11
2000	24.46	22.41	22.41		29.47	27.85
2001	26.43	21.94	21.94		28.84	28.33
2002	24.87	21.79	21.79		30.23	29.31
2003	24.03	19.90	19.90		29.20	26.97
2011	23.88	21.53	21.53		26.10	
2012	22.29	20.67	20.67		27.15	24.45
2013	22.33	22.33	22.33		28.94	28.58
2014	22.79	20.86	20.86	11.82	29.95	29.62
2015	22.63	21.01	21.01	15.24	29.39	29.39

Shasta River near the mouth (RM 0.6)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994	20.05	18.86	23.88	25.28	25.28	25.28
1995	21.87				22.01	
1996	24.18		24.45	24.45	27.80	27.80
1997	23.00	16.99	22.44	24.82	28.51	28.50
1998	26.02		21.01	22.41	28.70	28.70
1999	22.81	14.91	22.84	24.78	28.11	28.11
2000	24.46	16.41	23.89	27.85	29.47	28.67
2001	26.43		26.96	26.96	28.84	28.33
2002	24.87	17.51	24.19	27.82	30.23	30.23
2003	24.03	13.93	26.11	26.11	29.20	29.20
2011	23.88				26.10	25.76
2012	22.29		22.93	24.45	27.15	27.15
2013	22.33			22.18	28.94	28.94
2014	22.79	18.61	24.67	25.23	29.95	29.95
2015	22.63	18.42	26.10	28.15	29.39	29.39

Shasta River at mid-canyon (RM 5.7)







Shasta River at mid-canyon (RM 5.7)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2003					34.95%	61.54%
2012					23.21%	
2013			4.55%	30.56%	26.06%	21.92%
2014			0.00%	5.66%	24.10%	17.54%
2015			0.00%	5.66%	11.30%	5.00%

Shasta River at mid-canyon (RM 5.7)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2003	0.00%	0.00%	0.00%		34.95%	61.54%
2012	0.00%	15.38%	15.38%		23.21%	
2013	0.00%	18.18%	18.18%		26.06%	21.92%
2014	0.00%	35.00%	35.00%	0.00%	24.10%	17.54%
2015	0.00%	0.00%	0.00%	0.00%	11.30%	5.00%

Shasta River at mid-canyon (RM 5.7)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2003	3.33%			100.00%	44.66%	85.71%
2012	0.00%				37.50%	
2013	0.00%	4.76%	47.76%	52.05%	33.10%	36.05%
2014	0.00%	0.00%	36.90%	46.46%	33.85%	34.62%
2015	0.00%	0.00%	27.38%	34.41%	22.03%	27.59%

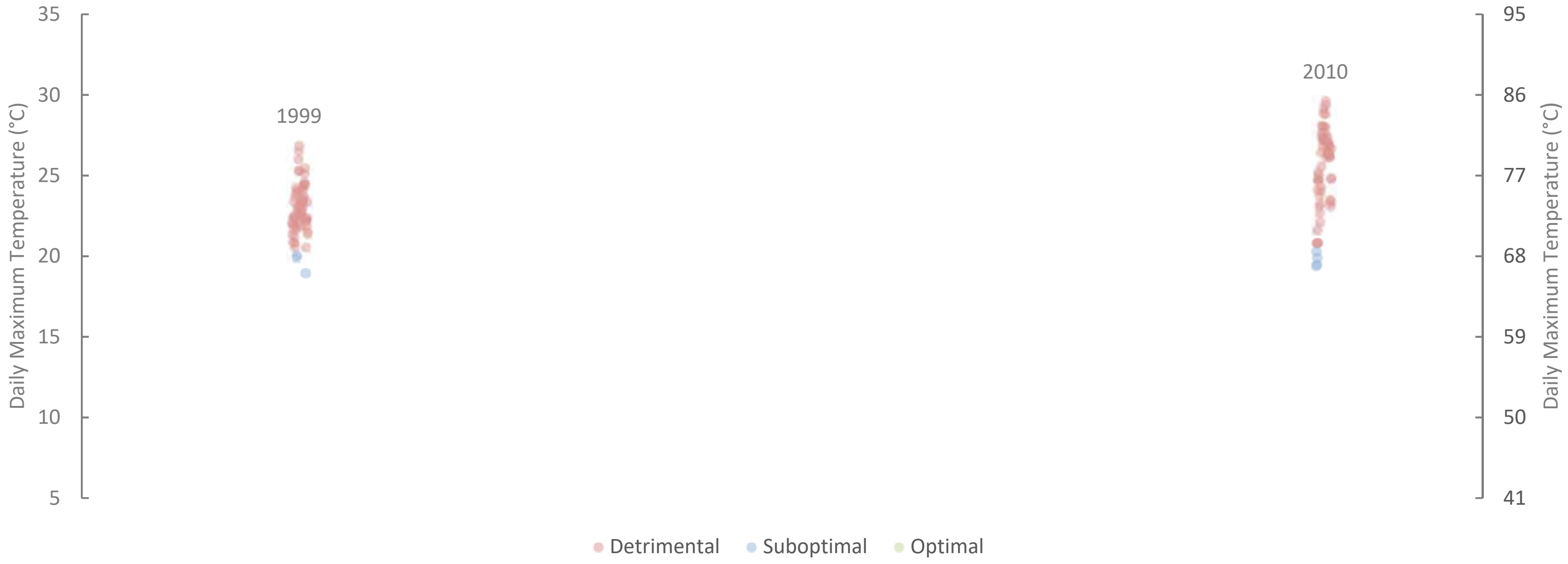
Shasta River at mid-canyon (RM 5.7)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2003					28.93	26.64
2012					26.65	
2013			18.76	21.72	28.42	26.68
2014			18.08	19.93	28.97	28.40
2015			17.93	19.61	26.03	24.70

Shasta River at mid-canyon (RM 5.7)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2003	23.91	19.96	19.96		28.93	26.64
2012	21.72	20.04	20.04		26.65	
2013	22.88	22.86	22.86		28.42	26.68
2014	22.57	20.88	20.88	11.69	28.97	28.40
2015	22.24	20.50	20.50	14.87	26.03	24.70

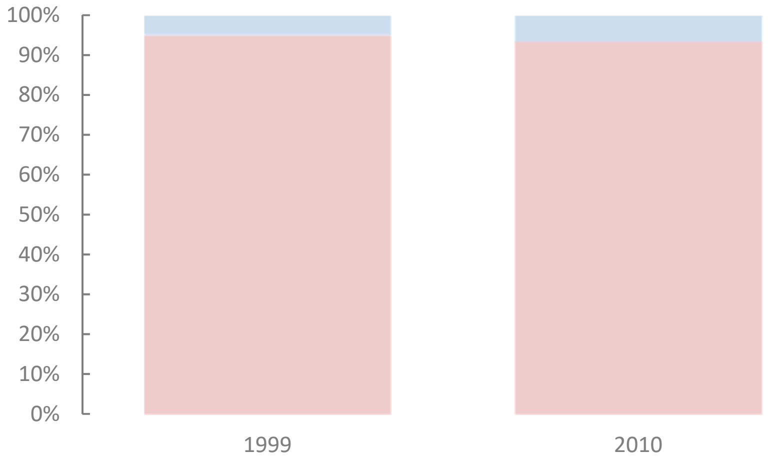
Shasta River at mid-canyon (RM 5.7)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2003	23.91			24.62	28.93	28.93
2012	21.72				26.65	
2013	22.88	18.76	26.59	26.68	28.42	28.42
2014	22.57	18.08	24.64	24.64	28.97	28.97
2015	22.24	17.83	24.70	24.70	26.03	25.92

Shasta River at Highway 263 (RM 7.29)

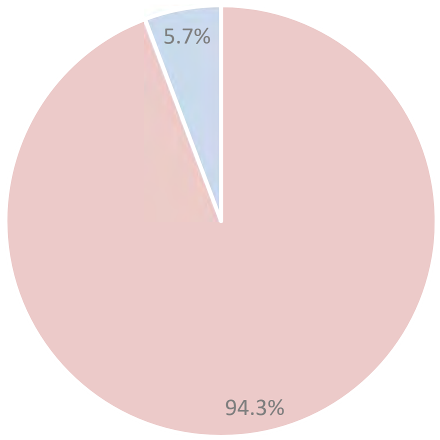
DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES



% IN CLASSIFIED RANGES BY YEAR



% IN CLASSIFIED RANGES CUMULATIVE



Shasta River at Highway 263 (RM 7.29)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1999			0.00%	0.00%	4.14%	5.43%
2010			0.00%	0.00%	23.21%	12.09%
2011					0.00%	0.00%

Shasta River at Highway 263 (RM 7.29)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1999	0.00%	0.00%	0.00%		4.14%	5.43%
2010	0.00%	0.00%	0.00%		23.21%	12.09%
2011					0.00%	0.00%

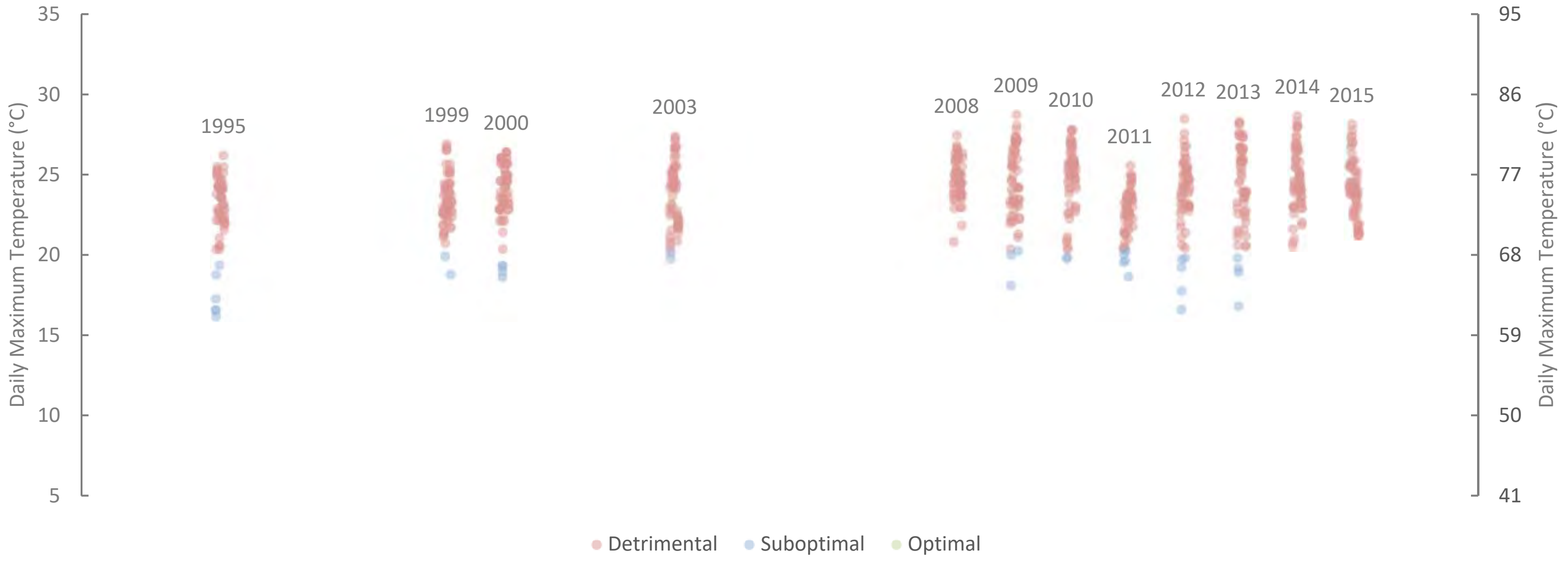
Shasta River at Highway 263 (RM 7.29)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1999	0.00%	0.00%	16.13%	32.47%	8.88%	9.26%
2010	0.00%	0.00%	9.84%	23.68%	29.76%	30.84%
2011			20.00%	48.57%	0.00%	0.00%

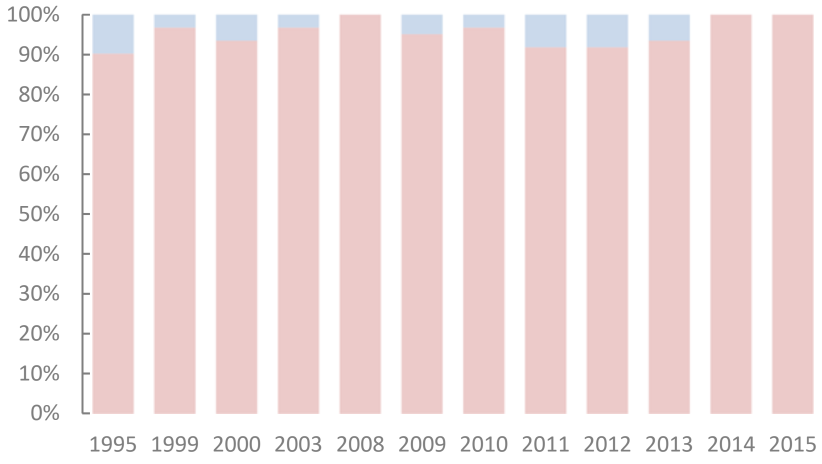
Shasta River at Highway 263 (RM 7.29)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999			14.16	14.70	25.35	25.35
2010			14.49	16.78	28.25	27.48
2011					22.18	22.18

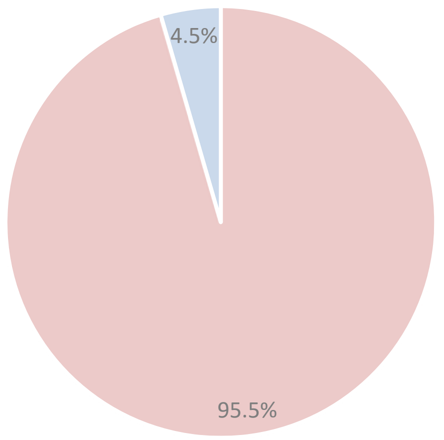
Shasta River at Highway 263 (RM 7.29)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999	20.52	18.86	18.86		25.35	25.35
2010	21.04	18.14	18.14		28.25	27.48
2011					22.18	22.18

Shasta River at Highway 263 (RM 7.29)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999	20.52	14.16	20.97	22.20	25.35	25.35
2010	21.04	14.49	20.80	24.64	28.25	28.25
2011			20.36	22.18	22.18	22.18

Shasta River at Highway 3 (RM 13.09)


DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES


% IN CLASSIFIED RANGES BY YEAR


% IN CLASSIFIED RANGES CUMULATIVE

Shasta River at Highway 3 (RM 13.09)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1995			0.00%	0.00%	4.14%	4.35%
1999			0.00%	0.00%	5.92%	6.52%
2000			0.00%	0.00%	11.11%	7.89%
2003			0.00%	14.29%	15.00%	7.94%
2004					37.50%	
2008					24.58%	45.24%
2009			6.82%	6.90%	17.96%	8.40%
2010			0.00%	3.23%	20.71%	14.13%
2011					0.79%	0.00%
2012			11.76%	25.81%	13.86%	10.87%
2013			5.88%	29.03%	21.21%	26.09%
2014			2.86%	12.24%	13.83%	14.55%
2015			0.00%	4.55%	10.44%	15.24%

Shasta River at Highway 3 (RM 13.09)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1995	0.00%	0.00%	0.00%		4.14%	4.35%
1999	0.00%	0.00%	0.00%		5.92%	6.52%
2000	0.00%	37.50%	37.50%		11.11%	7.89%
2003	0.00%				15.00%	7.94%
2004					37.50%	
2008	0.00%	20.00%	20.00%		24.58%	45.24%
2009	0.00%			0.00%	17.96%	8.40%
2010	0.00%	0.00%	0.00%		20.71%	14.13%
2011	0.00%	0.00%	0.00%		0.79%	0.00%
2012	0.00%	0.00%	0.00%		13.86%	10.87%
2013	0.00%	16.67%	16.67%		21.21%	26.09%
2014	0.00%	17.65%	17.65%	0.00%	13.83%	14.55%
2015	0.00%	0.00%	0.00%		10.44%	15.24%

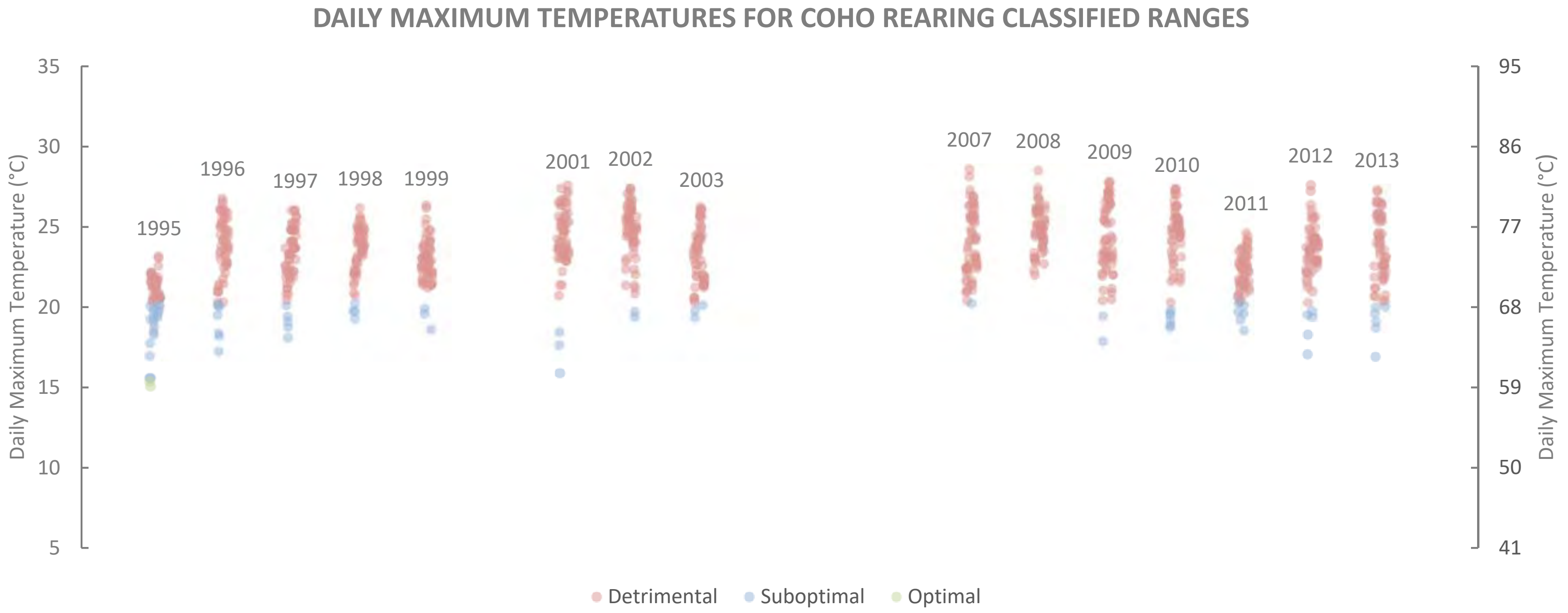
Shasta River at Highway 3 (RM 13.09)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1995	0.00%	0.00%	35.48%	41.56%	14.79%	18.52%
1999	0.00%	0.00%	19.35%	35.06%	11.24%	12.96%
2000	0.00%		43.48%	57.38%	19.61%	22.83%
2003	0.00%	0.00%	48.48%	62.50%	31.67%	44.30%
2004					37.50%	100.00%
2008	0.00%		41.67%	74.07%	39.83%	62.07%
2009	0.00%	6.98%	38.20%	46.15%	27.54%	26.67%
2010	0.00%	0.00%	9.68%	24.68%	28.99%	31.48%
2011	0.00%		30.00%	54.29%	7.09%	6.06%
2012	0.00%	12.50%	35.48%	42.86%	23.49%	25.00%
2013	0.00%	6.25%	48.39%	53.25%	25.45%	34.26%
2014	0.00%	0.00%	45.00%	53.68%	25.53%	30.95%
2015	0.00%	0.00%	29.33%	41.11%	19.23%	27.27%

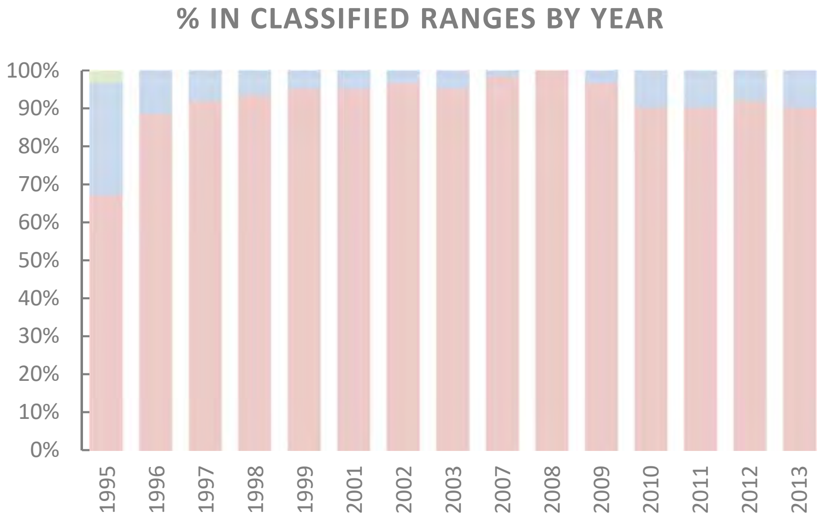
Shasta River at Highway 3 (RM 13.09)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995			16.66	16.66	24.97	24.97
1999			14.48	15.10	25.98	25.98
2000				16.21	26.11	25.76
2003			13.96	13.96	26.80	25.03
2004					23.90	
2008					26.56	26.56
2009			19.73	19.73	27.60	26.03
2010			14.86	17.40	26.94	26.70
2011					24.43	23.34
2012			18.93	21.04	26.89	26.89
2013			18.69	22.17	27.72	27.72
2014			17.92	20.45	27.79	27.61
2015			17.77	19.17	27.05	27.05

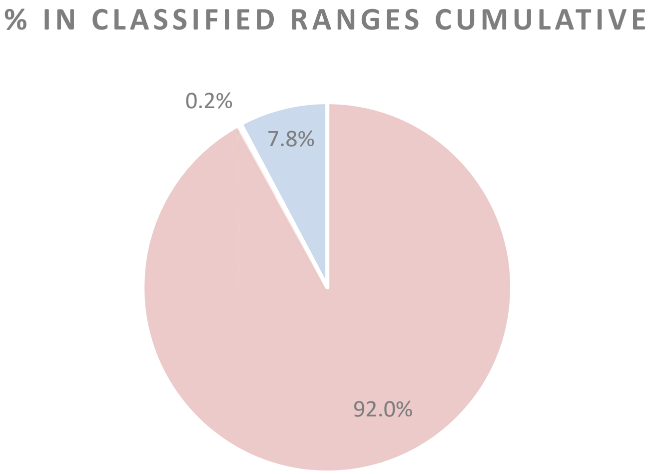
Shasta River at Highway 3 (RM 13.09)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995	20.40	20.31	20.31		24.97	24.97
1999	21.04	19.40	19.40		25.98	25.98
2000	21.51	20.51	20.51		26.11	25.76
2003	22.16				26.80	25.03
2004					23.90	
2008	21.57	20.39	20.39		26.56	26.56
2009	21.32			13.30	27.60	26.03
2010	20.67	18.40	18.40		26.94	26.70
2011	22.11	20.27	20.27		24.43	23.34
2012	20.19	18.82	18.82		26.89	26.89
2013	21.67	21.57	21.57		27.72	27.72
2014	21.33	19.92	19.92		27.79	27.61
2015	20.88	19.60	19.60		27.05	27.05

Shasta River at Highway 3 (RM 13.09)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995	20.40	16.66	22.97	24.97	24.97	24.97
1999	21.04	14.48	21.36	22.57	25.98	25.98
2000	21.51		22.10	25.76	26.11	25.76
2003	22.16	13.96	24.01	24.01	26.80	26.80
2004					23.90	
2008	21.57		21.01	25.18	26.56	26.56
2009	21.32	19.73	24.43	25.20	27.60	27.57
2010	20.67	14.86	20.66	25.05	26.94	26.94
2011	22.11		21.00	21.93	24.43	23.99
2012	20.19	18.93	22.20	22.69	26.89	26.89
2013	21.67	18.69	26.11	26.11	27.72	27.72
2014	21.33	17.92	23.95	23.95	27.79	27.79
2015	20.88	17.64	24.12	25.68	27.05	27.05

Shasta River at Montague-Grenada Road (RM 15.51)







Shasta River at Montague-Grenada Road (RM 15.51)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1994					27.85%	50.00%
1995			0.00%	0.00%	0.00%	0.00%
1996			0.00%	9.68%	11.24%	13.04%
1997				100.00%	6.98%	0.00%
1998			0.00%	0.00%	3.45%	1.03%
1999			0.00%	0.00%	2.37%	4.35%
2000			0.00%	0.00%	8.38%	4.35%
2001			0.00%	0.00%	15.98%	11.96%
2002			0.00%	6.45%	18.93%	25.00%
2003			0.00%	9.68%	5.92%	0.00%
2004					0.00%	0.00%
2005			0.00%	0.00%	14.19%	0.00%
2006					3.33%	0.00%
2007			17.65%	32.26%	14.20%	9.78%
2008				22.22%	21.92%	28.57%
2009			14.81%	12.20%	17.88%	7.84%
2010			0.00%	4.88%	14.77%	7.84%
2011					0.00%	0.00%
2012			12.50%	30.00%	6.06%	6.59%
2013			5.88%	25.81%	12.12%	13.04%
2014			0.00%	5.77%	0.62%	0.00%
2015			0.00%	2.78%	3.66%	6.82%

Shasta River at Montague-Grenada Road (RM 15.51)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1994	0.00%	31.25%	31.25%		27.85%	50.00%
1995	0.00%	0.00%	0.00%		0.00%	0.00%
1996	0.00%	0.00%	0.00%		11.24%	13.04%
1997	0.00%	0.00%	0.00%		6.98%	0.00%
1998	0.00%	12.50%	12.50%		3.45%	1.03%
1999	0.00%	0.00%	0.00%		2.37%	4.35%
2000	0.00%	12.50%	12.50%		8.38%	4.35%
2001	0.00%	18.75%	18.75%		15.98%	11.96%
2002	0.00%	6.25%	6.25%		18.93%	25.00%
2003	0.00%	0.00%	0.00%		5.92%	0.00%
2004	0.00%	0.00%	0.00%		0.00%	0.00%
2005	0.00%	0.00%	0.00%		14.19%	0.00%
2006	0.00%	0.00%	0.00%		3.33%	0.00%
2007	0.00%	0.00%	0.00%		14.20%	9.78%
2008	0.00%	20.00%	20.00%		21.92%	28.57%
2009	0.00%				17.88%	7.84%
2010	0.00%	0.00%	0.00%		14.77%	7.84%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2012	0.00%	0.00%	0.00%		6.06%	6.59%
2013	0.00%	16.67%	16.67%		12.12%	13.04%
2014	0.00%	0.00%	0.00%	0.00%	0.62%	0.00%
2015	0.00%	0.00%	0.00%		3.66%	6.82%

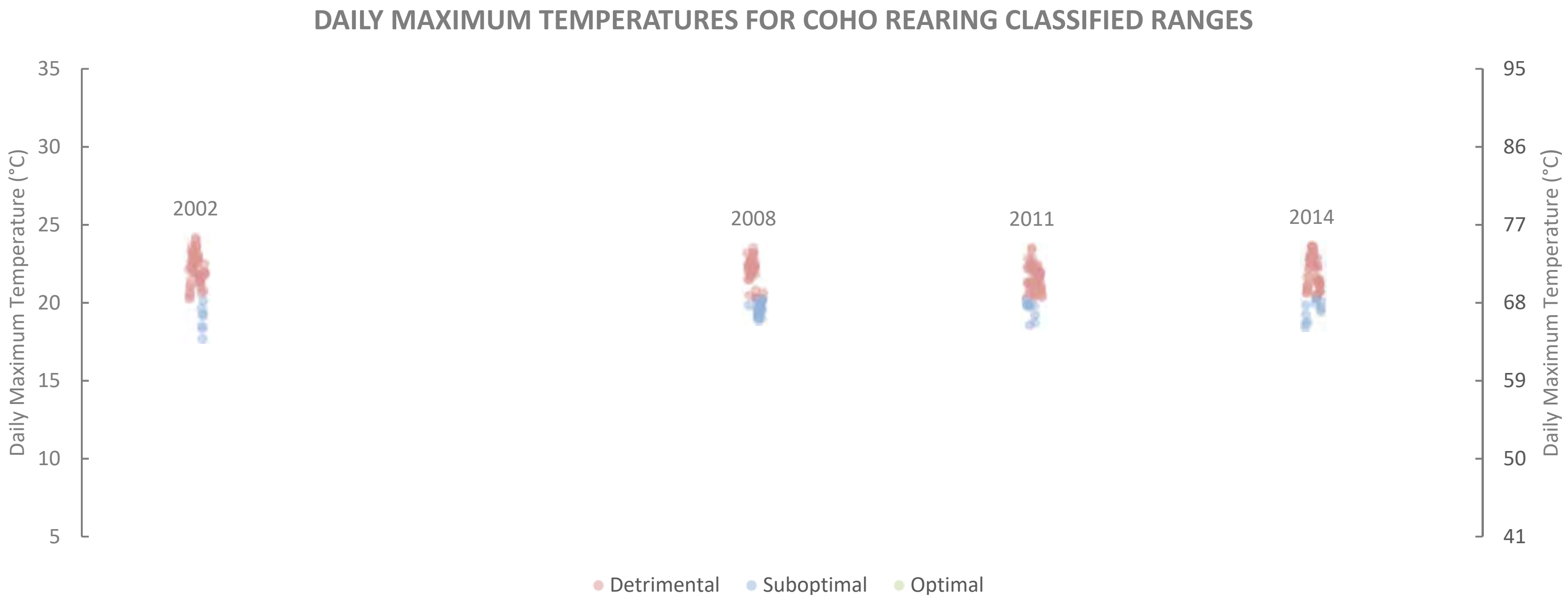
Shasta River at Montague-Grenada Road (RM 15.51)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1994	0.00%				37.97%	100.00%
1995	0.00%	0.00%	1.82%	12.86%	0.00%	0.00%
1996	0.00%	0.00%	32.26%	40.26%	20.12%	23.15%
1997	0.00%		70.27%	73.08%	17.05%	14.46%
1998	0.00%	0.00%	17.91%	29.27%	16.09%	17.70%
1999	0.00%	0.00%	19.35%	35.06%	6.51%	6.48%
2000	0.00%	0.00%	32.26%	45.45%	14.97%	17.59%
2001	0.00%	0.00%	41.94%	49.35%	27.22%	27.78%
2002	0.00%	0.00%	33.87%	46.75%	28.99%	38.89%
2003	0.00%	0.00%	48.39%	55.84%	15.38%	23.15%
2004	0.00%			0.00%	3.09%	2.70%
2005	0.00%	0.00%	24.19%	32.47%	16.13%	15.96%
2006	0.00%			50.00%	20.00%	62.07%
2007	0.00%	18.75%	54.84%	63.64%	20.12%	22.22%
2008	0.00%		42.50%	58.18%	37.67%	45.35%
2009	0.00%	15.38%	43.06%	50.57%	25.83%	25.42%
2010	0.00%	0.00%	11.11%	19.54%	23.86%	25.42%
2011	0.00%		100.00%	87.50%	4.63%	4.26%
2012	0.00%	13.33%	39.34%	47.37%	17.58%	18.69%
2013	0.00%	6.25%	43.55%	49.35%	21.82%	32.41%
2014	0.00%	0.00%	37.35%	44.90%	3.11%	3.00%
2015	0.00%	0.00%	32.84%	38.36%	6.10%	9.62%

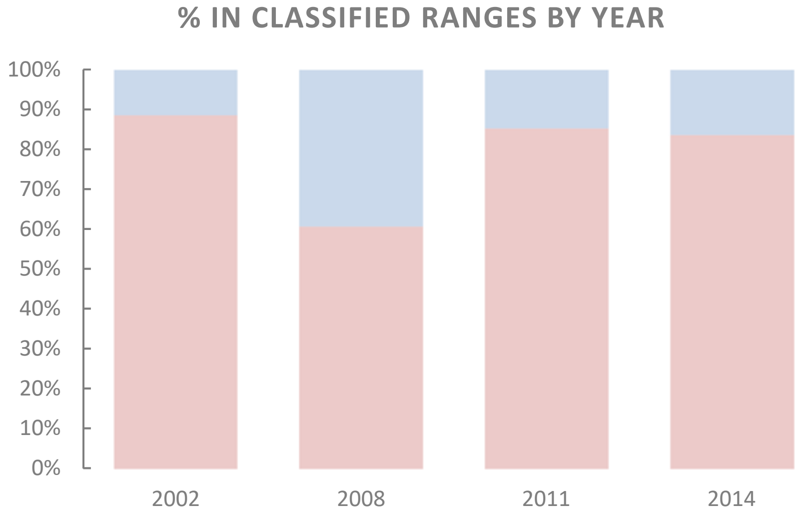
Shasta River at Montague-Grenada Road (RM 15.51)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994					27.12	
1995			16.33	16.33	22.04	21.90
1996			17.77	19.80	26.00	26.00
1997					24.93	22.85
1998			16.79	17.17	25.26	24.15
1999			14.73	15.48	25.07	25.07
2000			16.78	17.51	25.86	25.04
2001			17.28	18.98	26.56	26.13
2002			17.07	18.28	26.78	26.70
2003			13.97	17.59	25.65	24.22
2004					23.72	19.92
2005			18.43	18.52	26.55	22.60
2006					24.78	24.27
2007			19.65	20.64	27.08	27.08
2008				19.69	27.03	27.03
2009			19.71	19.71	27.19	25.84
2010			15.16	17.43	26.64	26.37
2011					23.67	23.10
2012			18.62	21.51	26.21	26.21
2013			18.92	22.36	26.55	26.55
2014			17.93	19.36	23.64	23.20
2015			18.11	19.30	25.67	25.67

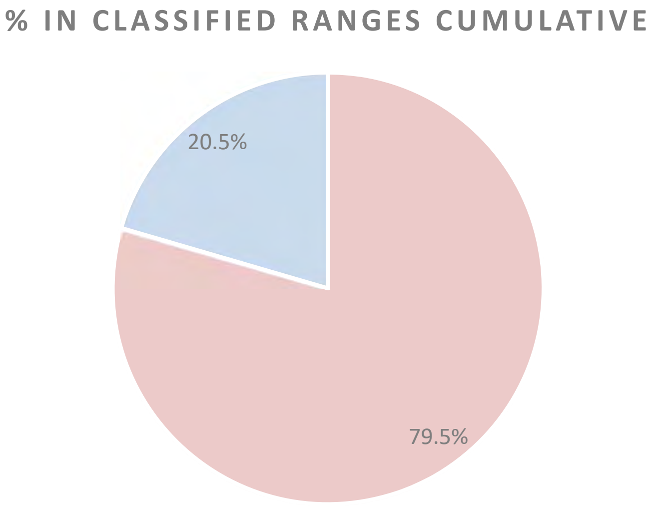
Shasta River at Montague-Grenada Road (RM 15.51)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994	22.16	20.32	20.32		27.12	
1995	18.53	18.53	18.53		22.04	21.90
1996	22.26	17.76	17.76		26.00	26.00
1997	20.22	18.94	18.94		24.93	22.85
1998	22.64	20.16	20.16		25.26	24.15
1999	20.69	18.84	18.84		25.07	25.07
2000	21.41	20.07	20.07		25.86	25.04
2001	23.63	19.67	19.67		26.56	26.13
2002	22.71	19.94	19.94		26.78	26.70
2003	21.64	18.55	18.55		25.65	24.22
2004	19.47	15.52	15.52		23.72	19.92
2005	20.93	17.53	17.53		26.55	22.60
2006	19.80	18.74	18.74		24.78	24.27
2007	23.11	19.75	19.75		27.08	27.08
2008	21.59	20.79	20.79		27.03	27.03
2009	21.23				27.19	25.84
2010	20.40	17.59	17.59		26.64	26.37
2011	21.48	19.48	19.48		23.67	23.10
2012	20.20	19.06	19.06		26.21	26.21
2013	21.18	21.18	21.18		26.55	26.55
2014	19.84	19.29	19.29	12.07	23.64	23.20
2015	20.06	18.82	18.82		25.67	25.67

Shasta River at Montague-Grenada Road (RM 15.51)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1994	22.16				27.12	27.12
1995	18.53	16.33	19.20	21.90	22.04	21.90
1996	22.26	17.11	23.80	23.80	26.00	26.00
1997	20.22		21.96	22.42	24.93	24.93
1998	22.64	16.44	21.36	21.83	25.26	25.26
1999	20.69	14.73	21.55	22.69	25.07	25.07
2000	21.41	16.67	22.67	25.04	25.86	25.24
2001	23.63	17.28	24.00	24.37	26.56	26.13
2002	22.71	17.07	23.23	25.85	26.78	26.78
2003	21.64	13.97	24.22	24.22	25.65	25.65
2004	19.47				23.72	23.16
2005	20.93	18.00	21.71	22.52	26.55	26.35
2006	19.80				24.78	24.78
2007	23.11	19.65	22.95	22.95	27.08	27.08
2008	21.59		24.08	24.99	27.03	27.03
2009	21.23	19.71	23.66	24.30	27.19	27.19
2010	20.40	15.16	20.30	24.21	26.64	26.64
2011	21.48			22.14	23.67	23.16
2012	20.20	18.62	22.46	22.50	26.21	26.21
2013	21.18	18.92	24.56	24.56	26.55	26.55
2014	19.84	17.93	23.20	23.20	23.64	23.20
2015	20.06	18.11	23.26	23.28	25.67	25.67

Shasta River at Freeman Lane (RM 19.2)


DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES


% IN CLASSIFIED RANGES BY YEAR


% IN CLASSIFIED RANGES CUMULATIVE

Shasta River at Freeman Lane (RM 19.2)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2002				0.00%	0.00%	0.00%
2003					9.09%	0.00%
2004					0.00%	
2008			0.00%	12.90%	0.00%	0.00%
2011			0.00%	0.00%	0.00%	0.00%
2013			18.75%	40.00%	4.69%	11.11%
2014			0.00%	5.26%	0.00%	0.00%

Shasta River at Freeman Lane (RM 19.2)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2002	0.00%	0.00%	0.00%		0.00%	0.00%
2003					9.09%	0.00%
2004					0.00%	
2008	0.00%	0.00%	0.00%		0.00%	0.00%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2013	0.00%	0.00%	0.00%		4.69%	11.11%
2014	0.00%	0.00%	0.00%		0.00%	0.00%

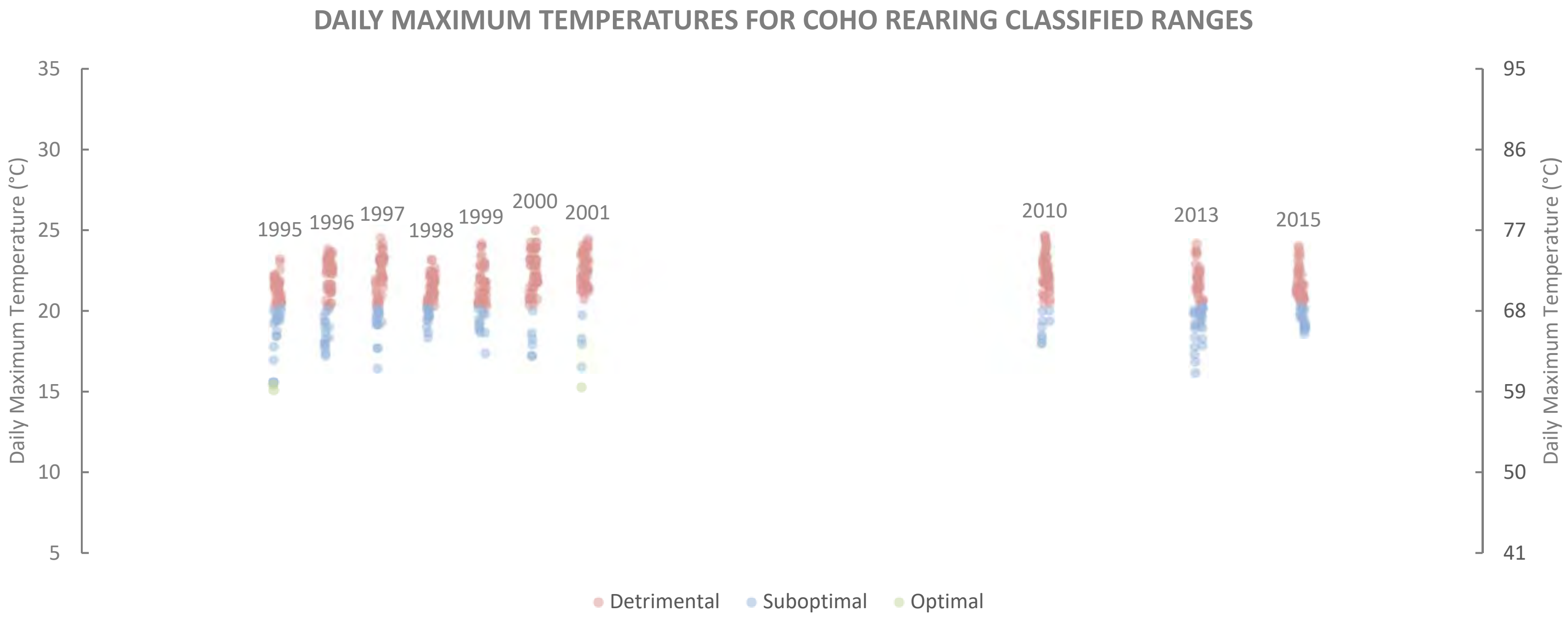
Shasta River at Freeman Lane (RM 19.2)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2002	0.00%		47.50%	61.82%	0.68%	1.16%
2003				75.00%	36.36%	57.14%
2004					0.00%	0.00%
2008	0.00%	0.00%	30.65%	42.86%	1.78%	2.78%
2011	0.00%	0.00%	8.06%	19.48%	0.00%	0.00%
2013	0.00%	20.00%	36.11%	41.03%	10.94%	20.00%
2014	0.00%	0.00%	36.23%	41.67%	0.00%	0.00%

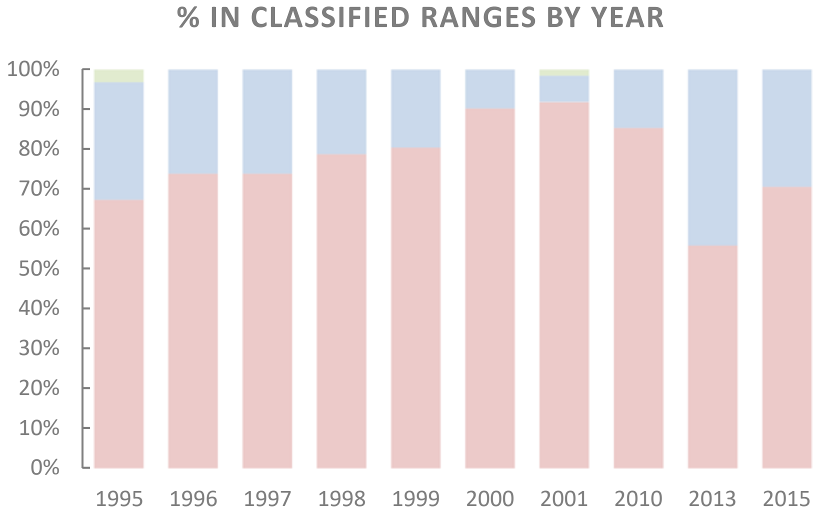
Shasta River at Freeman Lane (RM 19.2)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2002				17.90	23.52	23.52
2003						
2004					22.27	
2008			17.25	19.51	23.10	23.10
2011			14.24	16.48	22.82	22.82
2013			19.60	21.69	25.46	25.46
2014			18.41	18.63	23.25	23.25

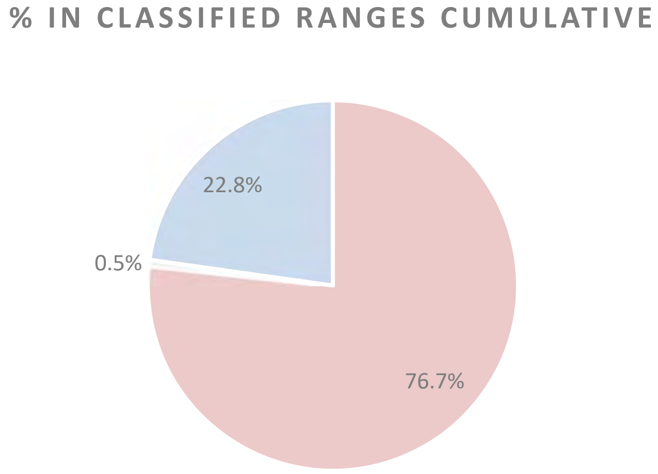
Shasta River at Freeman Lane (RM 19.2)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2002	20.04	17.78	17.78		23.52	23.52
2003						
2004					22.27	
2008	18.12	17.20	17.20		23.10	23.10
2011	19.81	19.02	19.02		22.82	22.82
2013	20.44	19.81	19.81		25.46	25.46
2014	19.15	18.31	18.31		23.25	23.25

Shasta River at Freeman Lane (RM 19.2)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2002	20.04		21.10	22.89	23.52	23.52
2003						
2004					22.27	
2008	18.12	17.05	23.10	23.10	23.10	23.10
2011	19.81	14.23	20.64	21.68	22.82	22.82
2013	20.44	19.60	21.69	21.69	25.46	25.46
2014	19.15	18.41	21.73	21.73	23.25	23.25

Shasta River at Highway A-12 (RM 24.11)


DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES


% IN CLASSIFIED RANGES BY YEAR


% IN CLASSIFIED RANGES CUMULATIVE

Shasta River at Highway A-12 (RM 24.11)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1995	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1996					0.00%	0.00%
1997			0.00%	19.35%	0.00%	0.00%
1998			0.00%	0.00%	0.00%	0.00%
1999			0.00%	0.00%	0.00%	0.00%
2000			0.00%	0.00%	0.00%	0.00%
2001			0.00%	2.70%	0.00%	0.00%
2002			0.00%	0.00%	0.68%	1.43%
2003	0.00%				0.00%	0.00%
2004					25.00%	
2010			0.00%	0.00%	0.00%	0.00%
2011					0.00%	0.00%
2013			0.00%	4.55%	0.00%	0.00%
2014			0.00%	3.77%	0.00%	0.00%
2015			0.00%	0.00%	0.00%	0.00%

Shasta River at Highway A-12 (RM 24.11)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1995	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1996	0.00%	0.00%	0.00%		0.00%	0.00%
1997	0.00%	0.00%	0.00%		0.00%	0.00%
1998	0.00%	0.00%	0.00%		0.00%	0.00%
1999	0.00%	0.00%	0.00%		0.00%	0.00%
2000	0.00%	6.25%	6.25%		0.00%	0.00%
2001	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2002	0.00%	0.00%	0.00%		0.68%	1.43%
2003	0.00%	0.00%	0.00%		0.00%	0.00%
2004					25.00%	
2010	0.00%	0.00%	0.00%		0.00%	0.00%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2013	0.00%	0.00%	0.00%		0.00%	0.00%
2014	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

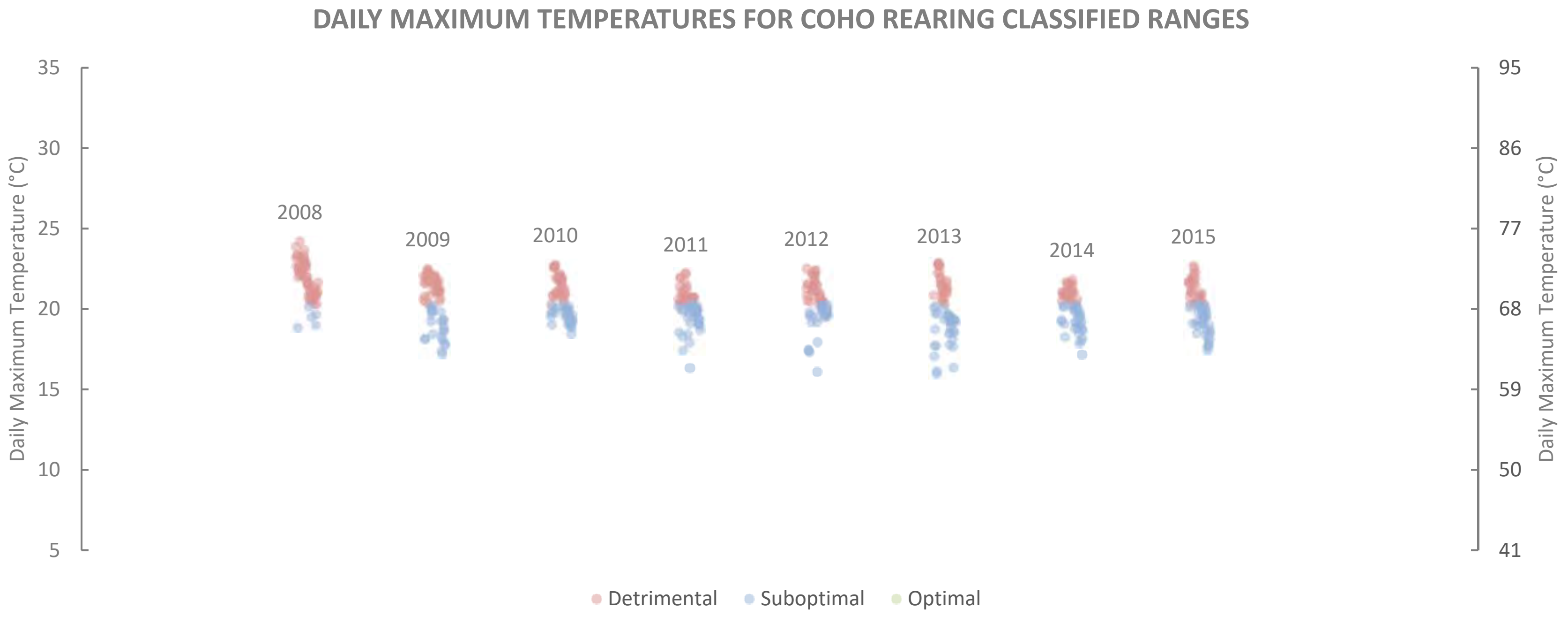
Shasta River at Highway A-12 (RM 24.11)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1995	0.00%	0.00%	1.41%	10.47%	0.00%	0.00%
1996	0.00%		90.00%	48.00%	0.00%	0.00%
1997	0.00%	0.00%	30.65%	36.36%	1.78%	1.85%
1998	0.00%	0.00%	8.06%	16.88%	0.00%	0.00%
1999	0.00%	0.00%	7.89%	18.68%	1.54%	2.46%
2000	0.00%	0.00%	11.29%	28.57%	2.37%	2.78%
2001	0.00%	0.00%	30.88%	37.35%	2.29%	1.75%
2002	0.00%	0.00%	25.45%	25.45%	4.08%	6.98%
2003	0.00%			60.00%	10.53%	22.22%
2004					62.50%	100.00%
2010	0.00%	0.00%	3.45%	15.07%	3.64%	5.77%
2011	0.00%			36.36%	0.00%	0.00%
2013	0.00%	0.00%	17.33%	20.00%	0.56%	0.83%
2014	0.00%	0.00%	26.19%	32.32%	0.00%	0.00%
2015	0.00%	0.00%	8.43%	22.45%	0.52%	0.78%

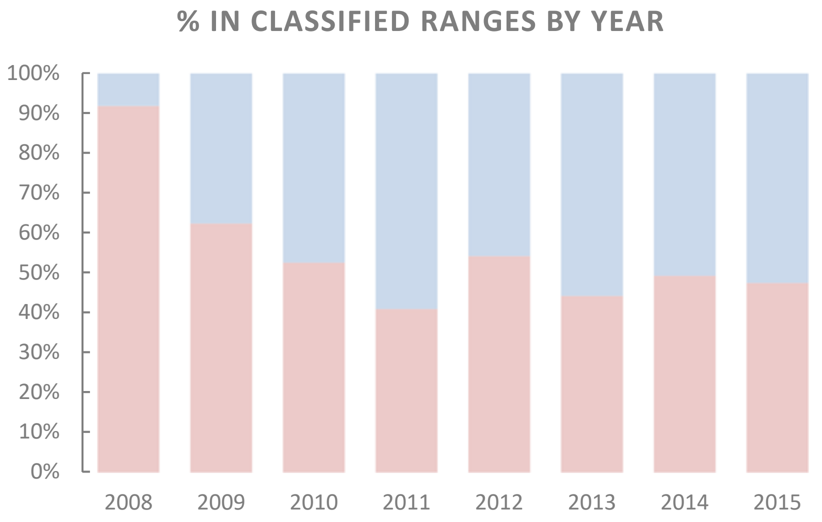
Shasta River at Highway A-12 (RM 24.11)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995	13.03	12.43	16.33	16.33	22.06	21.90
1996					23.34	23.34
1997			15.95	20.15	23.34	21.14
1998			16.46	17.12	22.47	21.50
1999			15.81	15.81	23.39	23.39
2000			15.47	15.71	24.02	23.67
2001			16.91	19.46	23.58	23.31
2002			16.00	17.85	24.51	24.51
2003						
2004					23.27	
2010			13.96	15.90	24.09	23.94
2011					21.79	21.55
2013			16.60	19.02	23.38	23.38
2014			15.90	18.06	23.31	22.82
2015			16.10	16.85	23.27	23.27

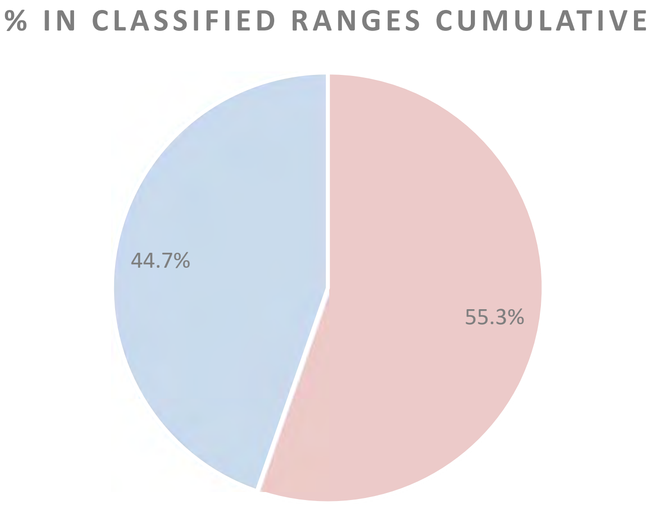
Shasta River at Highway A-12 (RM 24.11)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995	18.52	18.52	18.52	12.43	22.06	21.90
1996	21.40	17.28	17.28		23.34	23.34
1997	18.95	17.85	17.85		23.34	21.14
1998	20.97	18.95	18.95		22.47	21.50
1999	19.56	18.51	18.51		23.39	23.39
2000	20.31	19.62	19.62		24.02	23.67
2001	21.65	18.86	18.86		23.58	23.31
2002	20.82	18.63	18.63		24.51	24.51
2003						
2004					23.27	
2010	18.52	16.99	16.99		24.09	23.94
2011	19.62	18.69	18.69		21.79	21.55
2013	18.92	18.74	18.74		23.38	23.38
2014	18.43	17.90	17.90	12.00	23.31	22.82
2015	18.78	17.39	17.39	14.81	23.27	23.27

Shasta River at Highway A-12 (RM 24.11)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1995	18.52	16.33	19.34	21.90	22.06	21.90
1996	21.40		21.12	21.12	23.34	23.34
1997	18.95	15.95	20.92	21.14	23.34	23.34
1998	20.97	16.10	19.97	20.46	22.47	22.47
1999	19.56	15.81	20.01	20.62	23.39	23.39
2000	20.31	15.47	20.42	23.67	24.02	23.72
2001	21.65	16.91	22.92	22.92	23.58	23.52
2002	20.82	16.00	22.51	22.51	24.51	24.51
2003						
2004					23.27	
2010	18.52	13.96	18.73	22.69	24.09	24.09
2011	19.62			20.09	21.79	21.65
2013	18.92	16.60	21.66	21.66	23.38	23.38
2014	18.43	15.90	21.44	21.44	23.31	23.31
2015	18.78	16.10	20.63	22.34	23.27	23.27

Shasta River at Nelson Ranch (RM 31.88)







Shasta River at Nelson Ranch (RM 31.88)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2006					0.00%	0.00%
2008			23.53%	51.61%	2.37%	4.35%
2009			11.36%	15.52%	0.00%	0.00%
2010			0.00%	7.50%	0.00%	0.00%
2011					0.00%	0.00%
2012			18.75%	36.67%	0.00%	0.00%
2013			17.65%	35.48%	0.00%	0.00%
2014			100.00%	37.50%	0.00%	0.00%
2015			9.09%	16.67%	0.00%	0.00%

Shasta River at Nelson Ranch (RM 31.88)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2006					0.00%	0.00%
2008	0.00%	0.00%	0.00%		2.37%	4.35%
2009	0.00%			0.00%	0.00%	0.00%
2010	0.00%	0.00%	0.00%		0.00%	0.00%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2012	0.00%	0.00%	0.00%		0.00%	0.00%
2013	0.00%	0.00%	0.00%		0.00%	0.00%
2014	0.00%	0.00%	0.00%		0.00%	0.00%
2015	0.00%	0.00%	0.00%		0.00%	0.00%

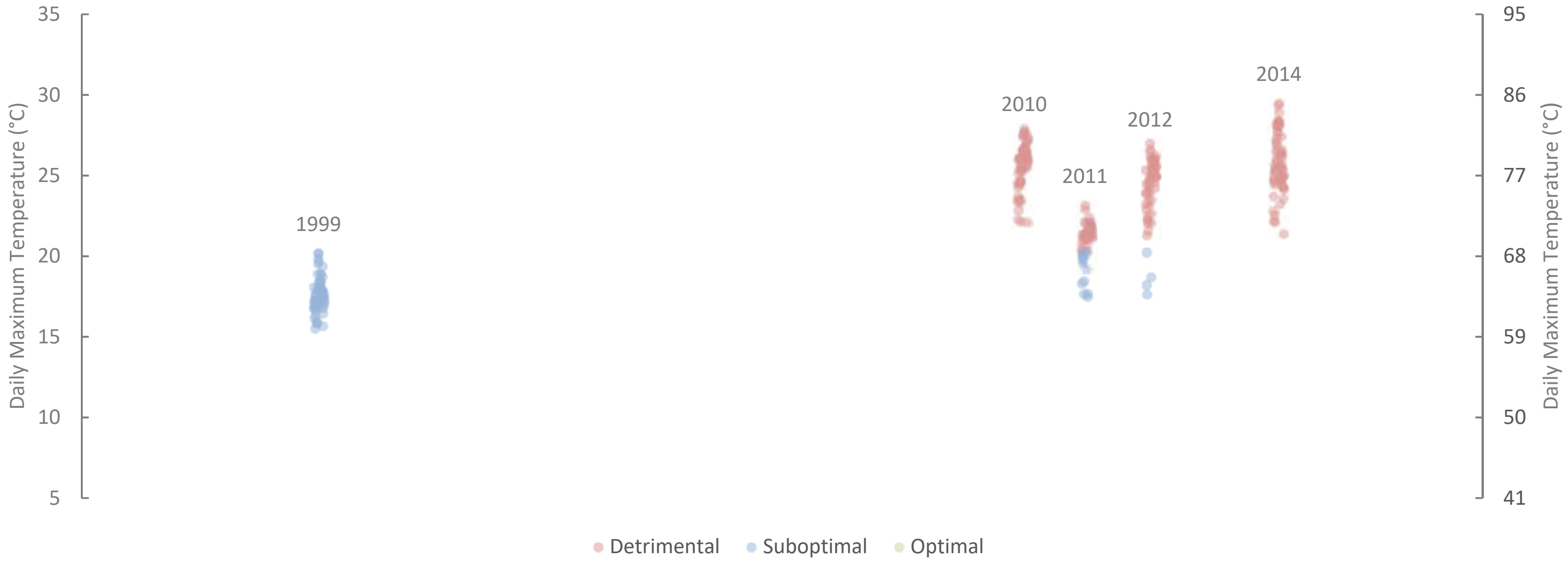
Shasta River at Nelson Ranch (RM 31.88)						
Steelhead Life Cycle	Adult Migration	Spawning	Incubation	Emergence	Rearing	Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2006			44.44%	64.29%	0.00%	0.00%
2008	0.00%	25.00%	59.68%	66.23%	3.55%	5.56%
2009	0.00%	11.63%	35.96%	43.27%	1.19%	1.48%
2010	0.00%	0.00%	15.49%	25.58%	0.00%	0.00%
2011	0.00%		100.00%	68.75%	0.00%	0.00%
2012	0.00%	20.00%	44.26%	46.05%	0.00%	0.00%
2013	0.00%	18.75%	48.39%	48.05%	0.00%	0.00%
2014	0.00%	100.00%	63.83%	66.13%	0.00%	0.00%
2015	0.00%	4.76%	37.31%	47.56%	0.00%	0.00%

Shasta River at Nelson Ranch (RM 31.88)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2006					22.14	22.14
2008			19.39	21.39	24.24	24.24
2009			20.95	20.95	23.42	23.42
2010			16.50	18.33	22.33	22.33
2011					21.51	21.51
2012			19.27	21.34	22.05	22.05
2013			20.38	21.46	22.66	22.66
2014				20.17	21.88	21.88
2015			18.86	19.76	21.91	21.91

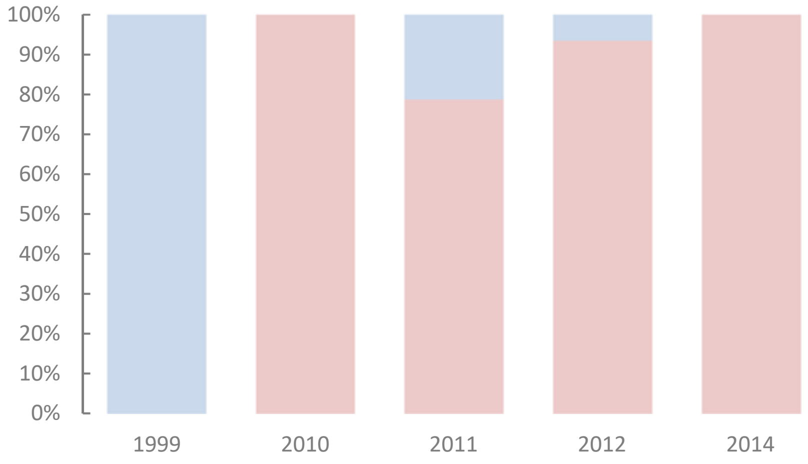
Shasta River at Nelson Ranch (RM 31.88)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2006					22.14	22.14
2008	18.46	17.85	17.85		24.24	24.24
2009	17.75			15.53	23.42	23.42
2010	17.00	15.94	15.94		22.33	22.33
2011	18.05	17.63	17.63		21.51	21.51
2012	17.29	16.83	16.83		22.05	22.05
2013	18.23	17.61	17.61		22.66	22.66
2014	17.74	17.22	17.22		21.88	21.88
2015	17.96	16.54	16.54		21.91	21.91

Shasta River at Nelson Ranch (RM 31.88)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2006			22.02	22.12	22.14	22.14
2008	19.39	19.39	24.24	24.24	24.24	24.24
2009	20.95	20.95	23.42	23.42	23.42	23.42
2010	17.00	16.50	20.82	22.33	22.33	22.33
2011	18.05			21.08	21.51	21.51
2012	19.27	19.27	21.80	21.80	22.05	22.05
2013	20.38	20.38	22.66	22.66	22.66	22.66
2014	17.74		21.88	21.88	21.88	21.88
2015	18.85	18.85	21.70	21.70	21.91	21.91

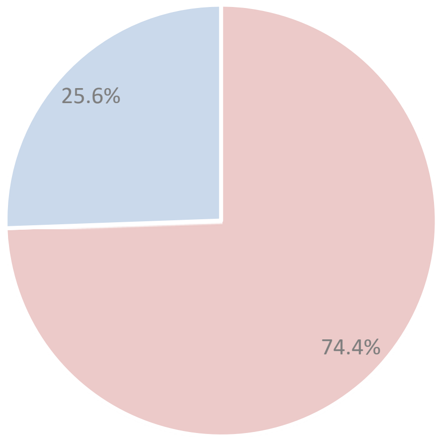
Shasta River at Hole in the Ground (RM 36.31)



DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES



% IN CLASSIFIED RANGES BY YEAR



% IN CLASSIFIED RANGES CUMULATIVE

Shasta River at Hole in the Ground (RM 36.31)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1999			0.00%	0.00%	0.00%	0.00%
2010			35.29%	51.61%	34.32%	22.83%
2011			0.00%	16.13%	0.00%	0.00%
2012	0.00%		66.67%	69.57%	17.89%	9.52%
2013					8.82%	
2014			8.57%	26.53%	27.27%	27.27%
2015			0.00%	4.35%	1.79%	1.00%

Shasta River at Hole in the Ground (RM 36.31)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1999	0.00%	0.00%	0.00%		0.00%	0.00%
2010	0.00%	75.00%	75.00%		34.32%	22.83%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2012	0.00%	20.00%	20.00%		17.89%	9.52%
2013	0.00%	12.50%	12.50%		8.82%	
2014	0.00%	43.75%	43.75%	0.00%	27.27%	27.27%
2015	0.00%	0.00%	0.00%	0.00%	1.79%	1.00%

Shasta River at Hole in the Ground (RM 36.31)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1999	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2010	6.52%	31.25%	51.61%	61.04%	43.79%	43.52%
2011	0.00%	0.00%	27.42%	33.77%	0.00%	0.00%
2012	0.00%	62.50%	66.67%	71.01%	28.42%	31.00%
2013	0.00%				25.00%	71.43%
2014	0.00%	5.88%	55.00%	62.11%	39.57%	45.24%
2015	0.00%	0.00%	32.47%	43.48%	6.55%	7.48%

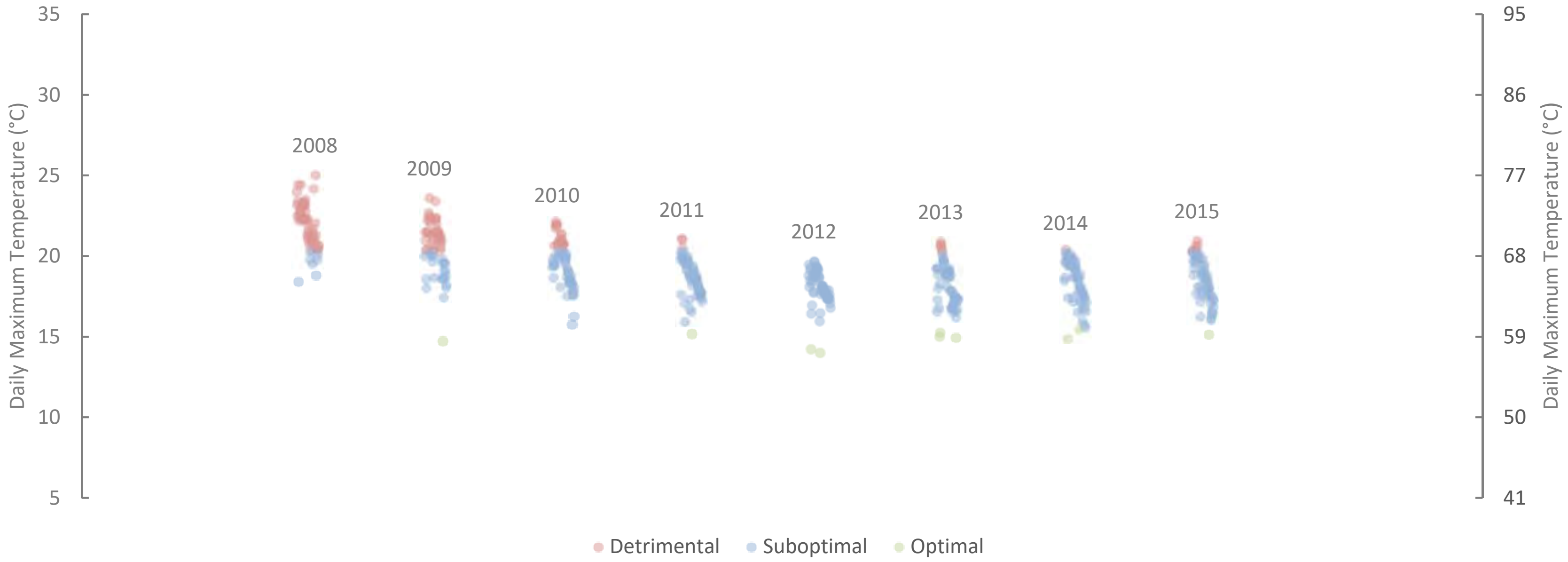
Shasta River at Hole in the Ground (RM 36.31)						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999			14.44	14.44	19.54	19.54
2010			19.05	22.05	27.02	25.81
2011			17.09	19.76	22.07	22.07
2012	15.89		20.17	22.26	26.09	26.09
2013					25.10	
2014			19.24	21.44	28.69	28.02
2015			18.85	19.53	24.25	24.00

Shasta River at Hole in the Ground (RM 36.31)						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999	16.63	16.47	16.47		19.54	19.54
2010	23.39	21.58	21.58		27.02	25.81
2011	21.28	20.21	20.21		22.07	22.07
2012	22.10	21.07	21.07		26.09	26.09
2013	22.66	22.56	22.56		25.10	
2014	21.84	21.63	21.63		28.69	28.02
2015	21.80	19.34	19.34		24.25	24.00

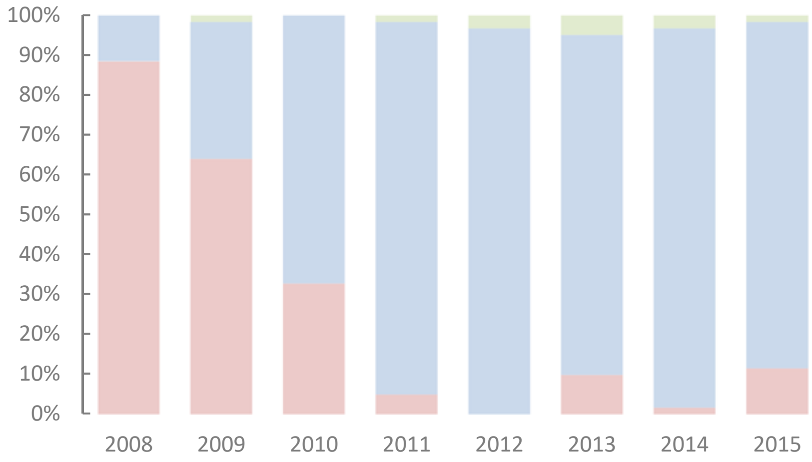
Shasta River at Hole in the Ground (RM 36.31)						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1999	16.63	14.44	17.44	17.44	19.54	19.54
2010	23.39	19.05	24.61	25.54	27.02	27.02
2011	21.28	16.48	20.73	20.73	22.07	22.07
2012	22.10	20.17	23.50	23.96	26.09	26.09
2013	22.66				25.10	25.10
2014	21.84	19.24	26.15	26.15	28.69	28.69
2015	21.80	18.85	23.38	24.00	24.25	24.00

Graphs and Charts for Tributaries to the Shasta River

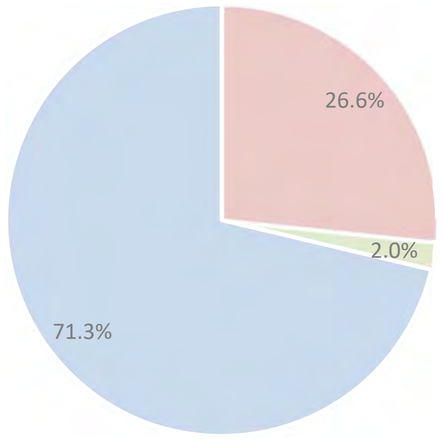
Big Springs Creek near the Mouth



DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES



% IN CLASSIFIED RANGES BY YEAR



% IN CLASSIFIED RANGES CUMULATIVE

Big Springs Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2008			29.41%	58.06%	2.37%	3.26%
2009			35.29%	48.39%	0.00%	0.00%
2010			0.00%	3.23%	0.00%	0.00%
2011			5.88%	3.23%	0.00%	0.00%
2012				0.00%	0.00%	0.00%
2013			0.00%	9.68%	0.00%	0.00%
2014			17.50%	24.07%	0.00%	0.00%
2015			5.00%	5.56%	0.00%	0.00%

Big Springs Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2008	0.00%	0.00%	0.00%		2.37%	3.26%
2009	0.00%	0.00%	0.00%		0.00%	0.00%
2010	0.00%	0.00%	0.00%		0.00%	0.00%
2011	0.00%	0.00%	0.00%		0.00%	0.00%
2012	0.00%	0.00%	0.00%		0.00%	0.00%
2013	0.00%	0.00%	0.00%		0.00%	0.00%
2014	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

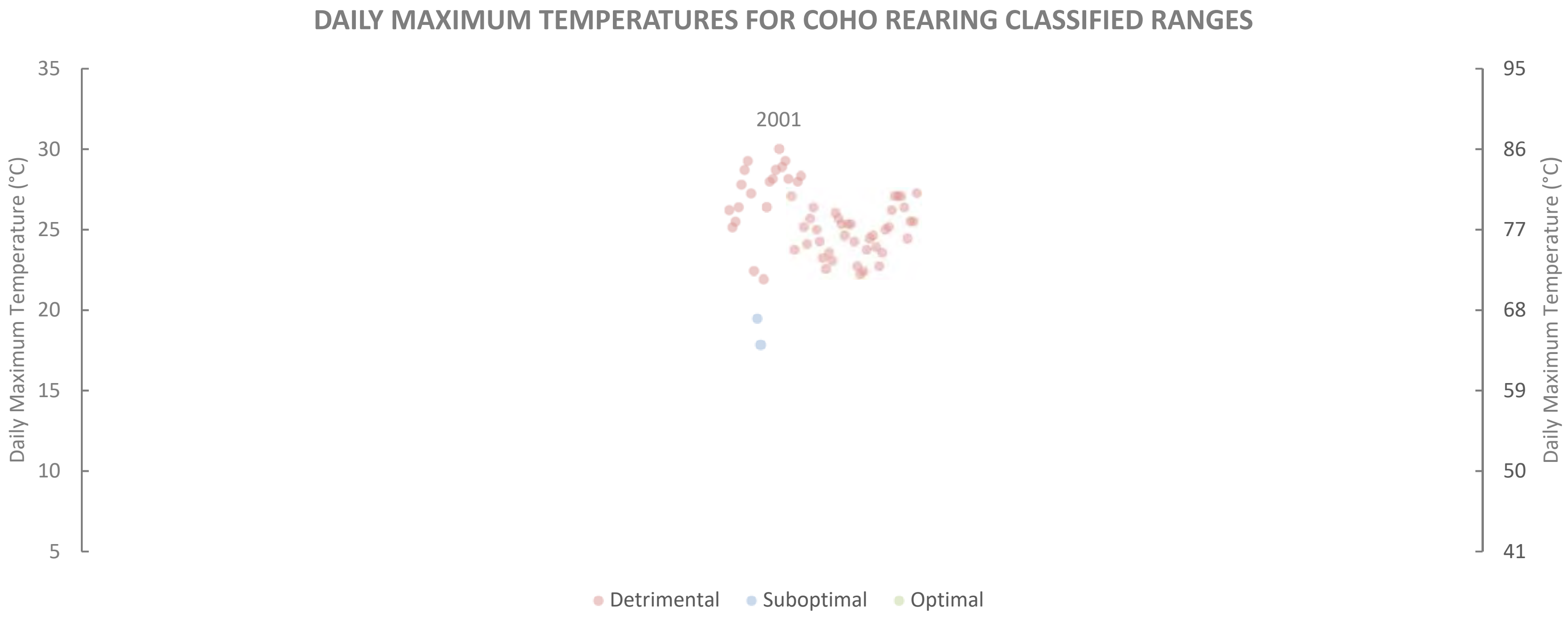
Big Springs Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2008	0.00%	25.00%	59.68%	66.23%	5.92%	7.41%
2009	0.00%	37.50%	58.06%	63.64%	0.00%	0.00%
2010	0.00%	0.00%	12.90%	22.08%	0.00%	0.00%
2011	0.00%	6.25%	17.74%	22.08%	0.00%	0.00%
2012	0.00%		4.44%	3.33%	0.00%	0.00%
2013	0.00%	0.00%	25.81%	25.97%	0.00%	0.00%
2014	0.00%	15.38%	41.18%	40.00%	0.00%	0.00%
2015	0.00%	2.56%	14.12%	20.00%	0.00%	0.00%

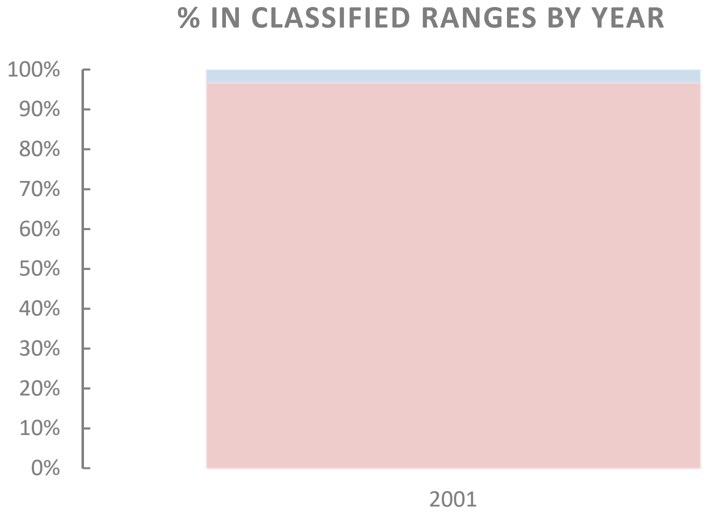
Big Springs Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2008			20.23	22.27	24.21	24.21
2009			21.05	21.05	22.85	22.85
2010			16.72	17.94	21.59	21.59
2011			17.23	18.11	20.33	20.33
2012				18.41	19.43	19.43
2013			18.99	19.81	21.25	21.25
2014			19.90	20.33	21.42	21.42
2015			18.98	19.58	20.20	20.20

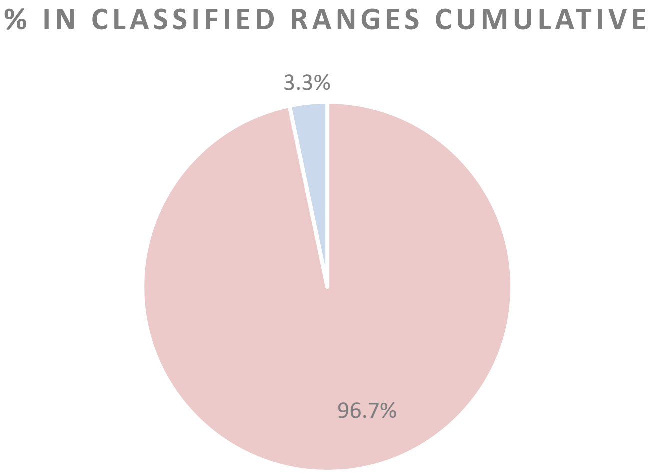
Big Springs Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2008	18.65	17.95	17.95		24.21	24.21
2009	17.94	17.00	17.00		22.85	22.85
2010	16.22	15.36	15.36		21.59	21.59
2011	16.85	16.34	16.34		20.33	20.33
2012	16.32	15.89	15.89		19.43	19.43
2013	16.83	16.35	16.35		21.25	21.25
2014	16.36	16.23	16.23	14.23	21.42	21.42
2015	16.49	15.42	15.42	16.35	20.20	20.20

Big Springs Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2008	20.19	20.19	24.21	24.21	24.21	24.21
2009	21.05	21.05	22.85	22.85	22.85	22.85
2010	16.72	16.72	20.64	21.59	21.59	21.59
2011	16.93	16.93	20.06	20.33	20.33	20.33
2012	16.32		19.43	19.43	19.43	19.43
2013	18.99	18.99	21.25	21.25	21.25	21.25
2014	19.90	19.90	21.42	21.42	21.42	21.42
2015	18.88	18.88	20.20	20.20	20.20	20.20

Little Shasta River near the Mouth







Little Shasta River near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2001			17.65%	32.26%	32.54%	39.13%
2003					54.29%	75.00%

Little Shasta River near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2001	0.00%	37.50%	37.50%		32.54%	39.13%
2003	3.33%	75.00%	75.00%		54.29%	75.00%

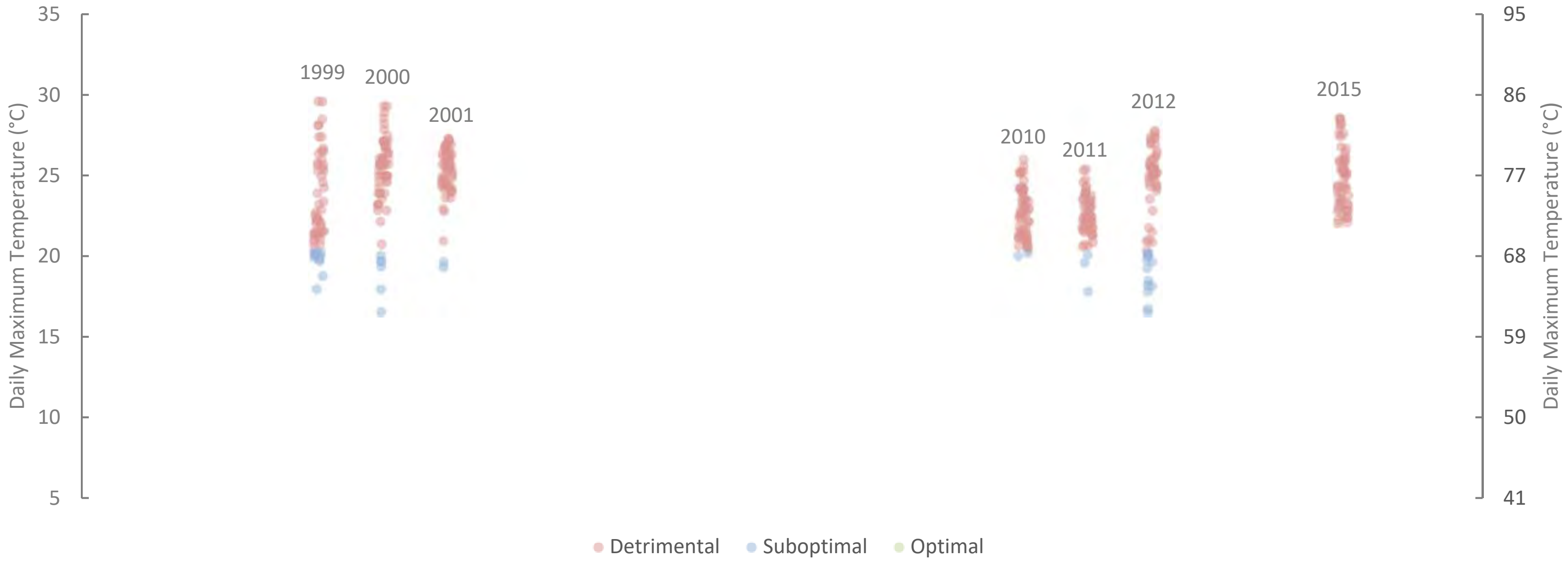
Little Shasta River near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Incubation	Emergence	Rearing	Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2001	0.00%	18.75%	66.13%	70.13%	40.83%	45.37%
2003	10.00%			100.00%	63.81%	84.09%

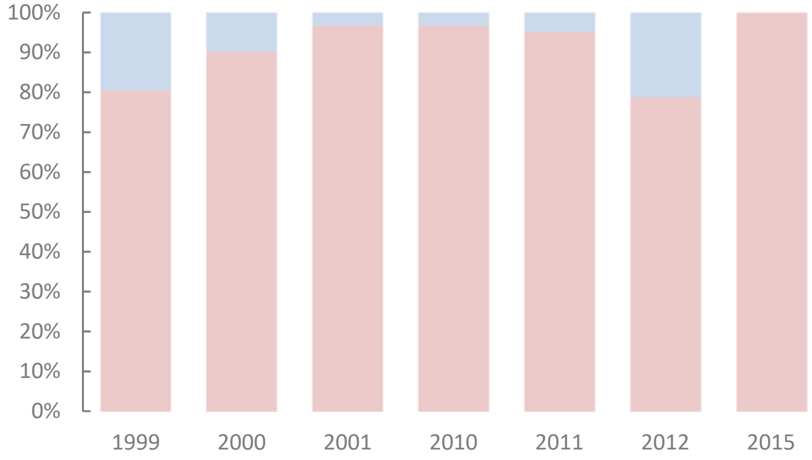
Little Shasta River near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001			19.18	22.47	28.77	28.77
2003					30.67	28.78

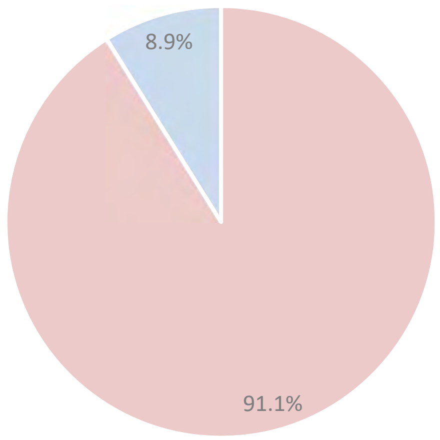
Little Shasta River near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001	23.64	21.90	21.90		28.77	28.77
2003	24.80	22.08	22.08		30.67	28.78

Little Shasta River near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001	23.64	19.18	26.32	27.18	28.77	28.77
2003	24.80			26.59	30.67	30.67

Parks Creek near the Mouth


DAILY MAXIMUM TEMPERATURES FOR COHO REARING CLASSIFIED RANGES


% IN CLASSIFIED RANGES BY YEAR


% IN CLASSIFIED RANGES CUMULATIVE

Parks Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1997					9.76%	0.00%
1999			0.00%	0.00%	11.83%	7.61%
2000				0.00%	33.33%	15.94%
2001				0.00%	31.13%	20.27%
2010					5.50%	12.50%
2011					1.83%	6.25%
2012			0.00%	6.45%	21.30%	11.96%
2015			6.90%	13.95%	17.68%	14.42%

Parks Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
1997	0.00%	0.00%	0.00%		9.76%	0.00%
1999	0.00%	31.25%	31.25%		11.83%	7.61%
2000					33.33%	15.94%
2001	3.33%	93.75%	93.75%		31.13%	20.27%
2010	0.00%	25.00%	25.00%		5.50%	12.50%
2011	0.00%	0.00%	0.00%		1.83%	6.25%
2012	0.00%	50.00%	50.00%		21.30%	11.96%
2015	0.00%	25.00%	25.00%		17.68%	14.42%

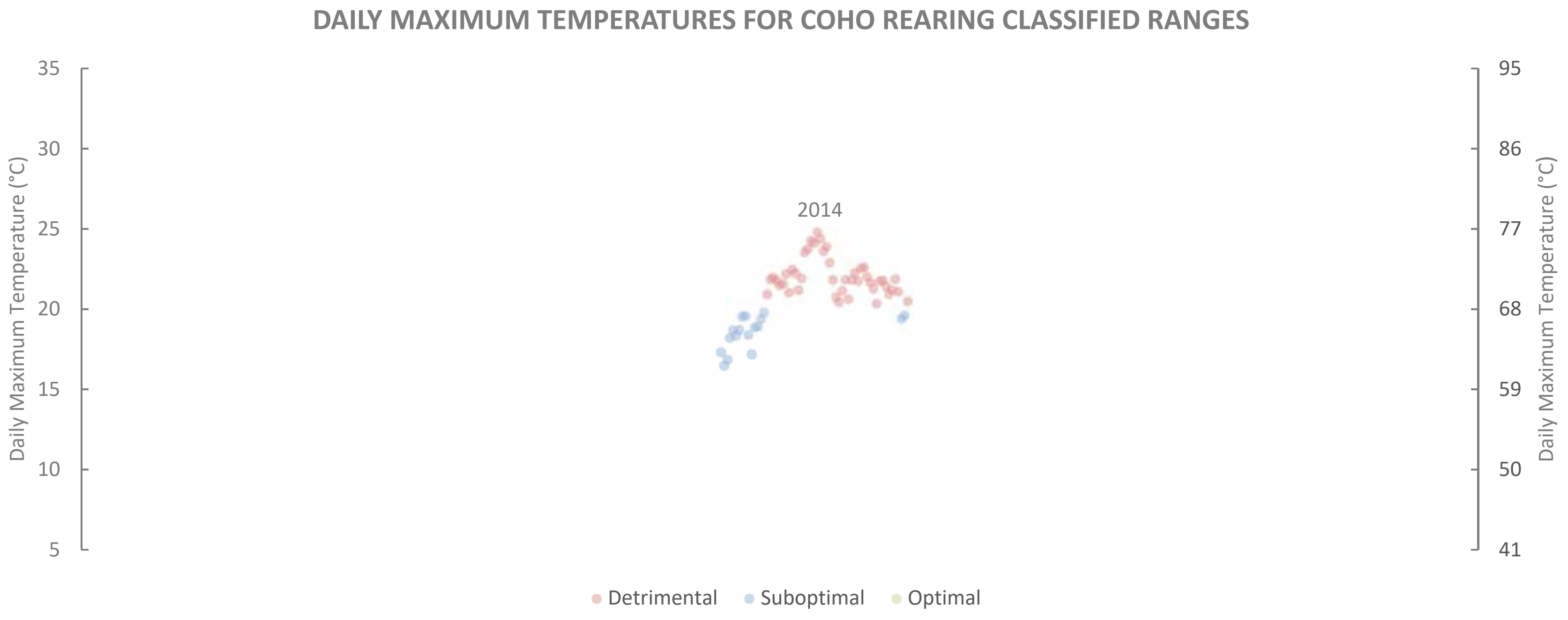
Parks Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
1997	0.00%		83.33%	61.90%	15.85%	0.00%
1999	0.00%	0.00%	14.52%	29.87%	14.20%	9.26%
2000			58.97%	70.37%	49.55%	40.00%
2001	10.00%		56.82%	64.41%	47.02%	47.78%
2010	0.00%		100.00%	100.00%	12.84%	29.17%
2011	0.00%		100.00%	94.12%	6.42%	14.58%
2012	0.00%	0.00%	16.13%	23.38%	28.40%	23.15%
2015	0.00%	7.14%	39.19%	49.44%	26.52%	30.83%

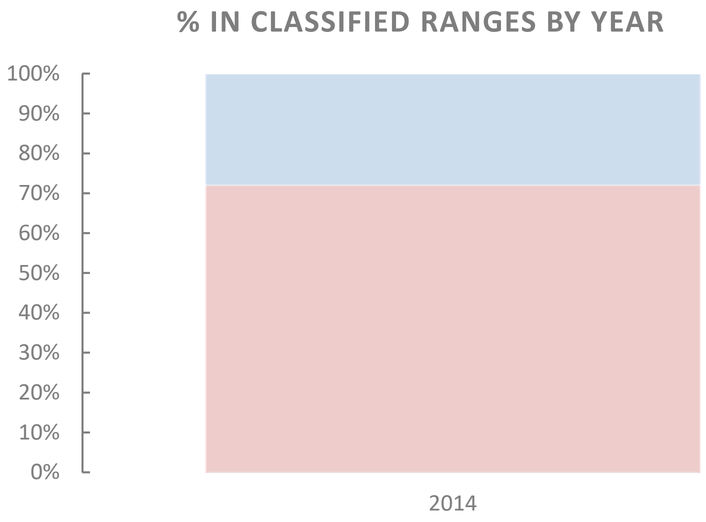
Parks Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1997					25.69	22.08
1999			15.11	15.80	27.25	27.00
2000				15.21	28.17	25.55
2001				16.02	26.81	26.21
2010					24.79	24.45
2011					24.35	24.35
2012			17.44	19.27	26.84	26.52
2015			19.22	19.97	27.76	27.76

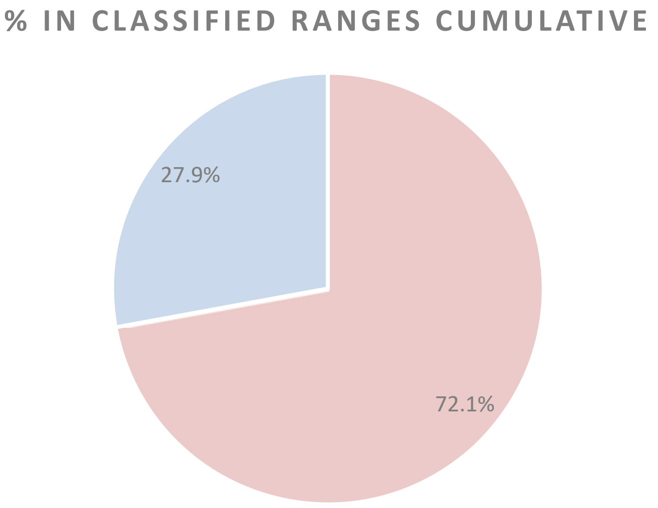
Parks Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1997	20.27	18.65	18.65		25.69	22.08
1999	20.13	20.13	20.13		27.25	27.00
2000					28.17	25.55
2001	25.61	23.84	23.84		26.81	26.21
2010	22.10	19.89	19.89		24.79	24.45
2011	20.13	19.63	19.63		24.35	24.35
2012	22.48	21.57	21.57		26.84	26.52
2015	22.57	20.55	20.55		27.76	27.76

Parks Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
1997	20.27			22.08	25.69	22.08
1999	20.13	15.11	21.07	21.16	27.25	27.25
2000			23.11	25.30	28.17	28.17
2001	25.61		23.21	25.29	26.81	26.81
2010	22.10			24.45	24.79	24.79
2011	20.13			23.49	24.35	24.35
2012	22.48	17.44	20.02	20.56	26.84	26.52
2015	22.57	18.77	24.02	26.08	27.76	27.76

Yreka Creek near the Mouth







Yreka Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15- Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
Coho Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2001					0.00%	0.00%
2013			0.00%	0.00%	0.00%	0.00%
2014			0.00%	0.00%	0.00%	0.00%
2015			0.00%	0.00%	0.00%	0.00%

Yreka Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - Mar 31	Jan 1 - Dec 31	Jan 15 - July 15
Chinook Daily Maximum Temperature Criterion (°C)	25	20	20	20	25	25
Year	Percent of Measurements Exceeding Criteria (15%)					
2001	0.00%	0.00%	0.00%		0.00%	0.00%
2013	0.00%	0.00%	0.00%		0.00%	0.00%
2014	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2015	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Yreka Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - Apr 30	Dec 15 - Apr 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
Steelhead Daily Maximum Temperature Criterion (°C)	24	20	20	20	24	24
Year	Percent of Measurements Exceeding Criteria (15%)					
2001	0.00%		100.00%	76.47%	2.63%	6.67%
2013	0.00%	0.00%	16.13%	23.53%	0.00%	0.00%
2014	0.00%	0.00%	0.00%	0.00%	2.05%	3.08%
2015	0.00%	0.00%	10.26%	10.26%	0.00%	0.00%

Yreka Creek near the Mouth						
Coho Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Coho Periodicity	Oct 15 - Jan 31	Nov 1 - Jan 31	Nov 1 - May 1	Feb 1 - May 15	Jan 1 - Dec 31	Feb 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001					23.49	23.49
2013			15.58	17.26	22.40	20.91
2014			14.74	15.26	24.12	22.78
2015			16.18	17.17	22.57	21.28

Yreka Creek near the Mouth						
Chinook Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Chinook Periodicity	Sept 1 - Dec 7	Sept 15 - Dec 31	Sept 15 - Feb 28	Nov 1 - March 31	Jan 1 - Dec 31	Jan 15 - July 15
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001	21.04	18.29	18.29		23.49	23.49
2013	19.80	18.69	18.69		22.40	20.91
2014	19.40	18.66	18.66	10.93	24.12	22.78
2015	19.96	18.57	18.57		22.57	21.28

Yreka Creek near the Mouth						
Steelhead Life Cycle	Adult Migration	Spawning	Egg Incubation	Fry Emergence	Juvenile Rearing	Juvenile Out-migration
Steelhead Periodicity	Sept 1 - April 30	Dec 15 - April 30	Dec 15 - June 15	Feb 1 - June 30	Jan 1 - Dec 31	Feb 1 - July 31
MWMT Criterion (°C)	20	13	13	13	18	18
Year	MWMT (°C)					
2001	21.04			22.44	23.49	23.49
2013	19.80	15.58	20.91	20.91	22.40	22.40
2014	19.40	14.74	18.97	18.97	24.12	24.12
2015	19.96	16.18	21.28	21.28	22.57	22.57