STUDY PLAN TO ASSESS SHASTA RIVER SALMON AND STEELHEAD RECOVERY NEEDS

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1. INTRODUCTION

The Shasta River is one of the most complex, unique, controversial, and potentially productive rivers in California. Located in central Siskiyou County (Figure 1), the Shasta Basin covers approximately 793 mi^2. The Shasta River originates from snowmelt in the Scott Mountains on the western side of the basin, while receiving substantial spring flows from Mt. Shasta on the eastern side. The mainstem Shasta River flows north, then northwestward, approximately 50 miles before entering the Klamath River at river mile (RM) 177. The mainstem Shasta River is impounded by Dwinnell Dam at RM 40.6. Primary tributaries are Parks Creek (RM 34.9), Big Springs Creek (RM 33.7), Willow Creek (RM 25.8), Little Shasta River (RM 16.3), and Yreka Creek (RM 7.8). Accretion from tributaries and springs, combined with agricultural diversion and return flows, contribute to a complex annual flow regime seasonally and longitudinally (Deas et al. 2004).

The Klamath River system ranked first in California in coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss*) produced, and second after the Sacramento River system in Chinook salmon (*O. tshawytscha*) produced annually (Leidy & Leidy 1984). Historically, spring-run Chinook salmon comprised a significant, if not dominant, proportion of the overall salmon runs entering the Klamath and Shasta rivers (Snyder 1931 and Wales 1951). This changed, however, during the early part of the last century due to habitat alterations and construction of dams that blocked access to historically productive spring-run Chinook habitats in the upper basin. Only the fall-run Chinook salmon run remains in the Shasta Basin. The California Department of Fish and Game (CDFG) has been monitoring the Shasta River fall-run Chinook salmon runs since 1930 at the Shasta River Fish Counting Facility (SRFCF). Annual counts have ranged from nearly 82,000 Chinook salmon in 1931 to 533 fish in 1990 (Figure 2).

Until recently, little information was available regarding coho salmon and steelhead distribution and abundance within the Shasta Basin. Skinner (1959) reported that adult steelhead spawned in the lower seven miles of the Shasta River (the ‘Shasta Canyon’), in the mainstem Shasta River above Big Springs Creek, in Big Springs Creek, and in Parks Creek when streamflows were adequate. Steelhead also spawned in the lower three miles of Yreka Creek. Skinner (1959) suggests that, because coho salmon have similar spawning requirements as steelhead, coho salmon probably spawned in similar areas. Steelhead runs are classified based on the season adults migrate up the Klamath River. Steelhead runs identified in the Klamath Basin are spring-run (better known as summer steelhead), fall-run, and winter-run. Fall-run and winter-run steelhead are present in the Shasta River. Recent CDFG studies have confirmed most coho salmon and steelhead spawning and rearing occurs within the mainstem Shasta River four to five miles below the Big Springs Confluence, in Big Springs Creek, in Parks Creek, and in several spring tributaries to these reaches (Chesney et al. 2007 and 2009). Coho salmon have also been observed spawning and rearing in the Shasta Canyon. Additional anecdotal information suggests that they also spawn in the Little Shasta River and Yreka Creek. Because coho salmon tend to have a 3-year life cycle, they have three unique cohorts before repeating. Recent evaluation of these three coho salmon cohorts found that two of the three cohorts are functionally extinct (Chesney et al. 2010).

No single factor has been responsible for declining anadromous salmonid populations in the Shasta Basin. The Shasta Watershed Restoration Plan (CRMP 1997), the CDFG Biological Needs Assessment (CDFG 1997), the California Department of Water Resources (CDWR 1998), the Klamath Task Force Technical Work Group (KTFTWG 2004), the National Marine Fisheries Service’s (NMFS) Factors for Decline (NMFS 1996 and 1998), the Recovery Strategy for California Coho Salmon (CDFG 2004), and the North Coast Regional Water Quality Control Board (NCRWQCB) Total Maximum Daily Load (TMDL) Action Plan have collectively identified physical barriers (dams and weirs), flow alterations due to irrigation withdrawals and return flows (tailwater), degraded salmonid habitat, poor water quality (primarily temperature and dissolved oxygen), and loss of riparian vegetation, as major factors contributing to declining salmonid populations. Several recent studies by UC Davis, working with The Nature Conservancy (TNC), describe current habitat conditions, streamflow regulation, and land-use practices that impair salmonid habitat (Jeffres et al. 2008, 2009, and 2010).

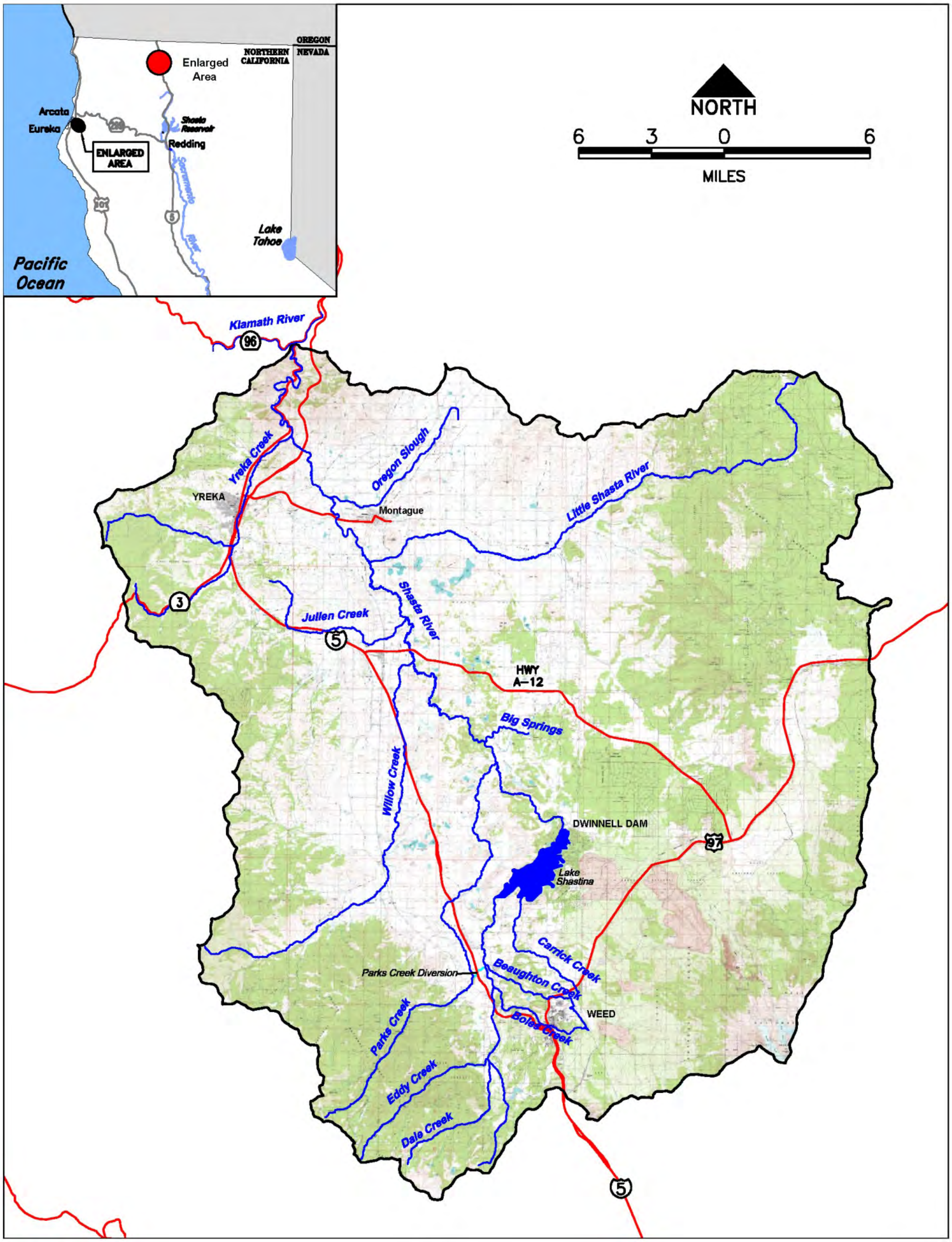

Figure 1. Location of the Shasta River Basin, Siskiyou County, CA.

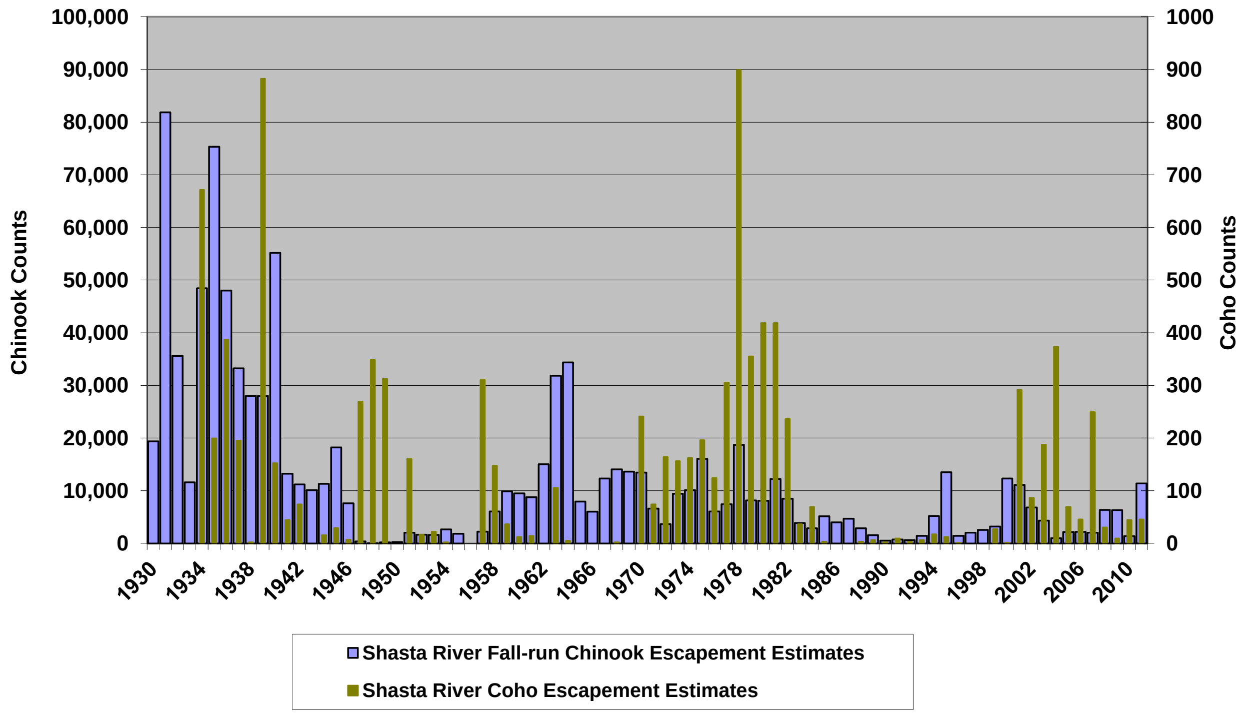

Figure 2. Historical Chinook salmon adult annual escapement estimates from the CDFG Shasta River Fish Counting Facility at the mouth of the Shasta River. Recent coho salmon adult returns have been extremely low and composed largely of hatchery fish.

Beginning in 1994, the regulatory environment surrounding the Shasta River has grown increasingly complex. In that year, the Shasta River was added to the U.S. Environmental Protection Agency (USEPA) 303d list of impaired watersheds. In 1997, NMFS listed the coho salmon Southern /Northern California Coast Evolutionarily Significant Unit (SONCC ESU) as threatened under the Federal Endangered Species Act of 1973. Then in 2004, the SONCC ESU was listed as threatened under the California Endangered Species Act (CESA) (CDFG 2004). The EPA 303d listing resulted in a TMDL allocation developed by the NCRWQCB for temperature and dissolved oxygen (NCRWQCB 2006). The proposal to list coho salmon under the CESA led the Fish and Game Commission to institute to a state-wide coho salmon recovery planning process and a Shasta-Scott pilot program. The Recovery Strategy for California Coho Salmon (CDFG 2004) lists coho salmon recovery tasks specific to the Shasta and Scott basins identified by the Shasta and Scott Recovery Team (SSRT). Acceptance of the pilot program by the local agricultural community was linked to developing watershed-wide permitting programs that would reduce take and provide protection from the consequences of take for routine agricultural activities. Permits issued pursuant to these programs would be integrated with other sections of the Fish and Game Code, including Section 5937 (bypass flows) and Section 5901 (fish passage). However, in February 2011, the watershed-wide permitting program in the Shasta Basin was halted in response to a writ of mandate issued by the Superior Court of California. CDFG is currently evaluating the future of the permitting program. Finally, intensive focus on the current status of salmonid populations in the Klamath River, as part of the Federal Energy Regulatory Commission (FERC) relicensing, has increased attention on the Shasta River for its contribution to Klamath River salmonid populations.

Research and monitoring have recently intensified, with CDFG implementing research-oriented monitoring in the upper Shasta River mainstem, tributaries, springs, and the Shasta Canyon. In 2005, The Nature Conservancy (TNC) purchased the 1,700 acre Nelson Ranch that encompasses the mainstem Shasta River from RM ~26.8 to RM ~32.0, and has been doing research with the U.C. Davis Center for Watershed Sciences and CDFG since 2006. In addition, the NCRWQCB has been modeling water quality in support of the Shasta River TMDL, and with assistance from the Shasta Valley Resource Conservation District (SVRCD), identifying ways to better manage agricultural return flows (tailwater) into the Shasta River mainstem. Other research and restoration actions have included barrier and diversion modification or removal, streamflow gaging, water quality data collection and modeling, salmon habitat inventories, juvenile and adult salmonid population trend monitoring, habitat use studies, and riparian vegetation investigations.

1.1. Study Plan Purpose

The SVRCD and several collaborators set out to locate and evaluate existing information and identify key informational gaps; the next step was to fill these information needs and develop a study plan. This study plan must identify the necessary scientific information to guide and prioritize actions that will move Shasta Basin salmonid populations toward recovery without unnecessary delay. This Study Plan has dual purposes: (1) identify and guide future scientific investigations and monitoring (including field data collection) in the Shasta Basin relevant to recommending future recovery actions that will be timely and cost-effective, and (2) recommend immediate recovery actions.

This Study Plan takes a broad approach by focusing on fish ecology, geomorphology, hydrology, water quality (including temperature), and the habitat needs for each salmonid life stage. The Study Plan should coordinate basin-wide research and monitoring and enhance the SVRCD's ability to address regulatory requirements and recover salmonid populations. Information generated by implementing this Study Plan will assist the SVRCD in complying with the California Endangered Species Act, the CDFG 1600 Streambed Alteration program, and the NCRWQCB TMDL. Developing the Study Plan required:

- Review of relevant documents and information from the Shasta Basin and from the literature (including streamflow, geomorphic, riparian, and water quality data, salmonid life histories, and habitat requirements);
- Description of historical streamflow and habitat conditions in the Shasta Basin, to the extent feasible, to help guide recovery planning efforts;
- Description of the geographical distribution of different life stages of salmonids (migration, spawning, rearing, etc.) to form life history tactics (LHTs) and the physical and biological constraints each life stage experiences;
- Anticipation of key restoration and management issues that will be most effective at rapid salmonid population recovery; and
- Evaluation of ongoing modeling, monitoring, and planning efforts to help synchronize future data collection for model input, calibration, and testing.

Occasionally we transcribe text verbatim, with author(s) permission, rather than 're-invent the wheel' by re-writing authors' summary descriptions. Appendix A lists primary documents reviewed during Study Plan development.

1.2. A Framework for Study Plan Development

First, unique geomorphic and hydrological characteristics of the Shasta Basin are described that once contributed to thriving salmonid populations. The purpose for describing historical conditions is not to advocate a return to those conditions. Instead, the historical context helps guide where and how salmonid recovery efforts should be directed. Second, we identify historical life history "tactics" that sustained Chinook salmon, coho salmon, and steelhead populations in the Shasta Basin before major land and water developments occurred (refer to Appendix D for more definition of life history tactics with examples). From these historical LHTs, a subset of high priority existing and recoverable tactics was recommended. Next, based on contemporary habitat conditions, we list the most important data and information needs required to address potential habitat limitations presently being imposed on each high priority life history tactic. In the final step, data and information needs are grouped by subject into nine Study Plan Elements (e.g., geomorphology, fish passage, riparian vegetation). Each Study Plan Element specifies how these needs can be accomplished, including the temporal and spatial scale of those elements, data collection methods, analytical approach and integration with other elements, timing and location of studies, work products to be completed, and other information needed to complete study elements.

2. FACTORS THAT LIKELY SUSTAINED HISTORICAL SALMONID POPULATIONS

An understanding of how salmonid populations once thrived in the Shasta Basin is needed to inform and sustain future recovery efforts. The following sections describe the unique geology and hydrology of the Shasta Basin and the diverse salmonid populations that once thrived there.

2.1. Unique Geologic and Hydrologic Settings

A unique blend of geology, hydrology, and climate in the Shasta Basin created an extremely productive river ecosystem. Situated between Mt. Shasta and the Klamath Mountains, Shasta Basin lies near the southern extent of the Cascade Range. Annual precipitation is considerably lower than more northerly Cascade basins in Western Oregon, a consequence of the Klamath Mountains to the west intercepting moist air moving east from the Pacific Ocean, creating a rain-shadow over the basin. The Shasta Basin is therefore much drier than either the Cascades to the north or the Sierra Nevada to the south. However, the melting snowpack during spring and early summer from Mt. Shasta and the Scott and Klamath mountains offsets the lower winter precipitation by replenishing river flows as winter rains subside. Following snowmelt, extensive year-round springs, derived from snowmelt seepage into the volcanic geology, deliver high and cold baseflows into the Shasta River mainstem during the dry, hot summer and early fall.

Mt. Shasta has had significant volcanic activity the past few thousand years. Crandell (1989) contends that the unusual morphology of Shasta Valley was the result of a huge debris-avalanche originating from Mt. Shasta more than 300,000 years ago that flowed across the valley floor (Figure 3).

As the Shasta River valley was buried in volcanic debris, the low-gradient valley bottom was formed. The Shasta River winds across this massive depositional feature comprised of a matrix of sand, silt, clay, and rock. The differential porosity of this material allows glacial-melt and snowmelt from Mt. Shasta to percolate into groundwater aquifers that resurface as springs, a few of which produce substantial, constant discharge to the Shasta River mainstem and several tributaries. These spring discharges are enriched by nitrogen and phosphorus because of local geological effects. Nutrient-enriched spring discharge of cold, constant streamflow into the Shasta River offsets an otherwise hostile arid and hot summer environment to sustain abundant and highly productive salmonid habitat in most years.

Another key element contributing to the high aquatic productivity of the Shasta Basin is the low-gradient, meandering nature of the mainstem river and tributaries, including more than 20 miles of the Shasta River mainstem, Parks Creek and Willow Creek bottomlands, Big Springs Creek, and the Little Shasta River bottomlands. Given frequent winter rainfall-induced floods and highly erodible volcanic material, the river channel likely experienced bank erosion, channel migration, and avulsion that ultimately shaped (though strongly influenced by woody riparian vegetation) the highly sinuous mainstem channel observed today (Figure 4). The valley bottom also likely supported a diverse mosaic of riparian and emergent wetland vegetation, submerged aquatic vegetation, and an abundant beaver population, resulting in an exceptionally productive aquatic ecosystem. The low-gradient, sinuous mainstem channel in the Shasta River valley bottom offered an ideal, year-round salmonid rearing environment: exceptionally high quality and quantity of food resources, cold year-round water temperatures, steady spring baseflows, abundant physical habitat cover from aquatic vegetation and large wood, and extensive off-channel rearing habitat during the predictable annual peak snowmelt runoff.

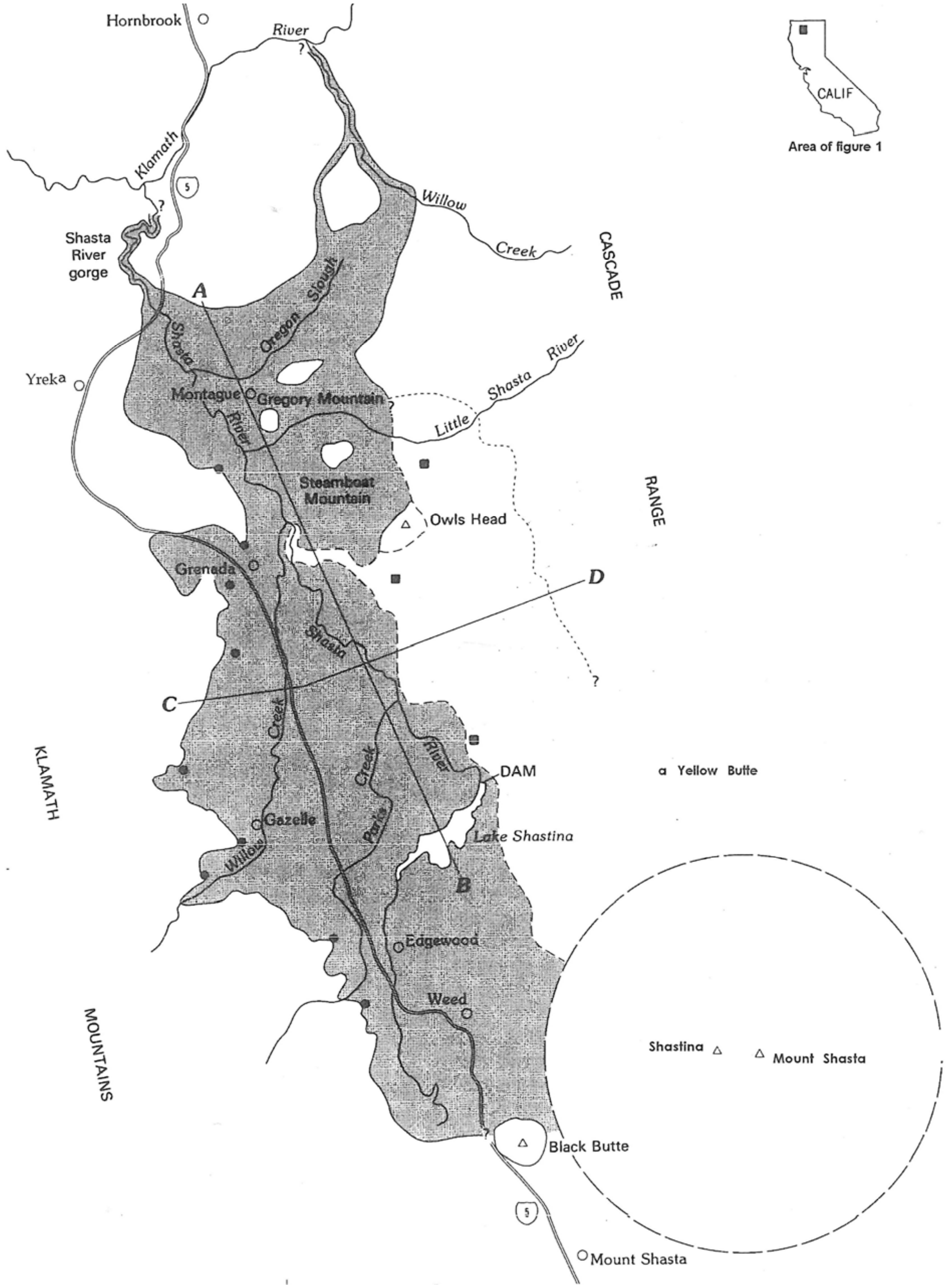

Figure 3. Approximate extent of a large avalanche debris deposit from over 300,000 years ago that filled Shasta Valley with volcanic debris (Crandell 1989).

Figure 4. Aerial photograph, from 2006 of the mainstem Shasta River at The Nature Conservancy's Nelson Ranch, of highly sinuous channel morphology with high-flow avulsion and side-channels.

Juvenile salmonids emigrating from the Shasta River do not directly enter the ocean, but instead must swim 177 miles (283 km) of the Klamath River mainstem and its estuary. Historical importance of the Klamath River mainstem and estuary to the Shasta Basin's salmonid populations is difficult to quantify, but early fish biologists had already begun speculating on how anadromous salmonids benefited from rearing in the Klamath Estuary. Snyder (1931) noted:

> *Late in the summer and in the early fall, king salmon of the year may be found near the mouth of the river. They are sometimes caught with hook and line and carried away as trout. They are six or seven inches long or even larger…. In pursuing these little salmon with net and rod, it became evident that their distribution in the estuary was general. They seemed, however, to prefer the fresh current, although they were sometimes taken in brackish water. ... Both sexes were represented and an occasional mature male was observed.*
>
> *One is at a loss to account for the presence of a precocious male among downstream migrants… There is no evidence that these fish have come in from the sea. On the contrary, it is certain that they are downstream migrants, lately arrived in the estuary where abundant food has contributed to very rapid growth.*

2.2. The Unimpaired Annual Hydrograph

Unimpaired flow is the natural streamflow without human alterations such as irrigation withdrawals, impoundments or diversions, forest management, and urbanization. The unimpaired annual hydrograph is the unaltered annual flow pattern, commonly presented graphically as annual daily average streamflows. Because the earliest streamflow gages were installed well after considerable water development had begun in the Shasta Basin, no flow records accurately gage annual unimpaired runoff to sufficiently document natural seasonal and year-to-year streamflow variability. However, the unimpaired average annual water yield at the mouth has been estimated by several investigators independently as follows:

- CDWR 1964: Bulletin 87 – Shasta Valley Investigation. For the base period of 1921 to 1955, the average seasonal natural runoff was estimated as 162,300 acre-ft (ac-ft).
- CDWR 1998: Klamath Basin Assessment. For the base period of 1945 to 1994, the annual natural flow was estimated as 218,800 ac-ft.
- USBOR 2005: the U.S. Bureau of Reclamation Natural Flow Study. For the period of 1949 to 2000, annual unimpaired flows were estimated as 224,182 ac-ft.

USGS and CDWR have operated at least four gages in the Shasta Basin (Table 1), with the earliest data from the Shasta River near Montague (USGS 11-517000) beginning in WY1912. Flow data have been collected extensively throughout the basin by CDWR Watermaster Services primarily to document seasonal irrigation allocations.

Table 1. Summary of USGS and CDWR daily average/peak streamflow data in the Shasta Basin. The CDWR Shasta River near Edgewood gage records only water stage data.

Gage Number or Station ID	USGS Station Name	Drainage Area (mi^2)	Period of Record
USGS 11-516750	Shasta River near Edgewood CA	70.3	1959 1998
USGS 11-516900	Little Shasta River near Montague CA	48.2	1958 1978
USGS 11-517000	Shasta River near Montague CA	673	1912 1913, 1917 1921, 1924 1933, 2002 Present
USGS 11-517500	Shasta River near Yreka CA	793	1934 1942, 1945 Present
CDWR MPD	Montague Water Conservation District (MWCD) Parks Creek Diversion near Edgewood CA	NA	From 11/14/2005 to Present
CDWR SRE	Shasta River near Edgewood CA	70.3	From 06/24/2004 to Present

For purposes of this Study Plan, we relied on the available USGS gaging and irrigation diversion data to describe unimpaired streamflow magnitudes and seasonal patterns to which salmonid populations were adapted. The most thorough description of contemporary and unimpaired hydrology in the Shasta Basin is provided by Deas et al. (2004), in which USGS streamflow gaging data, CDWR Watermaster records, and USGS precipitation records were used to estimate unimpaired flows at intermediate points along the mainstem Shasta River from Dwinnell Dam to the confluence with the Klamath River.

The NMFS's "Historical Population Structure of the SONCC ESU [Southern Oregon/North California Coast Ecologically Significant Unit]" (NOAA 2006) describes ecological and environmental conditions throughout the SONCC ESU. Plates 7 and 8 of NOAA (2006) included in this Study Plan (Figures 5 and 6) show the major geologic and hydrologic zones within the Shasta Basin.

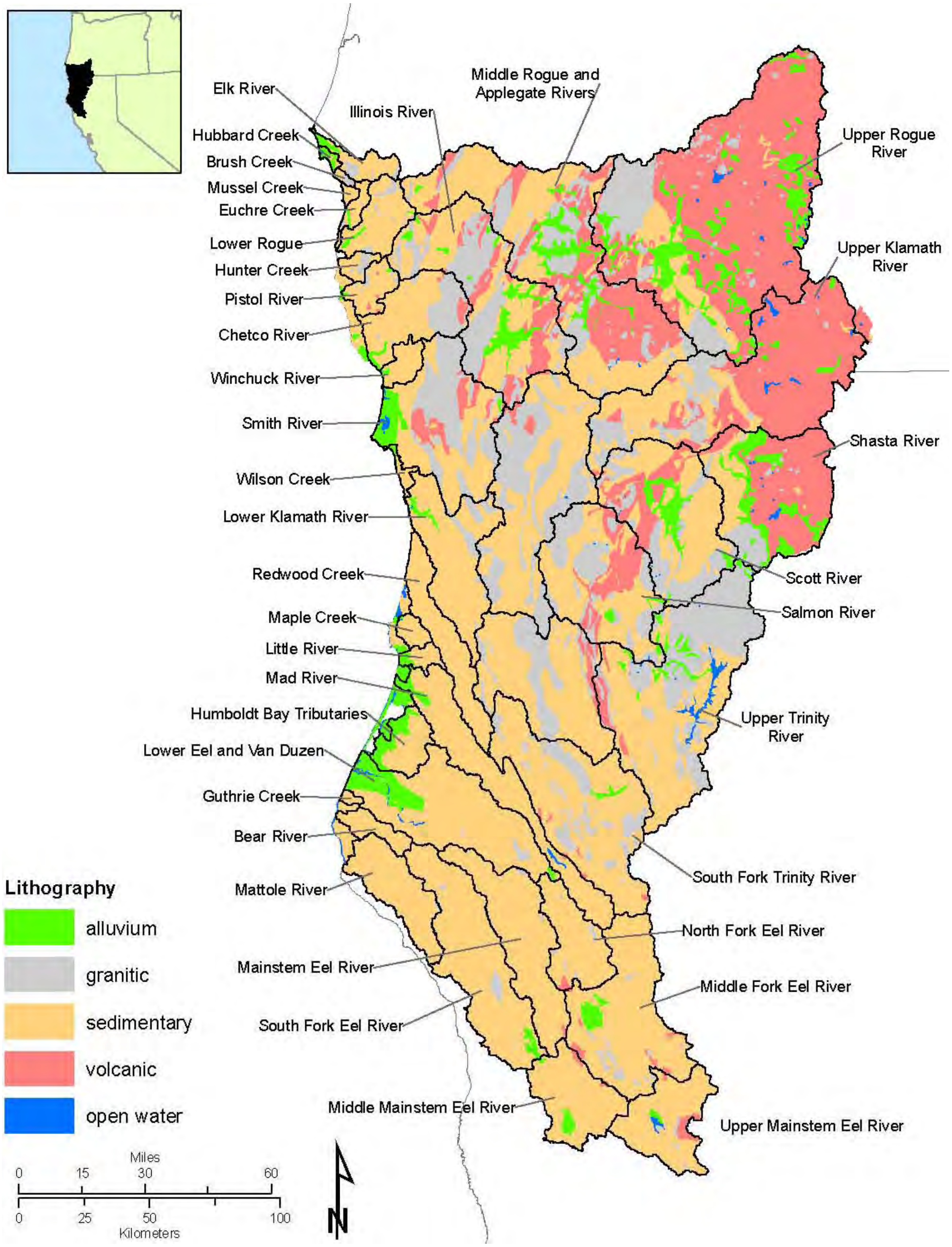

Figure 5. Geology across the Southern Oregon/Northern California Coasts coho salmon ESU.

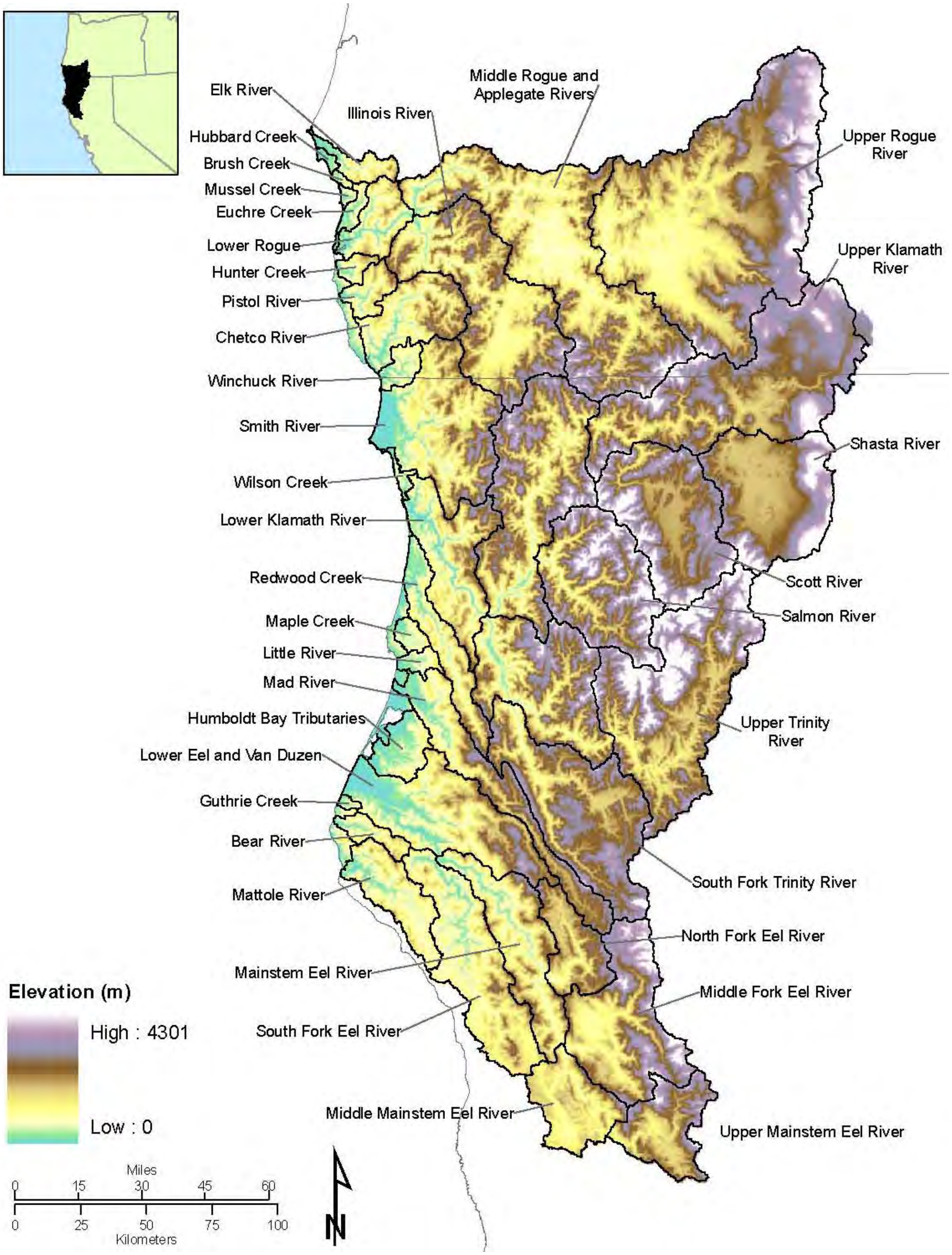

Figure 6. Elevations across the Southern Oregon/Northern California Coast coho salmon ESU.

On the basis of three ecoregions, four dominant lithologies, and several distinct high and low elevation regions, we assigned the Shasta Basin four hydrologic zones (Figure 7). Each zone has a distinctive annual hydrograph. Understanding the different flow patterns and the ways in which salmonids might have adapted to different parts of the Shasta Basin will be essential to recovery planning. These four zones and their characteristic magnitude, timing, duration, and frequency of runoff events are summarized below. Unimpaired streamflows contributed by each zone, and cumulatively along the river from Zone 1 through Zone 4, are estimated for each of four annual hydrograph components – summer baseflows, winter baseflows, winter floods, and spring snowmelt runoff events (Table 2). Daily average annual hydrographs were constructed from published USGS gaging records for the Shasta River near Edgewood and Little Shasta River near Montague for seven overlapping water years (WY1959 to WY1960, WY1963 to WY1967), supplemented with constant year-round spring discharges, to approximate unregulated annual hydrographs. These annual hydrographs will be important for evaluating baseline instream flow needs.

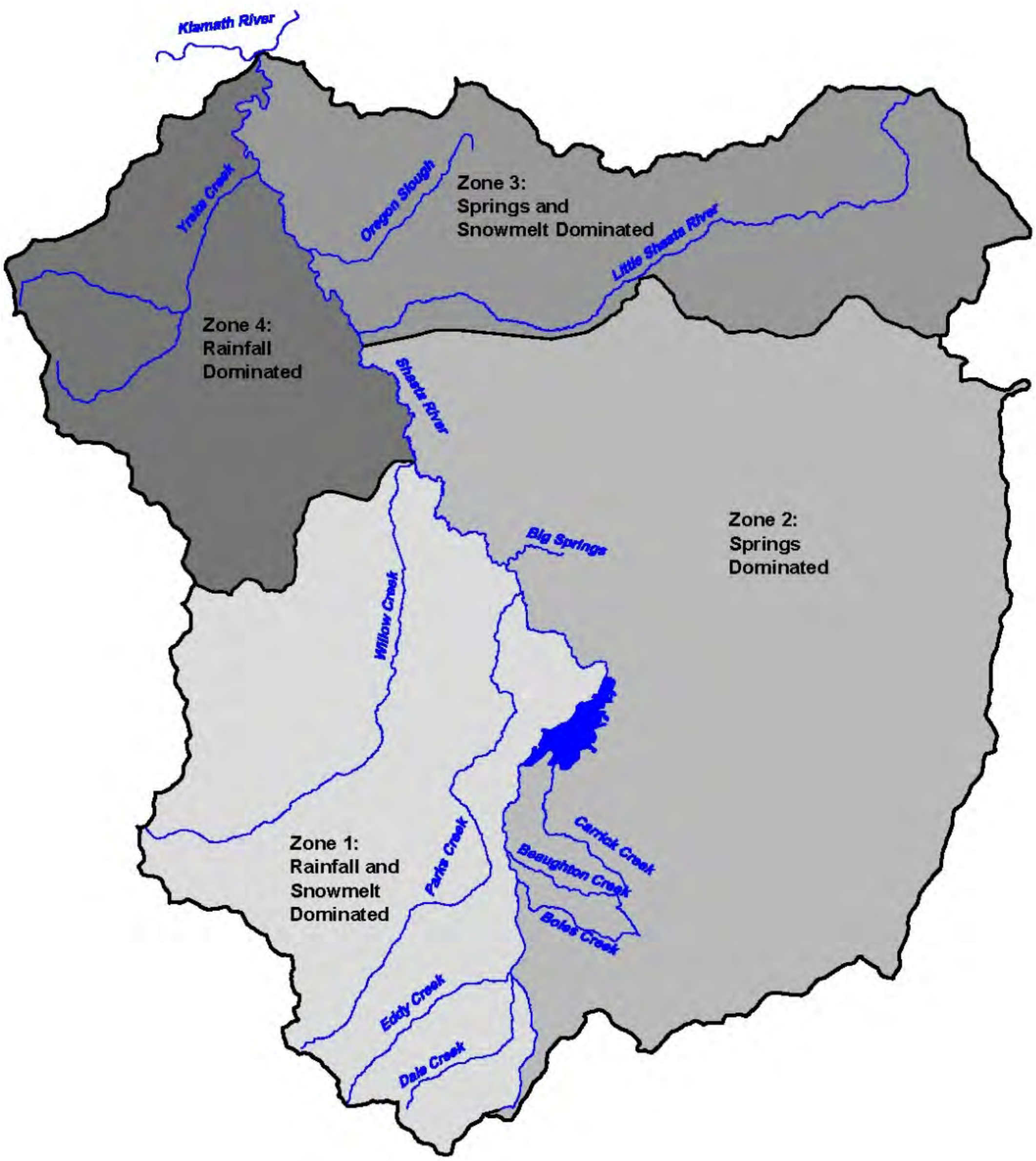

Figure 7. Hydrologic zones in the Shasta Basin based on the dominant hydrograph components that determine runoff patterns in the mainstem Shasta River. Boundaries are approximate.

2.2.1. Zone 1: A Rainfall and Snowmelt Hydrograph

In the southwest portion of the basin, Zone 1 drains the Scott Mountains, with elevations reaching as high as 9,025 ft on Mt. Eddy. There are at least three principal tributaries to the mainstem Shasta River that drain Zone 1 – the upper mainstem above Dwinnell Dam, Parks Creek, and Willow Creek (Figure 1). Several tributaries merge to form the upper mainstem, including Carrick, Beaughton, Boles, Dale, and Eddy creeks. The USGS records from the Edgewood gage (USGS 11-516750), located downstream of all but Carrick Creek (Figure 7), allow a quantitative description of unimpaired hydrology in this portion of the basin. Drainage area at the Edgewood gage is 70.3 mi^2. The gage elevation is 2,900 ft. Data are available for seven complete water years, WYs 1959 to 1960, 1963 to 1967 (Figure 8) and 33 years of incomplete water year records (April to September). The Edgewood data are not unimpaired data; there are winter diversions above the Edgewood gage at the Edson-Foulke diversion of up to 10 cfs from November 1 to March 1 and summer diversions up to 29 cfs from April 1 to September 30. In addition, the diversion of Parks Creek into the Shasta River occurs upstream of the Edgewood gage, and contributes up to 14,000 ac-ft of water to Lake Shastina between approximately November 1 and July 15. Average annual yield at Edgewood for the seven years of record was 53,345 ac-ft, which includes Parks Creek diversions. Smitherum (1926) estimated the annual runoff at Edgewood was 32,500 ac-ft for WY1922 (a wet water year), excluding July to September. Dwinnell Dam was constructed in 1928 (initially allowed a capacity of 36,000 ac-ft but then upgraded in 1955 to 50,000 ac-ft) to capture and store winter runoff from the upper Shasta River and Parks Creek basins.

To estimate typical unimpaired summer baseflows, a daily average exceedence curve was computed for June 21 through September 30 using the Edgewood USGS records and adding Edson-Foulke daily diversions from CDWR records for five water years with overlapping data. The 80% and 20% exceedence flows, characterizing typical summer baseflows over dry to wet water years, were 10 cfs and 27 cfs, respectively (Table 2). This conservative baseflow range does not include other known summer diversions upstream of the Edson-Foulke diversion. Smitherum (1926) reported data from the Edgewood gage and the Duke Ranch on Parks Creek for WY1922, and assumed the measured streamflow at these gaging sites represented the total runoff from the upper Shasta River and Parks Creek basins, i.e., there were no additional significant accretions from these gaging sites down to the confluence of Parks Creek. One exception, Carrick Creek, was noted to provide an additional approximately 10 cfs year-round discharge from springs. In WY1922, the upper Shasta Basin contributed 66.2% and Parks Creek contributed 33.8% of the total runoff (Smitherum 1926). For summer baseflow estimates, a constant 10 cfs was added to the Edgewood gage data for Carrick Creek, and a multiplier of 0.51 (33.8/66.2) was used to expand the Edgewood record. At least 18 cfs of additional cold-water springs emanate from the “Shasta Springs” on the Shasta River below Dwinnell Dam and Parks Creek below I-5. Typical mainstem summer baseflows were thus estimated at approximately 10 cfs to 27 cfs below the Edgewood gage and 43 cfs to 68 cfs below the Parks Creek confluence. Using the Edgewood USGS and CDWR published data and the constant spring discharges, daily average unimpaired hydrographs were constructed for the seven overlapping water years from WY1959 to WY1960 and WY1963 to WY1967 (Figure 9).

Table 2. Estimates of streamflow for major hydrograph components in four major hydrologic zones of the Shasta Basin under unimpaired conditions based on USGS streamflow data and anecdotal evidence of spring discharges.

Zone	River Mile	Reach	Summer Baseflows: July-October (cfs)	Winter Baseflows: November-March (cfs)	Winter Floods: November-March (cfs)	Snowmelt Floods: April-June (cfs)
1	~48-34	Mainstem Shasta River	10-27	55-120	No estimate	No estimate
		Parks Creek	5-13	Included in mainstem Shasta River	No estimate	No estimate
		Carrick Creek (springs)	10	10	No estimate	No estimate
		Shasta Springs (Hidden Valley, Clear, Bridgefield, Kettle, Hole in the Ground)	18	18	No estimate	No estimate
		Cumulative below Parks Creek confluence[1]	*45-70*	*85-150*	*500-800*	*200-300*
2	34-16	Big Springs Complex	125	125	125	125
		Cumulative below Big Springs[1]	*170-190*	*210-275*	*625-925*	*325-425*
3	16-7.8	Little Shasta River	20-30	20-30	50-200	50-100
		Cumulative below Little Shasta River[1]	*190-220*	*230-305*	*675-1,125*	*375-525*
4	7.8-mouth	Yreka Creek and Oregon Slough	10-20	25-50	100-300	25-50
		Cumulative below Yreka Creek[1]	*200-240*	*255-355*	*775-1,425*	*400-625*

[1] Cumulative values rounded to nearest 5 cfs

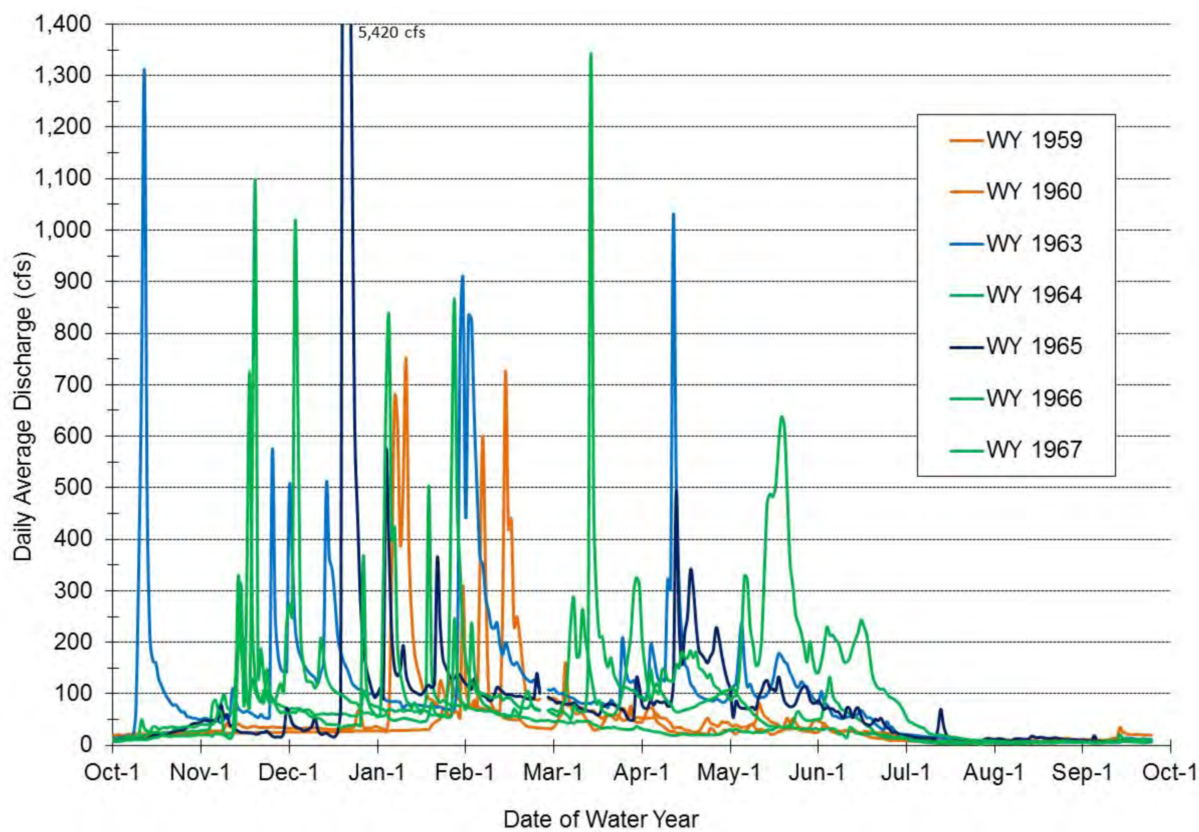

Figure 8. Published daily average streamflow data from USGS Shasta River near Edgewood gage (Station #11-516750).

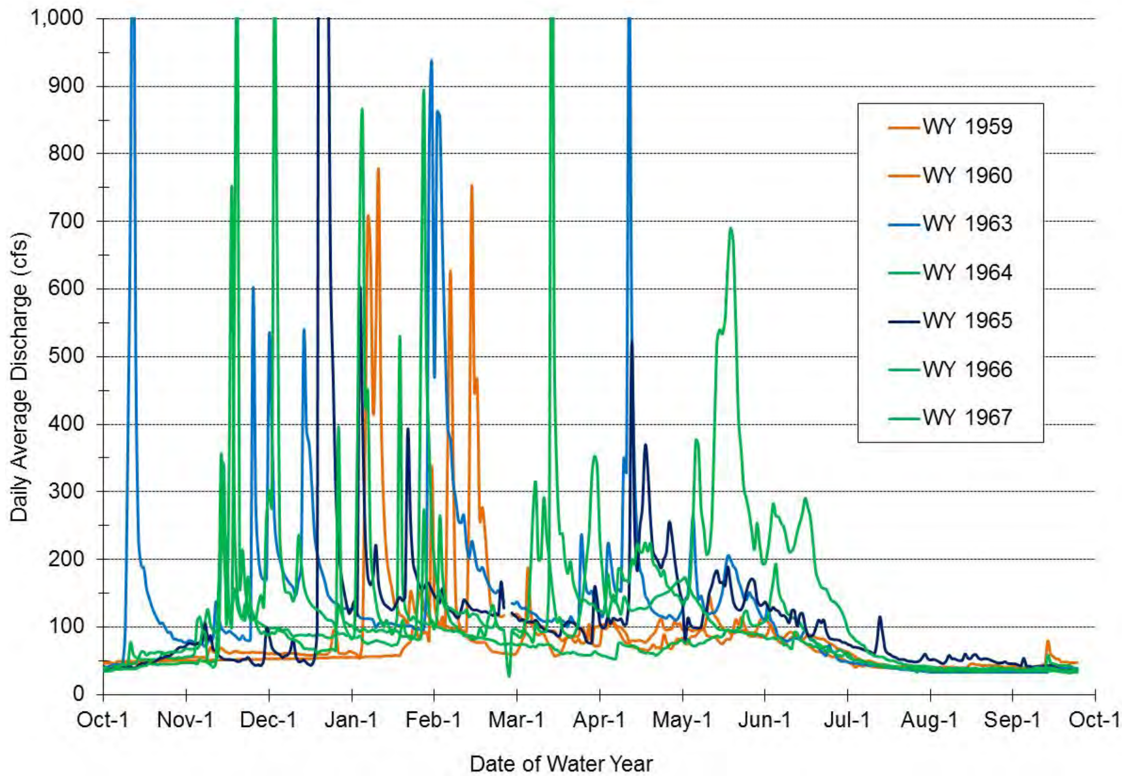

Figure 9. Estimated unimpaired daily average streamflows in the Shasta River below Parks Creek. Annual hydrographs were reconstructed from USGS Shasta River near Edgewood (Station #11-516750), Edson-Foulke summer diversions from CDWR Records, with 10 cfs added for Carrick Creek and 18 cfs added for Shasta Springs.

Winter streamflows in Zone 1 are a mix of rainfall and snowmelt runoff (Figures 8 and 9). Rainfall events resulting in high winter discharge were common through the late-fall and winter months (typically October-March) and frequently extended into spring. During the seven water years with records at Edgewood, at least 27 winter storms were noted, with peak daily average discharge ranging from 310 cfs to 5,420 cfs. Peak floods in the 500 cfs to 800 cfs range were common.

This range was used in Table 2 to demonstrate downstream propagation of typical winter floods. The December 22, 1964, flood of 5,420 cfs was a rain-on-snow event. The Edgewood gage combines winter runoff from the upper Shasta Basin and Parks Creek, so no adjustment was made to estimate unimpaired winter baseflows or winter floods below Parks Creek. To characterize winter baseflows, an exceedence curve was computed for December 21 to March 20. The 80% and 20% exceedence flows were 55 cfs to 120 cfs respectively. An additional 10 cfs was added for Carrick Creek springs and 18 cfs for springs below Dwinnell (Shasta River) and I-5 (Parks Creek). Winter diversions at Edson-Foulke were not included; winter baseflow estimates do not include flow accretions into Parks Creek, either from springs or surface runoff below the Montague Irrigation District (MID) diversion; no additional winter flood accretion from Carrick Creek was made. Thus, typical winter baseflows of 83 cfs to 148 cfs below Parks Creek are likely conservatively low.

The upper basin climate is dry by Klamath montane standards, with the Deadfall Lakes snow course averaging 33 inches of water on April 1. The snowmelt flood in Zone 1 had a lower magnitude but longer duration than winter floods and exhibited more inter-annual variation. Within-year variation was also high, i.e., snowmelt runoff was more 'pulse-episodic' rather than constant ascending and descending snowmelt runoff. Water years with dry to average precipitation had small or no snowmelt peaks, but wetter or colder water years exhibited distinct peaks, typically 200 cfs to 300 cfs in April and May.

2.2.2. Zone 2: A Spring-Fed Hydrograph

To the southeast of the Shasta River mainstem, Zone 2 is dominated by Mt. Shasta and is characterized by glacial and snowmelt runoff generating minimal surface runoff but high spring discharge. The Big Springs Complex is the dominant springs of this zone, but numerous other springs contributed flow to the Shasta River prior to major water developments. Several springs still flow into the mainstem, although flow records are not available to estimate their discharge. Big Springs Creek joins the mainstem at RM 33.7. Zone 2 runoff provided consistent year-round cold water to the upper Shasta River. Deas (2006) stated that "Big Springs Creek historically (pre-diversion) delivered on the order of 100 cfs to 125 cfs to the Shasta River …and that the flow does not exhibit a typical seasonal reduction through the summer period, rather the spring signal is persistent through the summer and into early fall." The 125 cfs estimate is supported by two additional sources: Smitherum (1926) and Wales (1951). The SWRCB Division of Water Rights Decision 3544-3555 D-9 (Smitherum 1926) stated: "Lower Shasta River, however, has a sustained flow of approximately 130 cubic feet per second, supplied mainly from Big Springs and several small springs tributary to Big Springs Creek." Wales (1951) stated: "A short way below the dam and a mile to the east of the river channel are the 'Big Springs' which have a combined flow of 125 cfs of water which rises from the lava rock in several smaller springs. The temperature of this water lies between 52°F and 53°F." There appears to have been additional smaller springs and subsurface flows that historically contributed (and may still contribute) measurable flow to the mainstem. Spring discharge into the mainstem Shasta River from the Big Springs area thus would have dominated the mainstem's summer hydrograph. Our analysis used 125 cfs total discharge for Big Springs Creek at its confluence with the Shasta River, even though Little Springs and other accretions likely contributed additional flow into Big Springs Creek. Streamflow estimates were not included for Willow and Julien creeks, and other smaller tributaries, although their seasonal contributions were likely significant.

2.2.3. Zone 3: A Snowmelt and Spring Hydrograph

In the northeast portion of the basin, Zone 3 is primarily the Little Shasta River drainage. Streamflow records for Little Shasta River near Montague (USGS 11-516900) are available for WYs 1958 to 1978 and are unimpaired because all large diversions are located below the gaging station. The gage elevation is 3,280 ft. This zone drains 48.2 mi^2 of the Cascade Range with several peaks (Goosenest and Ball Mountain) above 7,000 ft. Several smaller tributaries collectively feed the Little Shasta River; several significant springs near the base of Table Rock historically fed the Little Shasta River downstream of the USGS gaging station. Streamflow records indicate the annual hydrograph was dominated by moderate snowmelt runoff with small variations in annual yield and runoff events (Figure 10) compared to flashier rainfall-dominated systems. Winter and summer baseflows, ranging from 10 cfs to 20 cfs based on the USGS Little Shasta River gage, were likely higher with additional springs below the gage. For baseflow computations, a 10 cfs baseflow accretion was added from springs, although the actual accretion may have been higher. Unimpaired annual hydrographs exhibited minor winter rainfall events but did have a distinct, moderate snowmelt runoff event. Winter floods typically were from 50 cfs to 200 cfs at the USGS gage (Figure 10). The flood of December 22, 1964, had a peak daily average discharge of 794 cfs. Typical annual snowmelt floods were 50 cfs to 100 cfs, with longer durations than during rainfall events. The average annual yield calculated from the USGS gage data was 14,150 ac-ft, a much lower per unit-area annual yield than at Edgewood. The lower eight miles of the Little Shasta River traverse a low-gradient valley, which likely had gaining streamflows.

2.2.1. Zone 4: A Rainfall Hydrograph

In the northwest portion of the basin, Zone 4 is primarily the Yreka Creek watershed and Oregon Slough, and has no known historical streamflow records. Zone 4 is in the rain shadow of the Trinity Alps and Marble Mountains. Average annual precipitation is approximately 19.5 in/yr. Annual hydrographs were developed for the water years in which gages at the Shasta River at Yreka (USGS 11-517500) and Montague (USGS 11-517000) overlapped (WYs 2002present) by subtraction, thereby estimating streamflows for a 122 mi^2 portion of the basin including the Yreka Creek watershed. The area east of the Shasta Canyon draining into Oregon Slough provided a low percentage of the annual yield. Basin elevations are lower in the Yreka Creek drainage than in Zone 1. Since about 1966, up to 6 cfs have been imported to the Yreka area from Fall Creek for domestic consumption; a portion of this returns to the stream as urban infiltration and as treated wastewater. Snowmelt runoff appeared low based on the limited streamflow data analyzed; however, the data used for this analysis are regulated streamflows, so would likely not show a real snowmelt signature. Winter and summer baseflows were 10 cfs to 20 cfs, with a contribution of 25 cfs to 50 cfs of winter baseflow and snowmelt runoff from Yreka Creek. Winter rainfall events probably dominated this zone, but were less frequent and had lower unit-runoff magnitudes than Zone 1, ranging from 100 cfs to 300 cfs for typical winter storm events. The December 31, 2005, flood had an estimated peak discharge exceeding 4,000 to 5,000 cfs in Yreka Creek (B. Chesney, personal communication). Greenhorn Dam on Greenhorn Creek, completed in 1960, captures drainage from a 12.1 mi^2 watershed and stores approximately 251 ac-ft.

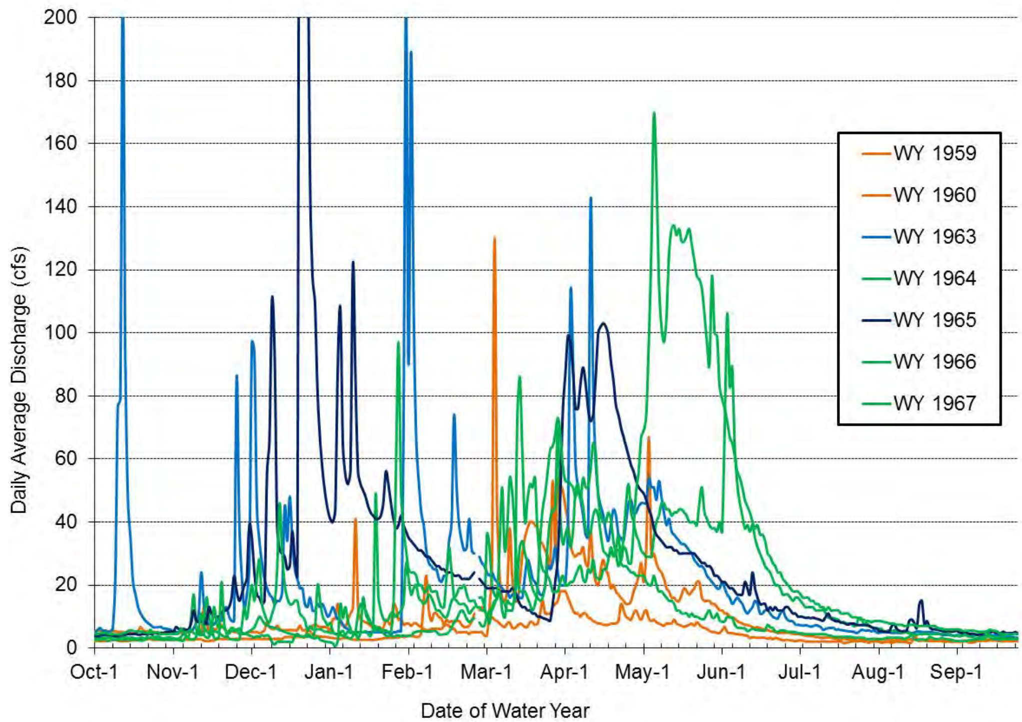

Figure 10. Published daily average streamflow data from USGS Little Shasta River gage (Station #11-516900).

2.2.2. Cumulative Daily Average Hydrographs

Annual streamflow variability and cumulative discharge in unimpaired conditions were summarized for the mainstem Shasta River. Estimates are intentionally conservative, acknowledging unaccounted diversions and augmentations, and therefore only roughly approximate streamflows and annual hydrographs.

The upper mainstem Shasta basin (Zone 1) had a typical arid-montane runoff pattern of short, intense winter rainstorm-generated floods of 500 cfs to 800 cfs, elevated winter baseflows at Edgewood of 55 cfs to 120 cfs, a spring snowmelt hydrograph during April and/or May in most years with peaks of 200 cfs to 300 cfs, and summer baseflows typically around 20 cfs sustained by several small springs. Summer baseflows increased with the addition of spring discharge below Carrick Creek, and again to approximately 43 cfs to 68 cfs below Parks Creek at RM 34.9. At RM 33.7, Big Springs Creek boosted summer and winter baseflows by 125 cfs, with cumulative summer baseflow estimates from 168 cfs to 193 cfs and winter baseflows between 208 cfs and 273 cfs (higher if including Willow Creek, Julien Creek, groundwater accretion, and miscellaneous springs). The estimate of unimpaired flows below Big Springs does not account for winter diversions from the upper Shasta mainstem into the Edson-Foulke ditch or summer diversions into lower Parks Creek. Also, the mainstem Shasta River may have gained additional groundwater as it meandered across its low-gradient valley. Cool spring-fed baseflows historically dominated the summer months when ambient air temperatures were high.

Winter floods and spring snowmelt were prevalent along the mainstem Shasta River below Big Springs, with short duration winter flows between 600 cfs and 925 cfs and longer duration snowmelt floods from 300 cfs to 425 cfs mostly during April and May.

The Little Shasta River joined the mainstem at RM 16, contributing baseflows to the mainstem (20 cfs to 30 cfs) from runoff and springs and moderate flood peaks (50 cfs to 200 cfs). The Little Shasta River also added an important snowmelt hydrograph of 50 cfs to 100 cfs during April or May of most years. The timing of the snowmelt flood from the Little Shasta River may not necessarily have coincided with the timing of snowmelt from the upper Shasta Basin, but our analysis assumed they were additive. Using the Edgewood and Little Shasta River USGS and CDWR published data and constant spring discharges, daily average annual hydrographs were constructed for seven water years. These hydrographs represent unimpaired estimated mainstem Shasta River streamflows below the Little Shasta River (Figure 11).

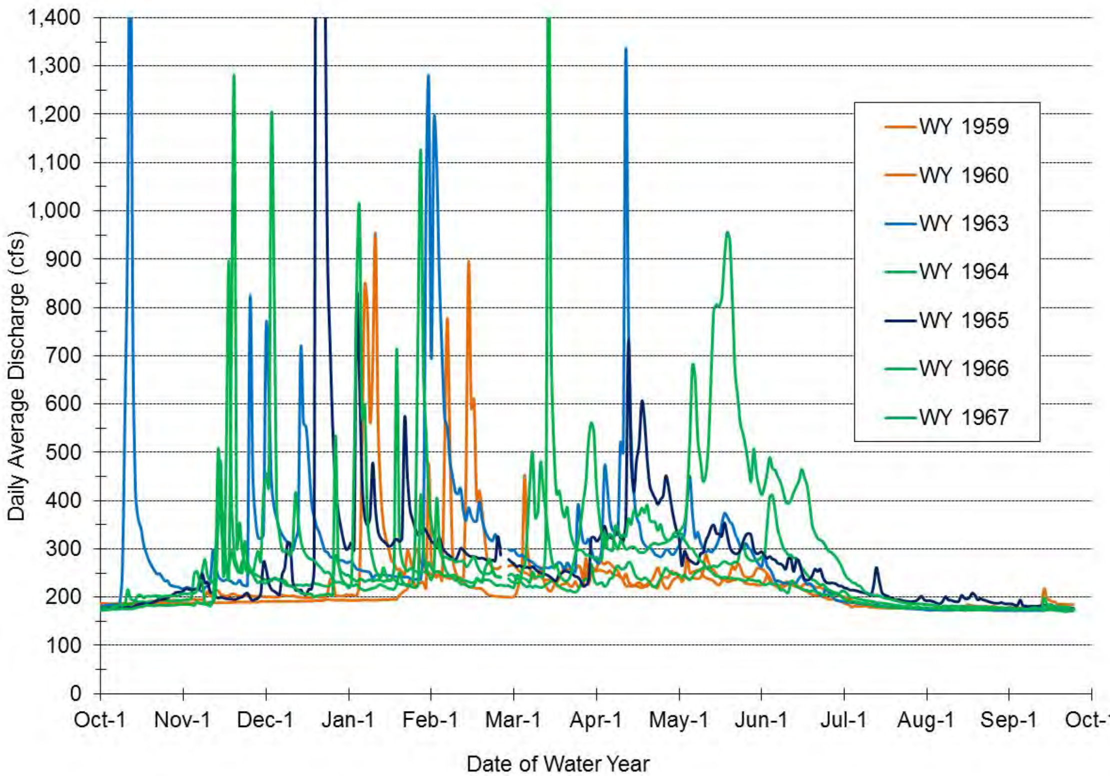

Figure 11. Estimated unimpaired daily average streamflow in the Shasta River below the Little Shasta River (RM 17.6) for the seven water years with overlapping flow data. Annual hydrographs were reconstructed from published USGS Shasta River at Edgewood data, 28 cfs from Carrick and Shasta Springs, 125 cfs year-round discharge from Big Springs, 10 cfs year-round discharge from Little Shasta River springs, and published USGS Little Shasta River near Montague streamflow data.

Finally, at RM 7.8, just before the Shasta River plunges into the mainstem Canyon, Yreka Creek joined, bringing a strong (if relatively infrequent) winter flood component with cumulative peaks in the Shasta Canyon typically from 750 cfs to 1,425 cfs and snowmelt peaks from 375 cfs to 575 cfs. Winter and summer baseflows below the Yreka Creek confluence were conservatively 210 cfs to 305 cfs and 150 cfs to 240 cfs, respectively (Table 2).

2.2.3. Water Year 2000 Unimpaired Model Simulation for Flow and Water Temperature

In addition to unimpaired flow estimates from Deas et al. (2004), the NCRWQCB developed an unimpaired flow and temperature simulation of the Shasta River for WY2000, based on existing models used in the Shasta River TMDL (Deas and Null 2007). Mean monthly unimpaired flows estimated for WY2000 from Deas and Null (2007) compared favorably with seasonal flow estimates described above (Table 3).

Table 3. Mean monthly unimpaired flow estimated for several locations along the mainstem Shasta River for Water Year 2000, from Deas and Null (2007).

Month	Dwinnell Dam (cfs)	Parks Creek (cfs)	Big Springs (cfs)	Little Shasta River (cfs)	Yreka Creek (cfs)	Depletion (cfs)*	Mouth (cfs)**	Mouth Water Balance (cfs)	Difference (cfs)
January	127	112	117	112	30	45	454	453	0
February	177	81	114	80	29	44	437	437	0
March	102	110	111	109	28	42	417	417	0
April	105	52	107	51	20	30	304	305	0
May	96	71	104	49	16	49	244	287	-43
June	65	40	107	30	14	44	218	212	5
July	38	13	111	17	10	31	155	158	-3
August	32	7	114	14	10	31	153	147	6
September	31	6	117	13	13	39	194	143	51
October	21	70	121	69	18	27	272	272	0
November	43	95	124	94	23	34	344	345	0
December	122	88	121	88	27	41	405	405	0

*Losses to groundwater, evaporation, and riparian vegetation evapotranspiration
**CDWR Unimpaired Flow Study

2.3. Diverse Salmonid Life History Tactics

Accommodating diverse salmon and steelhead life history types in the Shasta Basin is a restoration objective central to the Study Plan. Life history types are generally distinguished by the time spent in each life stage. At least three fall-run Chinook salmon life history types within the Klamath Basin can be differentiated by the extent and timing of juveniles rearing in freshwater (Sullivan 1989). Life history types are useful for distinguishing populations, but they do not sufficiently differentiate patterns of watershed use down to the stream-reach scale where many alternative life history patterns exist. A life history tactic (LHT) is a unique pathway in space and time that an annual salmonid cohort follows through successive life stages: adult migration, spawning and egg incubation, early fry emergence, juvenile rearing, and smolt outmigration. Differences between LHTs can be substantial or subtle. Chinook salmon with a Type I life history type rear in freshwater for several months before migrating to the Klamath River by mid-summer (Sullivan 1989). Several Chinook salmon LHTs would be possible with a Type I life history in the Shasta Basin. For example, one LHT would be to rear from egg to pre-smolt in the Shasta Canyon and another would be to rear entirely in the mainstem just downstream of the Parks Creek confluence before outmigrating as smolts. Both LHTs represent Type I life history types, although they differ in rearing location within the basin.

Each LHT is a unique strategy for a cohort of eggs to return as spawning adults. Some LHTs will perform better in drier years, whereas others will be better adapted for wetter years. Given the Shasta Basin's hydrological and geomorphological diversity, many LHTs likely evolved to sustain historically abundant salmon and steelhead populations. Recovering diverse, sustainable salmon and steelhead LHTs within the Shasta Basin is the overall strategy of this Study Plan. If any part of the longitudinal/temporal sequence of habitat availability for a given LHT is/becomes unsuitable, then that LHT cannot succeed and, as a consequence, fewer LHTs must then sustain the basin-wide population.

LHT diversity is an ecological necessity for at least two reasons. It supports a greater abundance by allowing juvenile salmonids to exploit different habitats and resources in unique ways. Second, it enhances long-term stability in the population by spreading the risk and providing redundancy in the face of environmental unpredictability. Resiliency derived from this diversity has been emphasized in salmonid ecology at multiple levels, with the highest level exemplified in the management of Ecologically Significant Units (ESU's) throughout the range of Pacific salmon and steelhead. The NOAA technical analysis of the SONCC ESU population structure focused primarily on two levels of biological diversity: the ESU and the 59 discrete populations comprising the ESU (Williams et al. 2006). Recently, CDFG provided juvenile abundance estimates for eight salmonid cohorts (Chesney et al. 2007):

- Chinook 0+
- Coho 0+
- Coho 1+
- Coho 2+ (rare)
- Steelhead 0+
- Steelhead 1+
- Steelhead 2+
- Steelhead 3+ (rare)

Appendix B describes the life histories of Chinook salmon, coho salmon, and steelhead in the Shasta Basin based on the existing literature and past studies. Appendix C describes their habitat requirements. With these life history patterns and habitat requirements in mind, this Study Plan identifies historical Chinook, coho, and steelhead LHTs in the Shasta Basin before major land and water uses. Then, within these historical LHTs, we identify a subset of existing and recoverable LHTs that are the focus for prioritizing data and information needs for the Shasta Basin (Appendix D).

2.3.1. Historical Shasta River Life History Tactics

At least 25 historical Chinook salmon, coho salmon, and steelhead LHTs sustained the anadromous salmonid population before major land and water developments occurred in the Shasta Basin (Table 4). There were probably considerably more. Re-establishment or recovery of some of these historical LHTs would require major restoration actions, while others could be improved substantially with small to moderate effort.

This Study Plan prioritizes 17 existing and recoverable LHTs, with a detailed description of each in Appendix D. Each LHT description addresses four life history phases: (1) spawning, incubation, and early fry rearing, (2) juvenile spring and summer rearing, (3) juvenile winter rearing, and (4) pre-smolt and smolt emigration (Table 4). Each LHT is also linked to the specific tributary/mainstem reach required by each life history stage. For each of the 17 existing and recoverable LHTs, we provide: (1) a map of the reaches required by the four life stages, (2) a timeline for life stages, (3) a description of the tactic, its population role, reaches of occurrence, and current status, and (4) data and information needed for planning its recovery (Appendix D).

To help describe LHTs and prioritize tasks, anadromous streams within the Shasta Basin were partitioned into 18 reaches, including five mainstem reaches below Dwinnell Dam, one reach above Dwinnell Dam, and two or three reaches in each of four major tributaries. Delineations of reach breaks were based on significant changes in stream morphology or below large diversions and tributary inputs (Table 5 and Figure 12). The region of the mainstem Shasta River referenced as the Big Springs Complex was included for convenience, even though it is a composite of several reaches.

Table 4. Important historical life history tactics for the Shasta Basin.

	Life History Tactics	Spawning/Incubation/ Fry Rearing	Juvenile Spring/ Summer Rearing	Juvenile Winter Rearing	Presmolt/Smolt Emigration
		Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
1	Fall Chinook Canyon 0+ Tactic	Canyon	→ 0+ ENTER KLAMATH		
2	Coho Big Springs Complex 1+ Tactic	Big Springs Complex [2]	Upper Mainstem	→	Mainstem/Canyon [1]
3	Coho Big Springs Complex 0+ Tactic	Big Springs Complex [2]	→ 0+ ENTER KLAMATH		
4	Coho Below Dwinnell Tactic	Below Dwinnell	Below Dwinnell, Big Springs Complex	→	Mainstem/Canyon [1]
5	Steelhead Little Shasta River 1+ Tactic	Little Shasta Headwaters	Lower Little Shasta	→	Mainstem/Canyon [1]
6	Steelhead Little Shasta River 2+ Tactic	Little Shasta Headwaters	→	→	Mainstem/Canyon [1]
7	Coho Parks Creek Headwaters Tactic	Parks Headwaters [3]	→	→	Mainstem/Canyon [1]
8	Coho Lower Parks Creek Tactic	Lower Parks	Lower Parks and Big Springs Complex	→	Mainstem/Canyon [1]
9	Coho Canyon 1+ Tactic	Canyon	→	→	→
10	Coho Middle Little Shasta River Tactic	Middle Little Shasta	→	Lower Little Shasta	Mainstem/Canyon [1]
11	Coho Lower Little Shasta River Headwaters Tactic	Middle Little Shasta	Lower Little Shasta	→	Mainstem/Canyon [1]
12	Fall Chinook Yearling Tactic	Canyon	→	0+ ENTER KLAMATH	
13	Fall Chinook Upper Basin Complex 0+ Tactic	Big Springs Complex [2]	→ 0+ ENTER KLAMATH		
14	Steelhead Upper Basin Complex 1+ and 2+ Tactics	Big Springs Complex [2]	→	→	Mainstem/Canyon [1]
15	Fall Chinook 1+ Tactic	Canyon	→	→	1+ ENTER KLAMATH
16	Coho Shasta Headwaters Tactic	Shasta Headwaters	→	→	Mainstem/Canyon [1]
17	Coho Shasta Headwaters 2+ Tactic	Shasta Headwaters	→	REAR TWO YEARS	Mainstem/Canyon [1]
18	Coho Shasta Headwaters/Mainstem Tactic	Shasta Headwaters	Below Dwinnell, Big Springs Complex	→	Mainstem/Canyon [1]
19	Spring Chinook Tactic	Big Springs Complex [2]	→ 0+ ENTER KLAMATH	→	Mainstem/Canyon [1]
20	Coho Parks Creek Headwaters/Winter Mainstem Tactic	Parks Headwaters [3]	→	Big Springs Complex	Mainstem/Canyon [1]
21	Coho Willow Creek Headwaters Tactic	Willow Creek Headwaters [3]	→	→	Mainstem/Canyon [1]
22	Coho Willow Creek Mainstem Tactic	Willow Creek Headwaters [3]	→	Big Springs Complex	Mainstem/Canyon [1]
23	Steelhead Parks Creek Headwaters 1+ and 2+ Tactics	Parks Headwaters [3]	→	→	Mainstem/Canyon [1]
24	Steelhead Willow Creek Headwaters 1+ and 2+ Tactic	Willow Creek Headwaters [3]	→	→	Mainstem/Canyon [1]
25	Steelhead 3+ Tactic		→	→	REAR THREE YEARS
26	Coho Yreka Creek Mainstem Tactic	Yreka Creek Headwaters	→	→	Mainstem/Canyon [1]
27	Steelhead Yreka Creek Mainstem 1+ Tactic	Yreka Creek Headwaters	→	→	Mainstem/Canyon [1]

[1] Presmolt/Smolt rear in the Mainstem and Canyon during downstream emigration

[2] Big Springs Complex = Upper Mainstem from GID to above Parks Creek, Big Springs Creek, and Lower Parks Creek

Table 5. Shasta River mainstem (1-7) and tributary (8-18) reach designations for life history tactics.

No.	Reach Name	Reach Extents	Reach Length (mi)	River Mile (at upstream boundary)
1	Shasta Foothills	Mainstem from Headwaters to Dwinnell Dam	~12.0	~52.6
2	Below Dwinnell	Mainstem from Dwinnell Dam to Parks Creek	5.7	40.6
3	TNC Shasta Springs	Mainstem from Parks Creek to Big Springs Creek	1.2	34.9
4	TNC Nelson Ranch	Mainstem from Big Springs to Novy Rice Obstruction	7.5	33.7
5	Middle Shasta	Mainstem from Novy Rice Diversion to Little Shasta River	9.9	26.2
6	Lower Shasta	Mainstem from Little Shasta River to Yreka Creek	8.6	17.6
7	Shasta Canyon	Mainstem from Yreka Creek to the Klamath River	7.8	7.8
8	Parks Headwaters	Parks Creek from Headwaters to Base of Foothills	7.9	21.2
9	Parks Foothills	Parks Creek from Foothills to I-5 Crossing	5.0	13.2
10	Parks Bottomlands	Parks Creek from I-5 Crossing to Confluence	8.2	8.2
11	Big Springs	Big Springs from Source to Shasta River Confluence	2.4	2.4
12	Willow Headwaters	Willow Creek from Headwaters to Gazelle	10.4	20.2
13	Willow Bottomlands	Willow Creek from Gazelle to Shasta River Confluence	9.8	9.8
14	Little Shasta Headwaters	Little Shasta River from Headwaters to Dry Gulch	10.1	27.5
15	Little Shasta Foothills	Little Shasta River from Dry Gulch to Blair Hart Diversion	5.6	17.4
16	Little Shasta Bottomlands	Little Shasta River from Blair Hart Diversion to Confluence	11.8	11.8
17	Yreka Headwaters	Yreka Creek from Headwaters to Greenhorn Creek	6.7	12.6
18	Lower Yreka	Yreka Creek from Greenhorn Creek to Confluence	5.8	5.8
	Big Springs Complex	Shasta River from Dwinnell Dam to GID Diversion, Parks Creek from I-5 to Shasta River, Big Springs Creek, and several small Spring Creeks	13.3	13.3

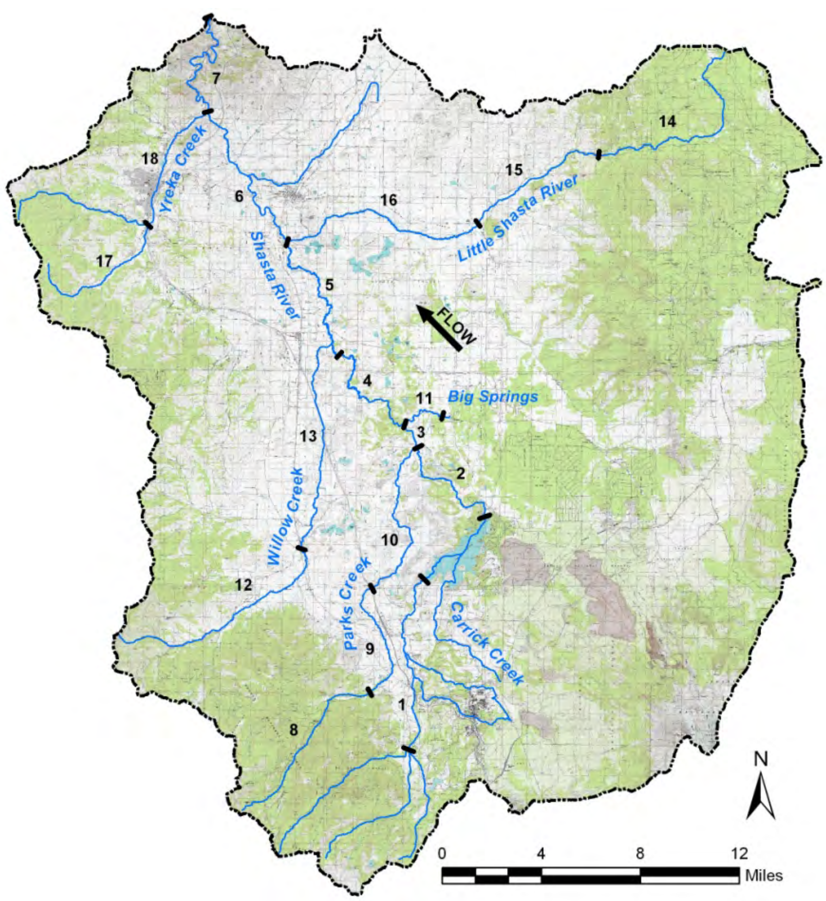

Figure 12. Location of Shasta River mainstem and tributary reaches and reach breaks.

3. CONTEMPORARY STREAMFLOW AND HABITAT CONDITIONS IN THE SHASTA BASIN

Describing historical watershed conditions that promoted abundant salmonid populations is an important step in prioritizing protection and recovery actions. To reiterate an important point, the historical context is provided not to advocate a return to those conditions, but because it provides an understanding of how things used to work, as well as a baseline to contrast current conditions. Several important studies and documents have attempted to describe contemporary streamflow and salmonid habitat conditions in the Shasta Basin. That effort is not repeated here. Instead, background and salmonid habitat information are excerpted relevant to developing tasks in this Study Plan.

3.1. Water Development

From the Biological Needs Assessment (CDFG 1997):

> *Water development within the Shasta basin dates back to the gold rush and the beginning of agricultural development in the late 1800s. Water for irrigation and domestic purposes is obtained from direct diversion of surface flow from the mainstem Shasta River and several tributaries, from the capture of spring discharge, and from groundwater development in some regions of the basin. By the early 1920's appropriated water rights had made claim to most surface flow available during the summer irrigation season, and in 1932 water rights were adjudicated by the State of California Department of Public Works, Division of Water Resources, a seminal document referred to as the Shasta River Adjudication.*
>
> *Dwinnell Dam was constructed in 1928 to capture winter and early spring run-off from the Shasta River and Parks Creek headwaters. The dam had an original storage capacity of approximately 34,000 ac-ft, and was expanded in 1955 to 50,000 ac-ft. Wales (1951) estimated that construction of Dwinnell Dam eliminated access to about 22 percent of the spawning habitat formerly available to salmonids, and approximately 17 percent of the drainage area.*
>
> *Numerous dams and diversions exist or once existed on the Shasta River and major tributaries, including Big Springs Creek, Little Shasta River and Parks Creek. When all diversions are operating, flows are substantially reduced, and in the case of the Little Shasta River, Parks Creek, and Willow Creek, streamflows essentially cease entirely in the lower several miles of stream, during the summer and fall irrigation season.*
>
> *Prior to the construction of Dwinnell Dam, four water service agencies had been formed in the Shasta Valley. The Shasta River Water Association (SRWA) was formed in 1912 and obtained a 1932 water appropriation notice for 42 cubic ft per second (cfs) for the period April 1 through October 1 each year. The SRWA serves the west side of the Shasta Valley near the town of Montague. The Grenada Irrigation District (GID) (formerly known as the Lucerne Water District) was formed in 1916 and has a right to 40 cfs for the period April 1 through October 1. The GID serves about 1,800 acres west of the town of Grenada. Downstream water rights with senior priority preclude GID from using its full entitlement in some years (DFG 1996). The Big Springs Irrigation District has a 30 cfs right for water from Big Springs Lake and serves about 3,600 acres north of the lake. Since the late 1980s, BSID has used ground water in lieu of water diverted from Big Springs Lake because its access to water became increasingly limited by senior demand.*
>
> *The Montague Water Conservation District (MWCD), also known as the Montague Irrigation District, was formed in 1925. As a result of a 1932 adjudication, MWCD obtained appropriative rights for winter storage between October 1 and July 15 of the Shasta River and Parks Creek in Lake Shastina to meet irrigation needs in the Little Shasta Valley and the northeast portion of the Shasta Valley during the April 1 through October 1 irrigation season. Except during above normal water years, when Lake Shastina is full, the only flow releases made to the Shasta River below the dam are those intended to satisfy the needs of several small users immediately*

downstream of the dam. Accounting for evaporative losses and seepage from the reservoir, the 49,000 ac-ft MWCD water right equates to an irrigation season (April 1 to October 1) delivery from Dwinnell Reservoir of >70 cfs.

Since 1934, available water resources in the Shasta River have been apportioned by the California Department of Water Resources (DWR) Watermaster Service in accordance with the 1932 statutory adjudication (Decree No. 7035) (Table 6). However, riparian water users along the Shasta River below Dwinnell Dam were not included in this adjudication and are not regulated by the Watermaster.

Table 6. The primary water right holders in the Shasta Basin and their approximate irrigation season diversions. The MWCD diversion is derived from winter storage and is thus not an estimate of streamflow available in the river during the irrigation season.

Irrigation District	Water Diversion (cfs)
Little Shasta Irrigation District	25
Big Springs Users	20
Shasta Water Association	42
Big Springs Irrigation District	30
Grenada Irrigation District (includes Huseman diversion)	40
Montague Water Conservation District	70
TOTAL	**227**

3.2. Impaired Annual Hydrographs

As described in Section 2.2, the USGS and CDWR have operated several streamflow gages in the Shasta Basin beginning in 1911. However, because streamflow diversions began early, none of the available USGS gaging records portray unimpaired conditions. The California Conservation Commission (1912) cites that Big Springs contributes a minimum approximating 125 cfs, with all the springs in the Big Springs Complex contributing approximately 150 cfs. The gages installed after 1911 document the history of flow regulation in the Shasta River during the irrigation season and the results of flow impoundment by Dwinnell Dam. To highlight the extent of streamflow regulation, daily average hydrographs from the USGS Shasta River near Yreka gage were overlaid on the unimpaired hydrographs presented in Figure 11, for six years of our estimated unimpaired streamflow data (Figure 13). The annual streamflow regulation results primarily from streamflow impoundment at Dwinnell Dam, seasonal irrigation withdrawals from the Shasta River and several principal tributaries, and from winter regulation withdrawals for stock pond storage and other purposes.

The primary changes in streamflows in the Shasta River and tributaries resulting from water management have been elimination of the spring snowmelt flood and reduced summer baseflows. Below Parks Creek (Figure 14) and below Big Springs Creek (Figure 15), the mainstem's typical unimpaired annual snowmelt flood, estimated to be 200 cfs to 300 cfs and 300 cfs to 425 cfs, respectively, would have persisted through April and May of most water years, and into June of many wetter water years. Currently, the start of irrigation season on April 1, combined with capture of snowmelt runoff in Dwinnell Dam, sharply reduces spring baseflows and eliminates most of mainstem's annual snowmelt floods. Spring baseflows under impaired conditions typically range from 50 cfs to 120 cfs. Summer baseflows along the Shasta River mainstem that historically ranged from 170 cfs to 250 cfs of cold baseflow are now reduced to 10 cfs to 40 cfs. In many locations, the mainstem carries a significant volume of warm irrigation drainage water (tailwater).

Owens and Hecht (1998) analyzed changes in streamflow in the Shasta Basin on three time-scales: within-month (daily) alterations, seasonal/annual alterations, and long-term. Evaluating daily average hydrographs from the USGS gage near Yreka, they demonstrated large daily fluctuations in baseflow during the irrigation season. Daily average streamflows at the UGSG gage near Yreka typically fluctuated between 30 cfs to 50 cfs on the low end of the range, and up to 80 cfs to 120 cfs on the upper end, with streamflows steadily declining through the summer and fall irrigation season. Their report also stated that "if the flow fluctuations were plotted on an hourly basis, the magnitude of the fluctuations would be even larger than the fluctuations in the daily average of flow."

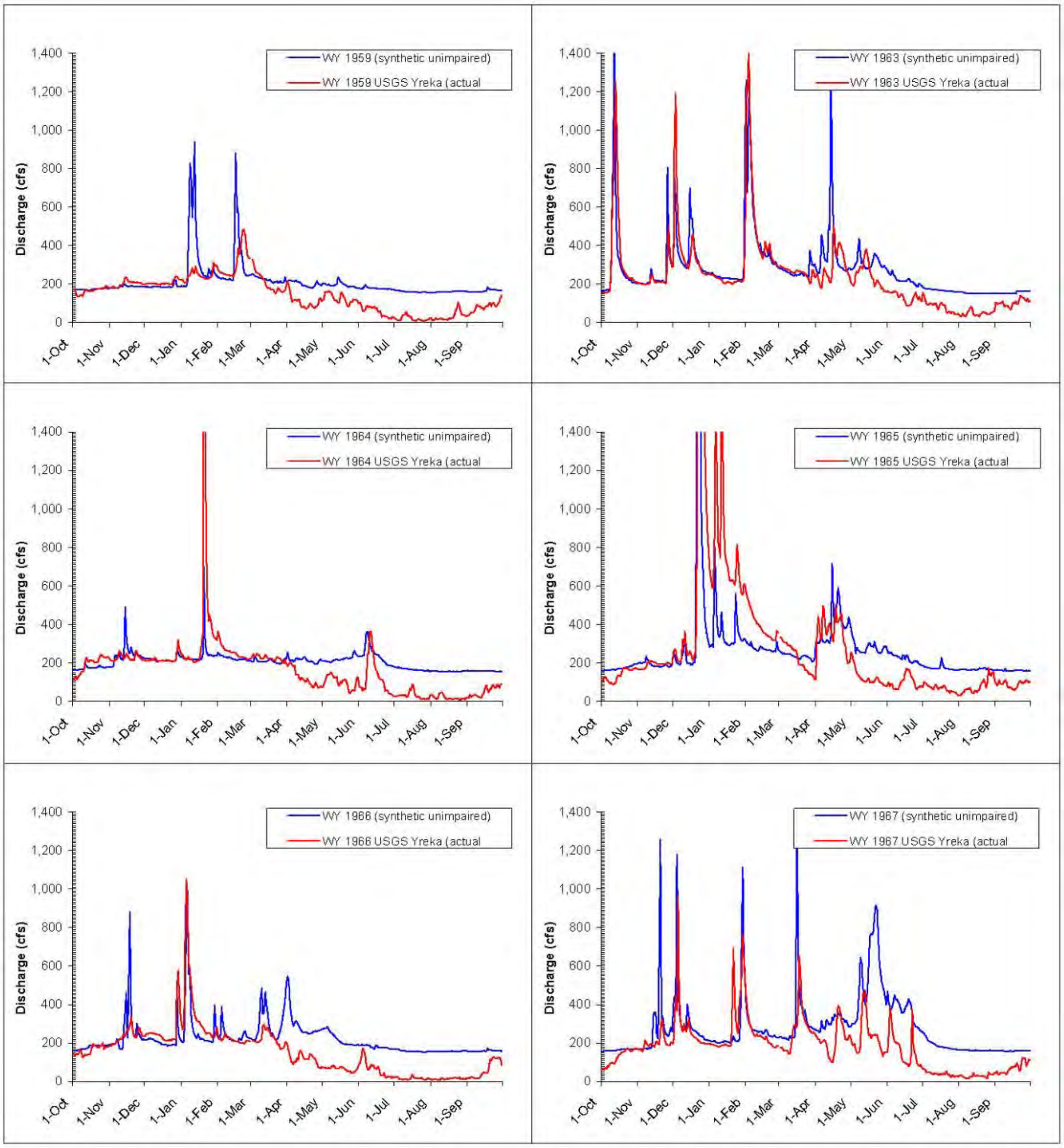

Figure 13. Annual hydrographs for the Shasta River below the Little Shasta River confluence for unimpaired conditions and the USGS Shasta River near Yreka gage with actual regulated (impaired) streamflows. These estimated unimpaired annual hydrographs do not account for daily streamflows from Yreka Creek.

Streamflow diversions for irrigation begins on March 1 and runs through November 1, and the combined diversions for irrigation and domestic uses are most evident during the April to October low-flow period, and are most severe in July and August (Figure 16). Owens and Hecht (1998) estimate that the "evapotranspiration of applied water," which they suggest most closely reflects the magnitude of seasonal flow alterations in the Shasta River, ranges between 59,000 ac-ft and 92,000 ac-ft, which equates to a 6 month dry season daily average loss of approximately 160 cfs to 255 cfs. This estimate is roughly equivalent to our conservative estimate of available summer baseflow at the USGS gaging station near

Yreka (i.e., 150 cfs to 240 cfs below Yreka Creek in Table 2). Owens and Hecht (1998) note that water demand is irregular throughout the irrigation season, thus resulting in observed fluctuations in monthly flows.

Figure 14. Shasta River just downstream of the confluence of Parks Creek (RM 34.8). This reach has partially maintained an alluvial channel and provides abundant salmonid spawning habitat. Photo taken July 19, 2010, at 34 cfs.

Figure 15. Lower Big Springs Creek approximately 4,000 ft upstream of its Shasta River confluence. Aquatic macrophytes provide extensive cover throughout Big Springs Creek. Photo taken June 23, 2010, at approximately 70 cfs.

Long-term changes in streamflow in the Shasta Basin are difficult to estimate for several reasons. First, most diversions predate most gaging operations. Also, much of the past gaging and flow data collection by CDWR (e.g., Watermaster records, etc.) that could describe changes in flows have been kept seasonally, not annually. Additionally, CDWR records are not as easily available as USGS records. From a long-term perspective, alterations in streamflow have steadily increased over the past century (or more) as water demand increased. However, CDWR (1964) estimated "natural runoff" for the Shasta Basin for a 35-yr base period from 1920 to 1955 at approximately 162,300 ac-ft. A more recent CDWR unpublished memorandum (CDWR 1998) estimated the Shasta River "full natural flow" as approximately 218,800 ac-ft. Owens and Hecht (1998) compared the CDWR 1964 unimpaired estimate to USGS measured streamflows and concluded the long-term flow alteration of 66,500 ac-ft applied during the six month irrigation season was approximately 183 cfs. Comparing the CDWR (1998) full natural flow estimate (218,800 ac-ft) to USGS measured flow (132,800 ac-ft) gives a long-term flow alteration of 86,000 ac-ft, which equates to a six month irrigation season average withdrawal of 233 cfs. These calculations do not account for the portion of diverted irrigation water then returned to the river as agricultural return flow (tailwater).

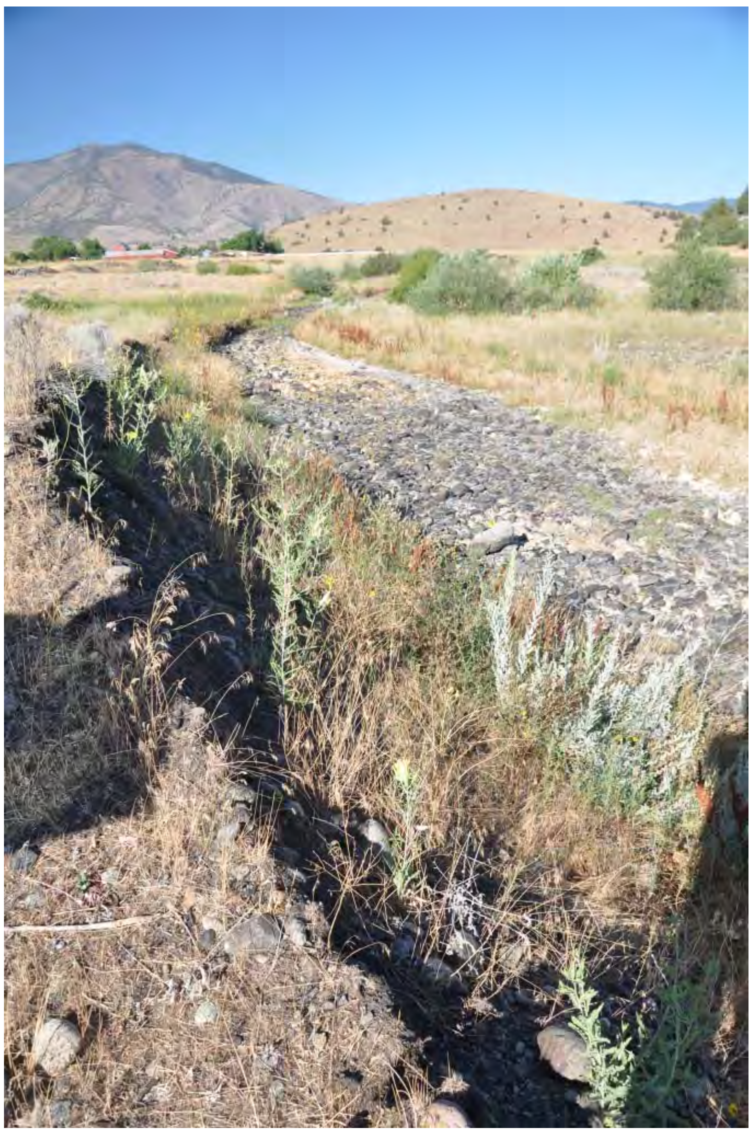

Figure 16. Upper Parks Creek downstream of Slough Road Bridge below I-5 (RM 7.8) in late-August 2010. Several miles of Parks Creek are dry or unsuitable for salmonids during the summer irrigation season.

3.3. Water Temperature Conditions

Assessing changes in seasonal water temperature regimes in the Shasta Basin has been much more challenging than assessing flow changes. According to Deas et al. (2004), "It is not possible to estimate the temperature regime of the Shasta River in the same manner that was used for estimating unimpaired flow. There are not historic data that extend back to the early 1900's. Instead, estimation of the temperature regime requires extrapolating information from existing conditions as well as utilizing existing model simulations."

The NCRWQCB implemented a temperature and dissolved oxygen TMDL study (NCRWQCB 2006). Several resulting documents describe in detail the contemporary water temperature conditions in the Shasta River mainstem and several tributary reaches. Segments of those reports are cited here.

From NCRWQCB (2006) Chapter 1: Overview and Geographic Scope of TMDL:

> *In accordance with Clean Water Act Section 303(d), the State of California periodically identifies those waters that are not meeting water quality standards. The State of California has determined that the water quality standards for the Shasta River are not being achieved due to elevated water temperature and organic enrichment/low dissolved oxygen concentrations. The United States Environmental Protection Agency (USEPA) added the Shasta River watershed to California's 303(d) List of Impaired Waters (303(d) List) in 1992 due to organic enrichment/low dissolved oxygen and in 1994 due to elevated temperature. The Shasta River watershed has continued to be identified as impaired in subsequent 303(d) listing cycles, the latest in 2002. These listings of the Shasta River watershed apply to the Shasta River from its mouth to headwaters, and include all tributaries and Lake Shastina. The Shasta River Total Maximum Daily Loads (TMDLs) for Temperature and Dissolved Oxygen were being established in accordance with Section 303(d) of the federal Clean Water Act (CWA).*

These listings were confirmed in the TMDL analysis for the Shasta River, its tributaries, and Lake Shastina. Dissolved oxygen concentrations were regularly too low to comply with the Basin Plan dissolved oxygen objectives, and water temperature conditions regularly exceeded temperature thresholds protective of salmonids. The designated beneficial uses that are not fully supported include: cold freshwater habitat; rare, threatened, and endangered species; migration of aquatic organisms; spawning, reproduction, and/or early development of fish, commercial and sport fishing; and contact and non-contact water recreation. The designated beneficial uses associated with the cold freshwater salmonid are the designated beneficial uses most sensitive to the dissolved oxygen and water temperature impairments. Important species in the Shasta River watershed include coho salmon, Chinook salmon, trout, and lamprey (NCWQCB 2006).

The collection of Staff Report chapters and appendices thoroughly describes existing water temperature conditions in the basin and corresponding adverse impacts to anadromous salmonid populations. Chapter 2 of the Regional Board Staff Report provides a thorough description of the water temperature problem in the Shasta River. Additional information from the Staff Report is presented in the following section.

3.3.1. Shasta River Temperature Profile

In July 2003, the NCRWQCB commissioned an airborne thermal infrared remote (TIR) sensing survey on selected streams in the Shasta Basin, to characterize spatial water temperature patterns in the basin (Watershed Sciences 2003). The Shasta River TIR and aerial photo imagery data were collected on July 26 and 27, 2003. The imagery and temperature data sets were used to support the NCRWQCB's total maximum daily load (TMDL) studies and temperature modeling efforts. TIR data measure surface water temperatures, which represent the water surface temperature, but do not measure subsurface water temperatures where stratification occurs. The water temperature data only represent a snapshot in time, i.e., the result of a unique set of daily streamflow and ambient temperature (climatic) conditions that may or may not be the norm or representative of most water temperature conditions. TIR-derived temperatures are generally within a desired accuracy of 0.5°C.

Rather than paraphrase, an excerpt from Shasta River TIR Final Report (Watershed Sciences 2003) is provided here, concluding with several questions that provide a basis for prioritizing subsequent temperature study recommendations:

> *At the upstream end of the survey, water temperatures in the Shasta River were shaped in part by surface inflows. At river mile 39.4 [Figure 17], a spring lowered stream temperatures in the Shasta River from 22.5°C to 19.3°C. Stream temperatures warmed rapidly downstream of the spring before exhibiting an overall cooling trend of 4.0°C between river miles 37.2 and 35.8. The source of the apparent cooling was not directly apparent from the imagery. However, the sharp decrease in water temperatures over a relatively short distance suggests a cooling influence. Moving downstream, Parks Creek was a source of warm water at river mile 34.8 and increased mainstem temperatures by 1.7°C. The warm inflow came from the southern channel of Parks Creek while the northern channel did not contain enough flow to obtain a radiant temperature sample.*
>
> *Downstream of Parks Creek, water temperatures in the Shasta River showed reach scale thermal patterns, but no longer exhibited dramatic response to detected inflows (i.e. tributaries, springs, etc). Local variability along the longitudinal profile was generally characteristic of the ±0.5°C noise common to TIR remote sensing. A slight cooling trend was observed between river mile 33.7 and 30.3. The general cooling trend was observed downstream of the confluence with Big Spring Creek although radiant temperatures at the mouth of Big Spring Creek did not vary significantly from those in the Shasta River [Figure 18]. Longitudinal heating was observed between river miles 30.3 and 23.5 and again between river mile 16.4 and the Klamath River confluence. A consistent water temperature of 23.0°C was observed between river miles 23.5 and 16.4. Given the warm air temperatures (~36°C) and general exposure of the stream surface to direct solar loading, a constant water temperature or cooling through a given stream segment suggests a buffering or cooling source within that reach.*
>
> 1. *The patterns provide a spatial context for analysis of seasonal temperature data from in-stream data loggers and for future deployment and distribution of in-stream monitoring stations. How does the temperature profile relate to seasonal temperature extremes? Are local temperature minimums consistent throughout the summer and among years?*
> 2. *The database provides a method to develop detailed maps and to combine the information with other spatial data sets. Additional data sets may include factors that influence heating rates such as stream gradient, elevation and aspect, vegetation, and land-use. In viewing the temperature patterns in relation to other spatial factors, correlations are often apparent that provide a better understanding of factors driving temperature patterns at different spatial scales. What are these spatial patterns?*
> 3. *What is the temperature pattern within critical reach and sub-reach areas? Are there thermal refugia within these reaches used by cold water fish species during the summer months? Do cool water tributaries represent potential thermal refugia? What is the availability/extent of the cool water habitat represented by these sources?*

3.4. Water Quality Standards

The following section is presented from the NCRWQCB (2006) Shasta River TMDL Staff Report, Chapter 2: Problem Statement:

> *In accordance with the federal Clean Water Act, TMDLs are set at a level necessary to achieve applicable water quality standards. California's water quality standards include designated beneficial uses, narrative or numeric water quality objectives established to protect those uses, and antidegradation policies and prohibitions. This section describes the state water quality standards applicable to the Shasta Basin.*

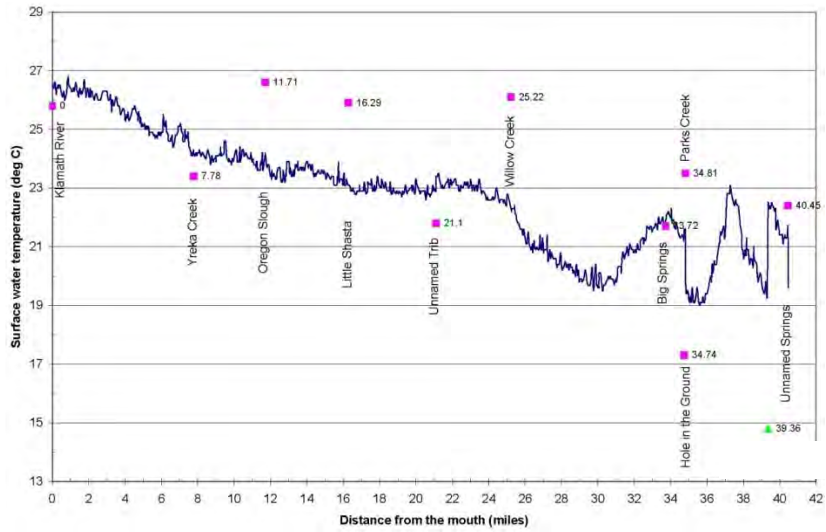

Figure 17. Median radiant temperature versus river mile for the Shasta River mainstem (solid blue line) and tributaries (pink squares) measured on July 26, 2003.The pink squares provide water temperatures (corresponding to the Y-axis) for tributary streams that enter the mainstem at the given river mile.

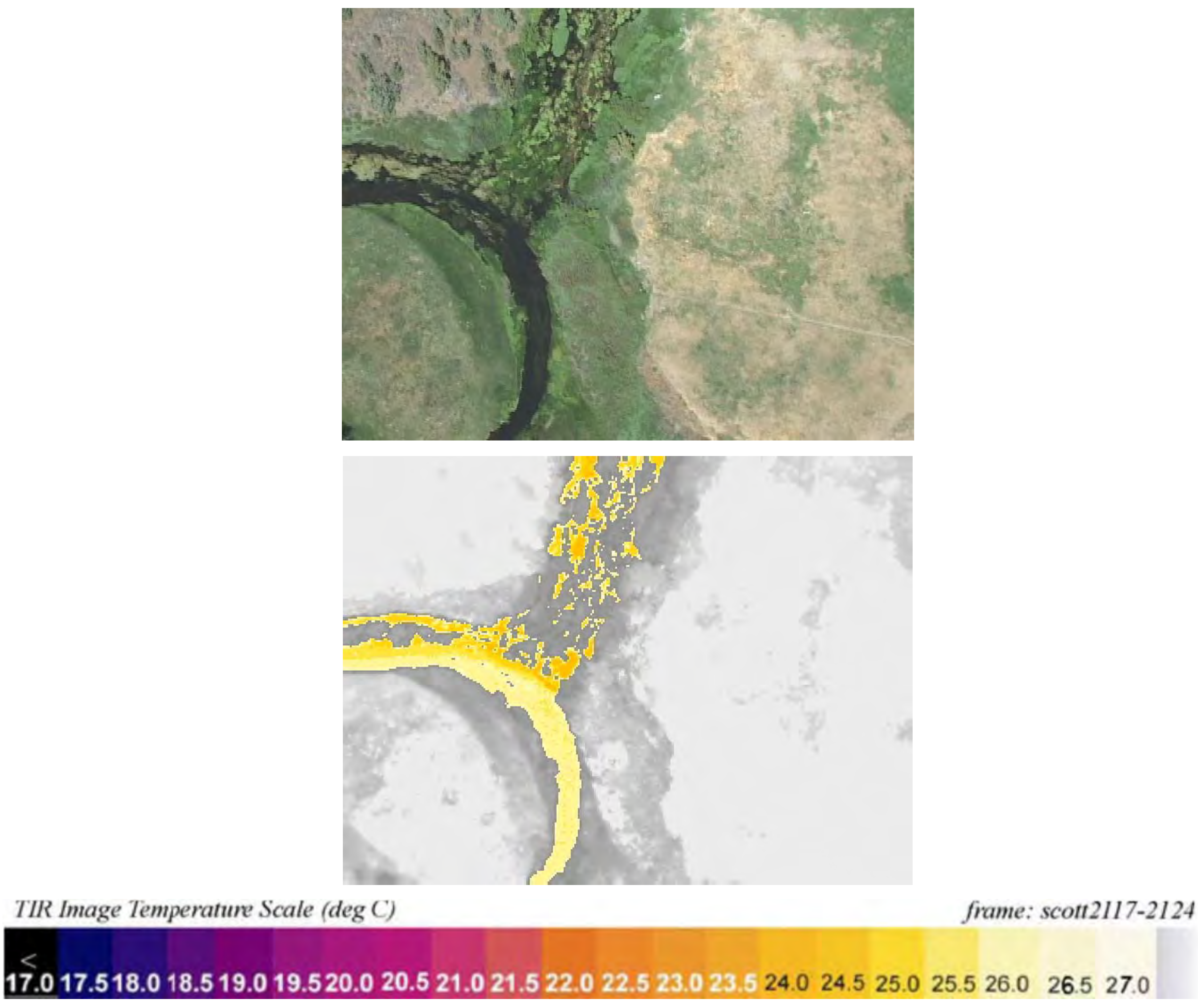

Figure 18. Aerial (top) and TIR imagery (bottom) from the Shasta River TIR study, at the confluence of Big Springs Creek with the mainstem Shasta River. Water temperatures ranged from 24-25°C and 25-26°C in Big Springs Creek and the mainstem, respectively.

3.4.1. Beneficial Uses

Existing and potential beneficial uses for the Shasta Basin are identified in the Water Quality Control Plan for the North Coast Region (Basin Plan) (NCRWQCB 2005)... The Shasta River Hydrologic Area is divided into three sections – Shasta River and tributaries, Lake Shastina, and Lake Shastina Tributaries; each with their designated beneficial uses.

3.4.2. Water Quality Objectives

The Basin Plan identifies both numeric and narrative water quality objectives for the Shasta River HA. These water quality objectives are developed to ensure protection of all beneficial uses. [Table 7] summarizes water quality objectives applicable to the Shasta River temperature and dissolved oxygen TMDLs. The biostimulatory substances narrative objective refers to any substance that promotes aquatic plant growth. Because photosynthesis and respiration of aquatic plants in the Shasta River affect dissolved oxygen concentrations, the biostimulatory substances objective is applicable to the dissolved oxygen TMDL. Similarly, pH is affected by the same processes that affect dissolved oxygen, most notably photosynthesis and respiration of aquatic plants.

The dissolved oxygen objective has two components, a minimum dissolved oxygen concentration and a 50% lower limit. The 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. In other words, 50% or more of the monthly means must be greater than or equal to a lower limit.The NCRWQCB's region-wide (including Shasta River) dissolved oxygen objectives are currently in the process of being reviewed/revised, so may change in upcoming years (http://www.swrcb.ca.gov/northcoast/water_issues/programs/basin_plan/dissolved_oxygen_amendment.shtml).

Table 7. Table 2.2 of the NCRWQCB Shasta River TMDL Staff Report, describing narrative and numeric water quality objectives applicable to the Shasta Basin TMDLs.

NARRATIVE OBJECTIVES	
Region-wide Objectives	
Objective	**Description**
Biostimulatory Substances	Waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.
Temperature	The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of any COLD or WARM intrastate water be increased more than 5°F above natural receiving water temperature.

NUMERIC OBJECTIVES				
Shasta Valley Hydrologic Area	**Dissolved Oxygen (mg/l)**		**Hydrogen Ion (pH)**	
	Minimum	**50% lower limit**[1]	**Maximum**	**Minimum**
Shasta River	7.0	9.0	8.5	7.0
Other Streams	7.0	9.0	8.5	7.0
Lake Shastina	6.0	9.0	8.5	7.0

[1] 50% lower limits represent the 50 percentile values of the monthly means for a calendar year. 50% or more of the monthly means must be greater than or equal to a lower limit.

In addition to narrative and numeric water quality objectives, the Basin Plan of the North Coast Region contains a provision for "controllable factors." This provision makes it a violation of the Basin Plan to discharge pollutants from controllable factors into an already impaired waterbody. The controllable factors provision is outlined below:

Controllable water quality factors shall conform to the water quality objectives contained herein. When other factors result in the degradation of water quality beyond the levels or limits established herein as water quality objectives, then controllable factors shall not cause further degradation of water quality. Controllable water quality factors are those actions, conditions, or circumstances resulting from man's activities that may influence the quality of the waters of the State and that may be reasonably controlled (NCRWQCB 2005).

This provision requires that controllable factors must be used to prevent the further degradation of water quality in areas where the water quality objectives (including the antidegradation policies and beneficial uses) are not being met or supported. In areas where the degradation of water quality beyond the levels or limits established in the Basin Plan have already occurred, no further degradation of water quality from controllable factors is allowed by this provision.

3.5. Fish Health in the Klamath and Shasta Rivers

Fish health on the Shasta River and Klamath River is one of the biggest challenges to population recovery, particularly when infection rates by parasites are high and water quality is low. A good summary of fish health on the Klamath and Shasta Rivers is provided by Dr. Jerri Bartholomew at Oregon State University (http://microbiology.science.oregonstate.edu/Klamath_River_salmon). The Klamath River Fish Habitat Assessment Program partners ranked fish health as one of the highest priorities for research and monitoring in the Klamath Basin. Subsequent research by Oregon State University, USFWS, and Yurok and Karuk tribes in 2009 and 2010 provides a finer resolution to parasite presence and distribution within the 44 mile-long 'highly infectious zone' of the Klamath River, from approximately the Shasta River (RM 174) downstream to Seiad Valley (RM 129) (Hallett et al. 2009). Monthly water samples for *Ceratomyxa shasta* DNA extractions were collected at 16 sites in 2009 and 25 sites in 2010 through the spring outmigration period (April-June). In all sampling events during 2009, *C. shasta* abundance exceeded the 10 spore per liter (spore/L) estimated threshold for salmonid infection. However, the spring 2010 water samples resulted in much lower parasite densities than observed in the 2009 samples, only exceeding the 10 spore/L threshold in a short localized 'hot zone' near the Scott River confluence (RM 141). In addition, the 2009 samples had the highest densities during May and generally decreased through the spring, whereas in 2010 this trend was reversed, with the April samples showing the lowest densities and June the highest densities.

The population level impacts of the Klamath River *C. shasta* infections on Shasta River Chinook and coho stocks are unknown. However, given the timing of Shasta River juvenile outmigration and the rates and timing of infection observed from the sentinel sites and water samples below the Shasta River confluence, significant mortalities are likely during some years. While the Shasta River is not a source of the infectious actinospore stage of the parasite (Stocking and Bartholomew 2007), returning Shasta River adults are likely contributors of the myxospores that infect the polychaete host within the Klamath River.

3.6. Contemporary Salmonid Habitat Studies

Several completed and ongoing studies have provided valuable insights into the condition of aquatic habitat in the Shasta Basin.

3.6.1. Instream Flow Needs (IFNs) Studies

CDFG initiated instream flow needs studies in 2006, with the goal of developing instream flows adequate to maintain fish in good condition pursuant to Fish and Game Code Sections 1603, 5901, and 5937. In addition, instream flow studies have been identified as a high priority action for coho salmon recovery and protection (CDFG 2004 and 2009), as well as Chinook salmon and steelhead populations (CDFG 1997, SRCRMP 1997). Recent CDFG studies will help identify higher priority LHTs, and consequently help focus IFN studies (Chesney and Knechtle 2010 and 2011; Chesney et al. 2010; Daniels et al. 2011). In 2010, in support of the recent Incidental Take Permit process, the Ocean Protection Council funded an IFN study at two locations within the Shasta Basin. At the first location, an analysis was performed to develop *Interim* IFN recommendations for five reaches (Figure 12 Reaches 2, 3, 4, 10, and 11) in the Shasta Basin referred to as the Big Springs Complex (McBain & Trush and HSU 2011). The second location, the Shasta River Canyon (Figure 12 Reach 7), and a more intensive habitat modeling effort was conducted (McBain & Trush and HSU in review). Both reports are progressing through a two tiered review process; the first by CDFG technical and field staff, and a second independent peer review by the California Ocean Science Trust following their peer review Policy 5.2.12 (OST 2012).

In summer 2011, CDFG initiated a phased approach to an instream flow study that will rely on a multidisciplinary, transparent, and collaborative process that will lead towards the development of the long-term instream flow requirements for the Shasta River and significant tributaries. This effort will follow the basic steps of the instream flow incremental methodology approach described by Stalnaker et al. (1995), as summarized below:

1. <u>Problem Identification and Diagnosis</u> – including a legal and institutional analysis, project goals, stakeholder involvement and collaboration, project schedule and timelines, project boundaries, existing data and information review, and baseline conditions.
2. <u>Study Planning and Objectives</u> – including target species and management objectives, products, choice of models, schedules/deadlines, resources and budget.
3. <u>Study Implementation</u> – including microhabitat suitability criteria, channel structure, hydraulics and hydrology microhabitat structure, water temperature, water quality and macrohabitat suitability criteria, as well as other evaluations deemed necessary.
4. <u>Analysis of Alternatives</u> – based on total habitat, alternative flow regimes, and other potential limiting factors.
5. <u>Resolution</u> – based on negotiation of total habitat, alternative flow regimes, and other limiting factors, including but not limited to environmental flow recommendations.

Environmental flow recommendations will either (1) be directly developed by the State, or (2) by a technical expert or team of technical experts and/or stakeholders as directed by the State. These recommendations will likely prove useful to CDFG in implementing the Fish and Game Code, as well as for the transmittal to the State Board for consideration in water rights decisions as set forth in 1257.5 of the Water Code and pursuant to the Public Resources Code Sections 10000-10005.

3.6.2. <u>Spawning Habitat Evaluations</u>

Nearly a century of sediment supply disruption and streamflow regulation have significantly altered the quantity and quality of spawning gravel available to salmon and steelhead within critically important spawning reaches of the Shasta Basin (e.g., Shasta River below Dwinnell Dam to Parks Creek, Parks Creek below the MWCD Diversion, Yreka Creek below Greenhorn Dam, and Shasta Canyon below the Yreka Creek confluence). Impairment to sediment supply and streamflow has direct and adverse consequences for current anadromous salmonid population production and recovery.

Gravel inventories and augmentation efforts in the Shasta Basin have occurred, most notably by CDWR in the early-1980's (Buer 1981) that focused on the Shasta Canyon reach. These efforts were successful at attracting spawning salmonids, but were seldom replenished with gravel, if at all. As a result, habitat benefits in the Shasta Canyon have probably diminished since the majority of augmented spawning gravels have dispersed downstream (McBain & Trush 2010). Additionally, gravels immediately below Dwinnell Dam have been colonized by riparian, herbaceous, and aquatic vegetation as the channel has narrowed, with remaining gravels accumulating with fine sediment. Spawning salmonids provide gravel cleansing and improved intra-gravel water flow during the process of digging redds; fine sediments are exposed and transported downstream, and the topography of the redd itself facilitates water flowing through the redd and egg pocket. Despite this cleansing process by spawning salmonids, the lack of gravel mobilizing flows has continued to allow fine sediment accumulation and channel narrowing in the Big Springs Complex (M&T 2010), with diminishing effect in the Canyon reach.

Several recent planning documents have identified the need for spawning gravel assessments. The Shasta River Watershed Restoration Plan (SVRCD 1997) recommended a detailed assessment of spawning gravel conditions and development of a gravel implementation plan. The Coho Salmon Recovery Plan (CDFG 2004) recommended preparation of a gravel budget for the watershed as a high priority task (Shasta HM-3a). The SVRCD and CDFG identified the need to develop and implement a Spawning Gravel Enhancement Plan for the Shasta Basin. The Spawning Gravel Enhancement Plan evaluated the quantity, quality, distribution, and sources of existing coarse sediment and spawning gravel supplies in the portions of the Shasta River and its major tributaries that were accessible to salmonids and/or provided gravel supply to areas accessible to salmonids (McBain & Trush 2010). The study initiated an assessment of whether geomorphic processes are impaired to the extent that spawning gravel mobility is currently limited, and whether coho and Chinook salmon spawning habitat may be enhanced by gravel augmentation. The study focused on gravel supply and storage based on prioritized reaches having known coho and Chinook salmon spawning in the mainstem Shasta River and its tributaries. Primary study components were: (1) spawning gravel supply evaluations to provide understanding of historical and contemporary spawning gravel source areas, (2) monitoring and modeling spawning gravel dynamics to link geomorphic processes of bed mobility and bed scour to streamflow thresholds, (3) spawning gravel inventories to document spawning gravel availability within primary reaches, and (4) strategic plans for enhancing spawning gravel supply and spawning habitat for specific coho and Chinook salmon LHTs.

3.6.3. Livestock Exclusion Fencing from Riparian Zone

Initial efforts focused primarily on installing riparian fencing to stabilize stream banks and protect riparian areas from livestock damage. Over the years, the SVRCD has assisted numerous landowners with installing riparian fencing. Benefits for the Shasta River include improving water temperature, lowering nutrient levels, increasing dissolved oxygen levels, and reducing erosion. A riparian fencing monitoring project by the SVRCD and Ecosystems Northwest collected data along the Shasta River and Little Shasta River where riparian zones are already fenced to limit cattle grazing (Mattson 2008). The project determined the effectiveness of riparian fencing and measured the aquatic habitat response to livestock exclusion (Table 8).

Mattson (2008) concluded that, regardless of the presence of riparian fencing, most of the Shasta River mainstem lacks structural cover. Without healthy riparian vegetation corridors, such as at the Freeman and Himmel-Fiock sites, there was only a minor volume of woody material available to enhance aquatic habitat. Although streambanks had some erosion, banks were not typically undercut sufficiently to provide significant juvenile salmonid habitat. Submerged aquatic vegetation covered at least 50% or more of the channel bottom, but larger fish did not appear to associate with this cover type.

Recently there has been renewed effort to install riparian fencing in areas that are critical to coho salmon rearing. The Shasta Working Group formed a riparian fencing committee in April 2010 to oversee prioritization, funding acquisition, and implementation of riparian fencing projects. They have been focusing primarily on the Big Springs Complex and the Nelson Ranch. As of spring 2011, riparian fencing is ongoing, funded, and/or completed in most of the following reaches:

- Shasta River below Dwinnell Dam (Reach 2) is entirely fenced from the EII Property boundary (RM 37.5) downstream to the confluence with Parks Creek (RM 34.9). Upper segments of this reach (Hidden Valley Ranch and Seldom Seen Ranch) have not been completed.
- Parks Creek (Reach 10) is mostly fenced from the Shasta River confluence (RM 0) upstream to I-5 (RM 8.2), including most of Kettle Springs Creek. Several notable exceptions are slated to be completed soon, including the Cardoza diversion on Parks Creek, the confluence of Kettle Creek and Parks Creek, Bridgefield and Black Meadow Sloughs, and short segments between Slough Bridge and I-5.
- All reaches on TNC properties (Reaches 3, 4, and 11), with the exception of ~1,000 ft on Nelson Ranch, are fenced. The Shasta River downstream of Parks Creek (Reach 3) is fenced with a generous floodway corridor up to several hundred feet wide on each side of the river. Big Springs Creek is similarly completed with a wide riparian corridor. Several phases of riparian vegetation planting have occurred in Reaches 3 and 11.

Riparian widths associated with the present placement of livestock exclusion fencing vary between the individual private landowners. Some fencing projects hold tightly against the active channel, while others may extend beyond the bankfull width. However, every cattle exclusion project is the result of a successful negotiation between an individual private landowner and the project proponent.

Table 8. Riparian fencing study sites visited on the Shasta River and Little Shasta River (Mattson 2008). "Intensive" monitoring included quantitative measures of stream channel and fish habitat, riparian vegetation regrowth and tree establishment, presence and abundance of aquatic organisms, and water chemistry. 'Extensive' monitoring included visual observations of riparian vegetation development, fencing condition, streambank erosion, and other aquatic activity.

Site Name	River	River Mile	Monitoring Strategy	Years Fenced
Salmon Heaven	Shasta River	6	extensive	Not Grazed
Peters	Shasta River	9	extensive	14
Lower Fiock	Shasta River	10	extensive	12
Upper Fiock	Shasta River	11	extensive	14
Manley	Shasta River	11	extensive	1
Tony Lemos	Shasta River	12	extensive	0
Norman Fiock	Shasta River	12	extensive	12
Easton Shasta	Shasta River	15	extensive	15
DS of Easton	Shasta River	15	extensive	0
Meamber	Shasta River	16	extensive	15
Kuck	Shasta River	16	extensive	6
Banhart	Shasta River	18	extensive	0
TNC	Shasta River	31	extensive	1
Kuck	Little Shasta River	0	extensive	0
Shasta Wildlife	Little Shasta River	4	extensive	15
Shasta Wildlife	Little Shasta River	5	extensive	15
Cowley	Little Shasta River	12	extensive	7
Dutra	Little Shasta River	14	extensive	10
Himmel/Fiock	Shasta River	12	intensive	10
Lemos	Shasta River	13	intensive	25*
Meamber	Shasta River	15	intensive	14
Freeman	Shasta River	20	intensive	12
Root/Nicolletti	Shasta River	21	intensive	3
Eckstrom	Shasta River	21	intensive	13
Marion	Shasta River	22	intensive	2

* Lemos site was not fenced but instead appeared to be effectively protected by the Lewis Ditch for at least 25 years according to landowner.

3.6.4. Priority Actions for Restoration of the Shasta River: Deas et al. (2004) Technical Report

A technical report was prepared for TNC by Watercourse Engineering, Inc. and U.C. Davis Center for Watershed Sciences (Deas et al. 2004) to evaluate flow and temperature of the Shasta River and help identify a short-list of priority actions in the Shasta Basin for restoring anadromous fishes. The Shasta River between Dwinnell Dam and the mouth was divided into six mainstem reaches and three tributary reaches (Little Shasta River, Parks Creek, and the Shasta River above Dwinnell Dam) to identify impacts from local changes in flow and water temperature.

While their report focused on flow and water temperature conditions, Deas et al. (2004) concluded that anadromous fish populations have been reduced in the Shasta River through a combination of processes and factors, and that many of the impacts continue to affect current populations (Table 9).

Table 9. Limiting factors for anadromous fish in the Shasta River (reproduced from Deas et al. 2004).

Limiting Factors	Mainstem	Tributaries
Migration Barriers		
Dams, weirs, diversion structures	x	x
Low-flow blockage	x	x
Thermal barriers	x	x
Hydrologic Changes		
Low summer and fall flows	x	x
Reduced peak winter flows	o	-
Reduced spring flows due to diversions	o	o
Reduced base-flow support from groundwater	x	x
Water Quality		
High temperatures	x	x
Low dissolved oxygen	x	x
pH, alkalinity, dissolved oxygen	-	-
Suspended solids	-	-
Geomorphology		
Loss of spawning gravel	x	o
Fine sediment deposition	x	x
Channel aggradation and instability	x	o
Reduced in-stream cover	x	o
Loss of riparian cover	x	x
Land Use Constraints		
Timber management practices	-	o
grazing and pasture in riparian areas	x	x
Grazing in upslope areas	-	o
Management of fuels	-	o
Land conversion to agriculture	x	x
Unscreened diversions	x	x
Tailwater return flows	x	-
Water development	x	x
Urbanization	o	o

Abbreviations:
o common and of moderate concern or significance
x widespread or important
probably not a limiting factor
Adapted from NAS (2004)

3.6.5. Studies on Nelson Ranch and Shasta Big Springs Ranch

Within six years, TNC purchased two important working ranches strategically located along the upper Shasta River. The 1,704-ac Nelson Ranch, purchased in 2005, is located along the mainstem Shasta River eight miles downstream of Dwinnell Dam, encompassing nearly five river miles (RM 26.8 to RM 31.9). Bordering the Nelson Ranch to the south (Figure 19), the 4,534-ac Shasta Big Springs Ranch was purchased in 2009. This property is clearly a centerpiece for salmonid recovery in the upper Shasta River. The Shasta Big Springs Ranch contains an additional three miles of the upper Shasta River contiguous with the Nelson Ranch upstream to the Parks Creek confluence (RM 34.9), as well as 2.2 miles of Big Springs Creek (Figure 19).

TNC riparian ecologists, the U.C. Davis Center for Watershed Sciences, and Watercourse Engineering Inc. have been investigating the mainstem Shasta River and Big Springs Creek for several years. The first phase of study assessed physical and biological factors affecting salmonids on the Nelson Ranch below the Big Springs confluence (Jeffres et al. 2008). The focus of this effort was to document a "year-in-the-life" of Shasta River aquatic ecology and to further refine factors suspected to limit salmonids during different life stages. The study included surveys of channel cross sections and longitudinal profiles, planform mapping of geomorphic features and aquatic habitat, direct observation surveys of seasonal salmonid rearing patterns, benthic macroinvertebrate studies, and riparian and aquatic vegetation studies. The first-year study was concluded, but additional studies are ongoing.

Rather than paraphrase their results, key observations provided at the conclusion of their study (Jeffres et al. 2008) are excerpted below:

- *Current hydrologic conditions on the Nelson Ranch are significantly affected by upstream water resource development and operations, including the impoundment of Lake Shastina by Dwinnell Dam, Parks Creek diversions to meet MWCD demands, and upstream irrigation practices in lands adjacent to the Shasta River and Parks Creek. Operation of the GID diversion, located adjacent to the Nelson Ranch, has direct impacts on reach hydrology during irrigation season.*
- *The Shasta River exhibits hybridized characteristics of both "spring-dominated" and "rainfall/snowmelt runoff-dominated" rivers. Historically, the geomorphology of the upper river (above Big Springs Creek) reflected runoff-dominated flow conditions, while the lower river (below Nelson Ranch) reflected spring-dominated flow conditions. The Nelson Ranch represents a geomorphic and hydrologic transition zone between the upper and lower Shasta River.*
- *Channel planform morphologies, particularly downstream from the GID diversion, remain largely unchanged across both the pre- and post-Dwinnell Dam periods. This suggests channel geometries are scaled to largely invariable spring-fed baseflows sourced in Big Springs Creek, a hydrologic condition which has remained relatively unchanged since the early 1900's.*
- *The proximity of the Nelson Ranch to Big Springs Creek results in water temperature conditions that exhibit seasonal variability imposed on a spring-stream dominated thermal regime. Coupled with this unique thermal regime are impacts associated with upstream water resources development and management. Specifically, during spring and summer months, impacts of land and water use activities, coinciding with the maximum annual thermal loading, create warm water conditions on the Nelson Ranch.*
- *Mean weekly maximum water temperatures (MWMT) on the Nelson Ranch were greater than 18°C (64.4°F) for 151 days between April 1 and September 30 along the Nelson Ranch (82.5 percent of the period), which are above thresholds considered suitable for juvenile salmon.*
- *Aquatic macrophytes have a significant impact on aquatic habitats of the Nelson Ranch. Increased bed roughness from aquatic macrophytes increase river stage relative to discharge throughout the summer, increasing the availability or access to shallow water habitat. Aquatic macrophytes also create and alter mid-channel habitats available to fish throughout the seasonal growth and senescence cycle.*
- *Natural abundance stable isotope and food web sampling shows that the Shasta River along the Nelson Ranch is very productive, and the food web contains complex trophic interactions that vary seasonally. For instance, [they] found that instream autochthonous production supported food web productivity throughout the year.*

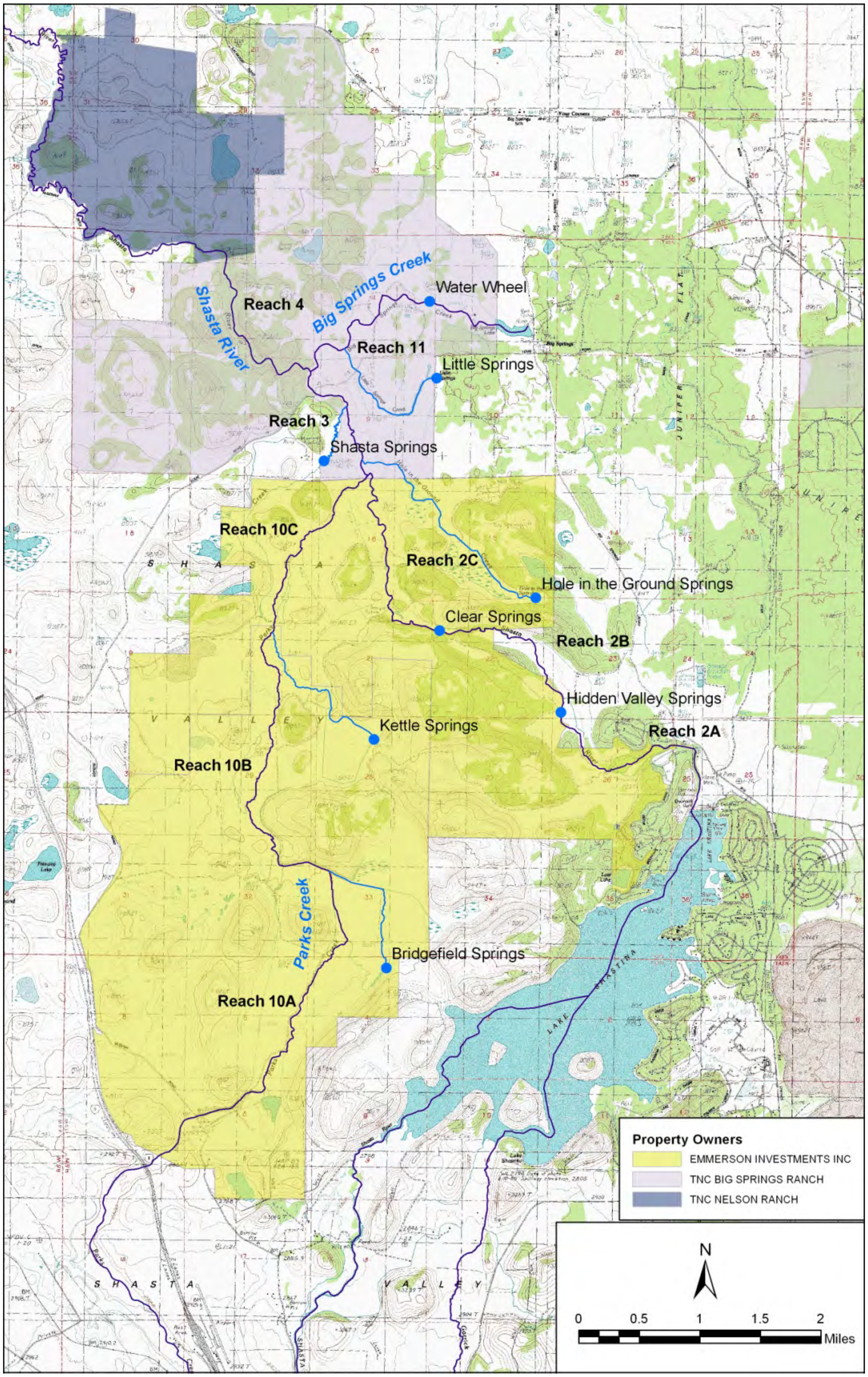

Figure 19. Two ranches purchased in the Big Springs Complex by TNC totaling several thousand acres have significantly reduced and maintained cold water temperatures in Big Springs Creek and in the Shasta River mainstem downstream of Big Springs Creek during the summer rearing season and may provide long-term benefits to salmonid recovery efforts.

Following the purchase of the Shasta Big Springs Ranch in 2009, the second phase of study has focused primarily on 2.2 mile long Big Springs Creek and the 1.2 mile long mainstem Shasta River between Big Springs Creek and Parks Creek. Both of these reaches, provide abundant spawning and rearing habitat for Chinook, coho salmon, and steelhead, and are key to recovering several salmon and steelhead LHTs.

The final report, Assessment of Restoration Actions on Big Springs Creek (Jeffres et al. 2010), states the following study approach and objectives:

> *From March 2008 through January 2009, the U.C. Davis Center for Watershed Sciences and Watercourse Engineering conducted a comprehensive baseline assessment of physical, chemical, and biological conditions throughout Big Springs Creek prior to initiation of restoration actions by TNC (see Jeffres et al. 2009). Following the purchase of Shasta Big Springs Ranch and the Busk Ranch easement, and the initiation of restoration actions by TNC in March 2009, monitoring and assessment of aquatic habitat conditions were continued by U.C. Davis and Watercourse Engineering as part of this study. The objectives of this study were three-fold:*
>
> *(1) document change in the physical, chemical, and biological condition of aquatic habitats following the initiation of restoration actions along Big Springs Creek from April 2009 through March 2010;*
> *(2) identify and quantify factors that continue to limit salmonid production in Big Springs Creek; and*
> *(3) identify the restoration and water resource management actions that improved habitat during the project period and will continue to directly improve salmonid spawning and rearing conditions throughout Big Springs Creek.*

The Big Springs Creek final report (Jeffres et al. 2010) concludes the following:

> *The implementation of passive restoration actions (i.e. fencing and cattle exclusion) resulted in significant changes throughout Big Springs Creek, culminating with the reduction of maximum water temperatures and improved habitat conditions for anadromous and resident salmonids. The key factor driving physical, chemical, and biological changes in Big Springs Creek was the growth of aquatic macrophytes. Both submerged and emergent macrophyte growth improved salmonid habitat by promoting geomorphic changes such as scouring of fine sediments from gravels; hydraulic changes such as creating diverse lateral velocity profiles and increasing mean flow velocities; and water temperature changes principally illustrated by reduced maximum water temperatures through the reduction of potential solar loading by providing shade and reducing travel times. The resulting improved salmonid habitat was evident by the increased abundance of salmonid populations. Observations made for each abiotic and biotic element monitored during this study have yielded recommended monitoring and assessment actions that will provide a foundation of information from which to understand complex spatial and temporal interactions between physical stream conditions and biotic community structure and behavior. Understanding such interactions is necessary to effectively and adaptively manage ongoing restoration actions in an effort to meet the principal objectives of increasing the spatial extent of habitat suitable to salmonids throughout Big Springs Creek and the Shasta River below.*
>
> - *Aquatic macroinvertebrate sampling showed that during spring a large number of the highly tolerant Dipteran family Chironomidae (non-biting midges) were present in the samples. Large numbers of the Chironomidae are generally indicative of nutrient rich (e.g., eutrophic) water quality and increased water temperatures.*
> - *Juvenile coho were observed utilizing relatively fast deep-water habitats where instream woody material was present on the Nelson Ranch. By early June, water temperatures warmed, and very few juvenile coho were observed and only in a backwater habitat. After July 3, 2007, no coho were observed on the Nelson Ranch.*

- *Juvenile steelhead were the most abundant salmonid observed during snorkel surveys conducted on the Nelson Ranch. Adult steelhead were observed along the Nelson Ranch in June, and appeared to be fresh from the ocean. This is evidence that summer run steelhead reside in the Shasta River. Steelhead have higher temperature tolerances than coho, and are thus able to utilize habitat on the Nelson Ranch throughout the summer.*
- *During October 2006, while cooperating with CDFG, [they] observed mature 0+ male Chinook in redds with adult female Chinook. This is the first time that mature male parr have been observed in the Shasta River. How mature parr may contribute to the population is unknown, but this life history strategy may help the population hedge bets against poor migratory conditions downstream.*

These conclusions may equally apply along the mainstem from Dwinnell Dam to the Shasta Canyon:

> *The Shasta River on the Nelson Ranch is a highly productive system with significant potential for restoration of salmonid habitat. The unique hydrology and abundant aquatic macrophytes provide various habitats for fishes during all life stages. Currently the primary limiting factor to salmonids on the Nelson Ranch is elevated water temperature. The quality of spawning habitat is also low. If water temperatures along the Nelson Ranch can be reduced (e.g., through management actions), then the abundant habitat and high natural productivity could support relatively large populations of salmonids, including the federally and state-listed coho salmon.*

4. GENERAL STUDY PLAN RECOMMENDATIONS

The Study Plan prioritizes those life history tactics that can be improved or recovered in the short-term and that would be sustainable under future hydrologic conditions and land use practices over the long-term. The Study Plan identifies nine *Study Plan Elements* (presented in Section 5), each specifying tasks in sufficient detail to guide recovery actions. Specific recovery actions are justified based on explicit recovery goals for prioritized LHTs. Several timely actions affecting all Study Plan Elements are recommended as follows:

4.1. Recommendation #1. Form a Technical Working Group

Technical representatives of resource agencies, Tribes, and stakeholders should form a Technical Working Group (TWG) to coordinate regulatory/funding programs and direct salmonid recovery actions. Stakeholder groups such as the Shasta Coordinated Resource Management Program (CRMP), the Coho Salmon Shasta and Scott Recovery Team (SSRT), or the ongoing Shasta Working Group (SWG) could facilitate TWG formation. Primary functions of the TWG should be to:

1. Prioritize which LHTs for Chinook salmon, coho salmon, and steelhead can be improved or recovered in the short term, then coordinate funding allocations that will implement high priority actions to achieve short-term recovery;
2. Provide parties with equal access to information, while developing a rigorous adaptive management and monitoring program;
3. Coordinate activities (e.g., TMDL, ITP, CDFG 1603, NOAA ESA Recovery Planning) among regulatory agencies and with nearby restoration programs (e.g., in the Klamath Basin);
4. Keep landowners informed and engaged by making the science transparent and comprehensible, and by hosting frequent ‘status’ meetings and occasional demonstration projects.

4.2. Recommendation #2. Instream Flow Need Recommendations

Instream Flow Needs (IFN) recommendations should focus on restoring components of the natural hydrograph that benefit the targeted species and life stages and the river ecosystem. In addition, during the scoping and implementation phases of the of the IFN evaluations, the following should be considered: (1) provide appropriate snowmelt hydrographs in April and May for most water years, and into mid-June for wet water years, as these events are necessary for channel/riparian maintenance, sediment transport, and river productivity, (2) specifically quantify the role of the snowmelt hydrograph in expanding smolt habitat availability, increasing smolt growth, and affecting smolt outmigration timing from the Big Springs Complex through the Shasta Canyon, (3) determine the streamflow – habitat rating curves for targeted species and life stages (e.g., for salmonids: adult migration, spawning and incubation, and fry, pre-smolt and immature-smolt), (4) evaluate streamflows necessary for successful germination and recruitment of native woody riparian and wetland plant species, and (5) evaluate instream flow needs for specific life history phases of salmonids, especially water temperatures during the spring, summer, and early fall for juvenile rearing. Because streamflow in the Shasta River comes from different sources, increased streamflow does not always translate to better water quality or better habitat. Surface flow releases directly from Lake Shastina at particular times of year may be undesirable because of poor water quality in the reservoir. Also, even though there may be adequate streamflow available to meet microhabitat needs during parts of the irrigation season, adverse water quality could override the microhabitat needs. Finally, the Shasta River mainstem could be vulnerable to episodic events of poor water quality: one “pulse” of poor water quality from a single irrigation source at the wrong time could eliminate benefits accrued from months of good water quality.

Given the management flexibility provided by the ability to store and release water, Dwinnell Dam could play a key role in developing innovative water management strategies, such as water transfers, a water trust, and dry year management plans. For example, to obtain the highest quality cold water in the Big Springs Complex, irrigators with diversion rights to cold spring flows could allow that water to flow to the river and receive water deliveries from Lake Shastina. The volume of cold water remaining in the upper Shasta River could be diverted by MWCD downriver (e.g., to approximately Oregon Slough) where its primary summer instream flow and temperature benefits had been accomplished. This alternative would require pumping, but would maintain current water supply availability. A similar scenario could be implemented for the Little Shasta River, in which Lake Shastina water could be delivered to water users in the Little Shasta River watershed in trade for allowing cold water from the Little Shasta River watershed or Cold Springs to remain instream. On Parks Creek, fall and winter instream flows could be provided for spawning and early fry rearing, in return for the opportunity to divert an equivalent volume of Parks Creek spring and summer flow into Lake Shastina. Also, flow releases from Dwinnell Dam timed to mimic the historic spring snowmelt flood in April or May could simultaneously benefit juvenile and pre-smolt rearing and emigration life stages, as well as recruitment of native riparian vegetation along the mainstem Shasta River. Other opportunities may be available for innovative water management strategies that could reduce or minimize impacts to irrigation supply and offset habitat losses from Dwinnell Dam. In addition, understanding thermal gradients in Lake Shastina as a function of season and reservoir storage, combined with water release infrastructure opportunities and constraints, will be necessary to estimate the effect of potential reservoir releases on downstream salmonid habitat, particularly in the warm summer months.

Null et al. (2010) evaluated the potential to enhance fish habitat by managing flow and water temperature regimes in the mainstem Shasta River. They used theoretical analysis, field monitoring, simulation, and optimization modeling to evaluate a range of management scenarios. Modeling results indicated that restoration of cold-water flows in Big Springs Creek "would provide approximately ten miles of optimal thermal conditions directly downstream of the Big Springs confluence, [whereas] water temperature remains above the 16.7°C target with all other alternatives" (Figure 20; reprinted from Null 2008). TNC, after recently purchasing Shasta Big Springs Ranch, has a long-term goal of dedicating cold water to instream flows.

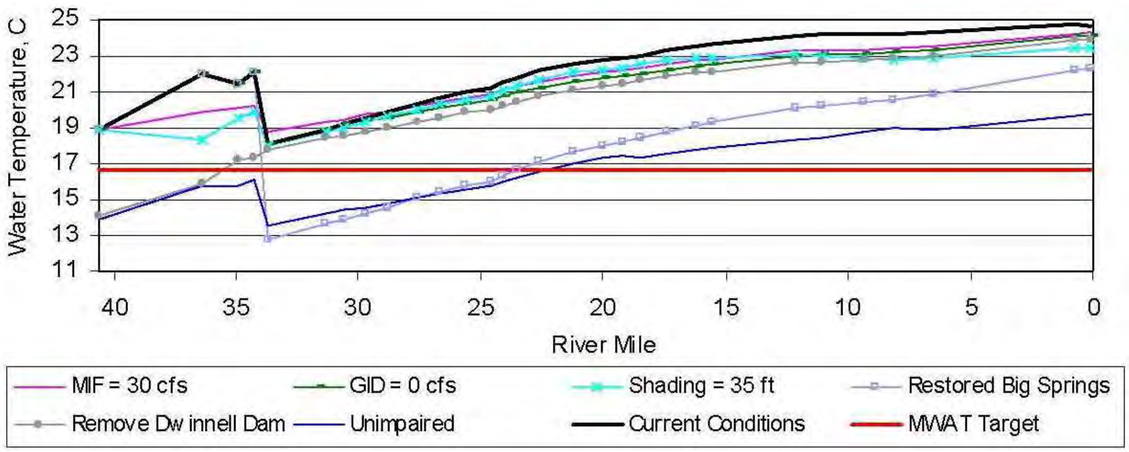

Figure 20. Longitudinal maximum weekly average water temperature (MWAT) under different restoration alternatives with MWAT target, 8/5/01 – 8/11/01 (Null et al. 2010). "MIF=30 cfs" refers to Minimum Instream Flows of 30 cfs; "GID= 0 cfs" refers to no diversions from the Grenada Irrigation District; "Shading=35 ft" refers to increased shading up to 35 ft canopy width from riparian vegetation; "Restored Big Springs" refers to increasing instream flows by approximately 34 cfs from Big Springs; "Remove Dwinnell Dam" refers to complete dam removal and elimination of Parks Creek diversions. [Figure reprinted from Null 2008 with permission of the author].

4.3. Recommendation #3. Evaluate the Feasibility of Recovery with and without Dwinnell Dam

Since construction of Dwinnell Dam and diversion of Parks Creek into Lake Shastina in 1928, anadromous salmonid access to the Shasta Basin's headwaters has been blocked. Several important LHTs relied on the headwaters abundant spawning and rearing habitat (CDFG 1997, 2004) (Table 4). Without fish access to the habitat inundated by the reservoir and upstream of the reservoir, the potential for partially recovering basinwide anadromous salmonid populations will be more difficult.

The National Research Council (NRC 2003) concluded "…serious evaluation should be made of the benefits to coho salmon from elimination of Dwinnell Dam." Can salmon and steelhead populations thrive in the Shasta Basin without access to habitat above Dwinnell Dam and above the MWCD diversion? This uncertainty must be investigated (e.g., likely requiring 5 to 10 years) while not delaying other recovery actions. In addition to direct habitat losses upstream of Dwinnell Dam, flow and sediment regulation by Dwinnell Dam and the MWCD Parks Creek diversion affect instream flow needs for high priority LHTs by altering the natural snowmelt hydrograph, which in turn has impaired natural fluvial and riparian processes, which has in turn degraded channel morphology, aquatic habitat, and riparian habitat downstream of Dwinnell Dam.

4.4. Recommendation #4. Support Actions for Improved Klamath River, Estuary, and Stock Harvest Management.

The intent of this Study Plan is to recommend studies that will provide scientific information and management strategies to produce abundant, healthy fry, juveniles, and smolts in the Shasta Basin. However, increasing adult recruitment will also require a healthy mainstem Klamath River and estuary.

All life history tactics rely on the Klamath River during at least two life stages, adult fresh water migration and juvenile ocean migration, with several LHTs highly dependent on the mainstem and estuary to reach sufficient size prior to ocean entry. While we cannot control ocean conditions, advancements in genetic stock identification (GSI) technologies, such as single nucleotide polymorphisms, SNPs (pronounced "snips"), are becoming available for providing rapid stock identification data that will be necessary for setting real-time harvest management guidelines. These GSI advancements have a high potential for successful ocean and in-river weak stock management (Clemento et al. 2011). Excessively high mortalities of Shasta River adults and juveniles emigrating through the Klamath River, the estuary, and the ocean environments could undermine effective restoration within the Shasta Basin. However, the larger and healthier juveniles become while residing in the Shasta Basin, the greater the likelihood that they will survive to adulthood. This growth/health factor will be key to guiding in-basin habitat restoration and recovery efforts, including the provision of instream flows promoting river productivity.

5. STUDY PLAN ELEMENTS

Following an extensive review of available literature, reports, and data, the following nine prioritized Study Plan Elements, associated Priority Questions, and Tasks were determined as the necessary steps to address key data gaps and gather information essential to aid in the primary, recoverable salmonid LHTs. The Study Plan elements are:

Study Plan Element #1: Water Balance Modeling

Study Plan Element #2: Physical Habitat Assessment for High Priority LHTs

Study Plan Element #3: Water Quality Assessments

Study Plan Element #4: Riparian Vegetation Studies

Study Plan Element #5: Salmonid Migration Assessments

Study Plan Element #6: Geomorphic Assessments

Study Plan Element #7: Spawning Gravel Assessments

Study Plan Element #8: Salmonid Population Studies

Study Plan Element #9 Coho Salmon Population Modeling

These Study Plan Elements are considered the priorities, as there will likely be other studies and information needs identified later; however, these Study Plan Elements will need additional prioritization and sequencing, and we recommend that this further prioritization and sequencing details be discussed and recommended by the Technical Working Group as one of their initial tasks.

5.1. Study Plan Element #1: Water Balance Modeling

Priority Questions:

- What are the quantities, locations, and timing of surface water inputs attributed to precipitation, snowpack, and groundwater (seeps and springs) and natural storage (wetlands, beaver ponds, natural lakes and ponds)?
- What are the quantities, locations, and timing of surface water diversions, storage, and connected groundwater pumping in the Shasta Basin and associated groundwater basin(s)?
- How have the rates of evaporation, transpiration, and groundwater recharged changed from unimpaired conditions?
- How have those activities affected the hydrology at a basin-wide scale?
- Based on the developed Water Balance Model, what opportunities exist for increasing instream flows in the Shasta River mainstem and tributaries while minimizing economic impacts to water users?

Task 1.1: Develop a Water Balance Model.

A basin-wide water balance model is necessary to support instream flow needs and water allocation analyses. The Coho Recovery Strategy (CDFG 2004) WM-11b recommends, “Preparation of a water balance study for the Shasta River to learn how water behaves in the river, in particular [to] establish the fate of water added to the river to increase instream flow.” A water balance model quantifies water inputs from precipitation and examines how inputs are manifested into surface water flows, groundwater storage, and snowpack storage to be delivered later though snowmelt or seepage via springs. The analysis examines diversions of surface water and pumping of groundwater effects at a basin-wide scale. A water balance modeled approach would improve water management practices, help justify the implementation of water leasing or water trust programs, facilitate drought planning, and facilitate the prioritization of stream reaches with the highest potential for habitat restoration. The water balance model should establish the unimpaired, baseline conditions, and include daily average annual hydrographs (i.e., daily average streamflows are needed) for multiple hydrologic reaches within the basin.

Timing and location of studies

A water balance model should include the entire Shasta Basin, from headwaters to the Klamath River. To improve the water balance model, the existing stream gage network should be maintained and expanded. Therefore, install and maintain continuous streamflow gaging stations at the following locations for at least 5 years to supplement the USGS Montague and Yreka gages (Figure 21):

- *Shasta River upstream of the Edson-Foulke diversion (to gauge unimpaired runoff)*
- *Shasta River near Edgewood (at the former USGS gage site)*
- *Parks Creek near Stewart Springs Road (to gauge unimpaired runoff)*
- *Parks Creek near the confluence with the Shasta River*
- *Shasta River below Dwinnell Dam*
- *Shasta River at the TNC Nelson Ranch upstream property boundary*
- *Little Shasta River near Montague (at the former USGS gage site, to gauge unimpaired runoff)*
- *Little Shasta River at the CDFG Wildlife Area*
- *Lower Yreka Creek at Hwy 3 bridge or Anderson Grade Road bridge*

Study methods

A variety of tools could be used to develop a water balance model, from spreadsheet models to software packages specifically designed for water balance modeling. Regardless of the software used, historical and contemporary streamflow data will be needed for input and model calibration. CDWR Watermaster and gaging records, USGS gaging records, new gages currently operated by TNC/U.C. Davis at the Nelson Ranch, CDFG at the Shasta Valley Wildlife Area, and SVRCD on Yreka Creek can provide initial streamflow data. This effort should evaluate the seasonality and variation of various water year types and integrate groundwater and surface runoff, as well as account for the location and effects of diversions, pumping, storage facilities, and the effects for evaporation, transpiration, and evapotranspiration of applied surface water. The model should generate annual hydrographs of daily average streamflows for unimpaired conditions, contemporary conditions, and future conditions. It should also be robust enough to allow adjustments to enable rapid evaluation or sensitivity analyses needed during IFN development.

Integration with other tasks

A water balance model will be necessary to support analyses associated with evaluations of instream flow needs quantification, sediment transport, water quality (including temperature), and river ecosystem productivity, and balancing the resource needs with domestic, agricultural, and recreational requirements. Application of a water balance model must provide unimpaired and impaired annual hydrographs for at least 10 to 20 years to accommodate different water year types including drought years.

Task Deliverables

The product of this element will be a calibrated and validated water balance model for the Shasta River Hydrologic Basin. This model should be capable of estimating the discharge at pre-defined hydrologic nodes for 10 to 20 years of annual hydrographs within acceptable error. The modeling effort should reconstruct the unaltered annual hydrograph given the existing landscape. The model should account for the significant storage and diversion facilities allowing the user to conduct alternative analyses, such as complete and partial dam removal and changes in diversion amounts and timing.

5.2. Study Plan Element #2: Physical Habitat Assessment for High Priority LHTs

Priority Questions:

- What are the physical habitat and flow requirements for the anadromous salmonid and lamprey life stages by hydrologic and geomorphic reach?
- What has changed from the unimpaired hydrograph and what were the effects of these changes on suitable habitat for the various life stages of anadromous fish and lamprey by hydrologic and geomorphic reaches?

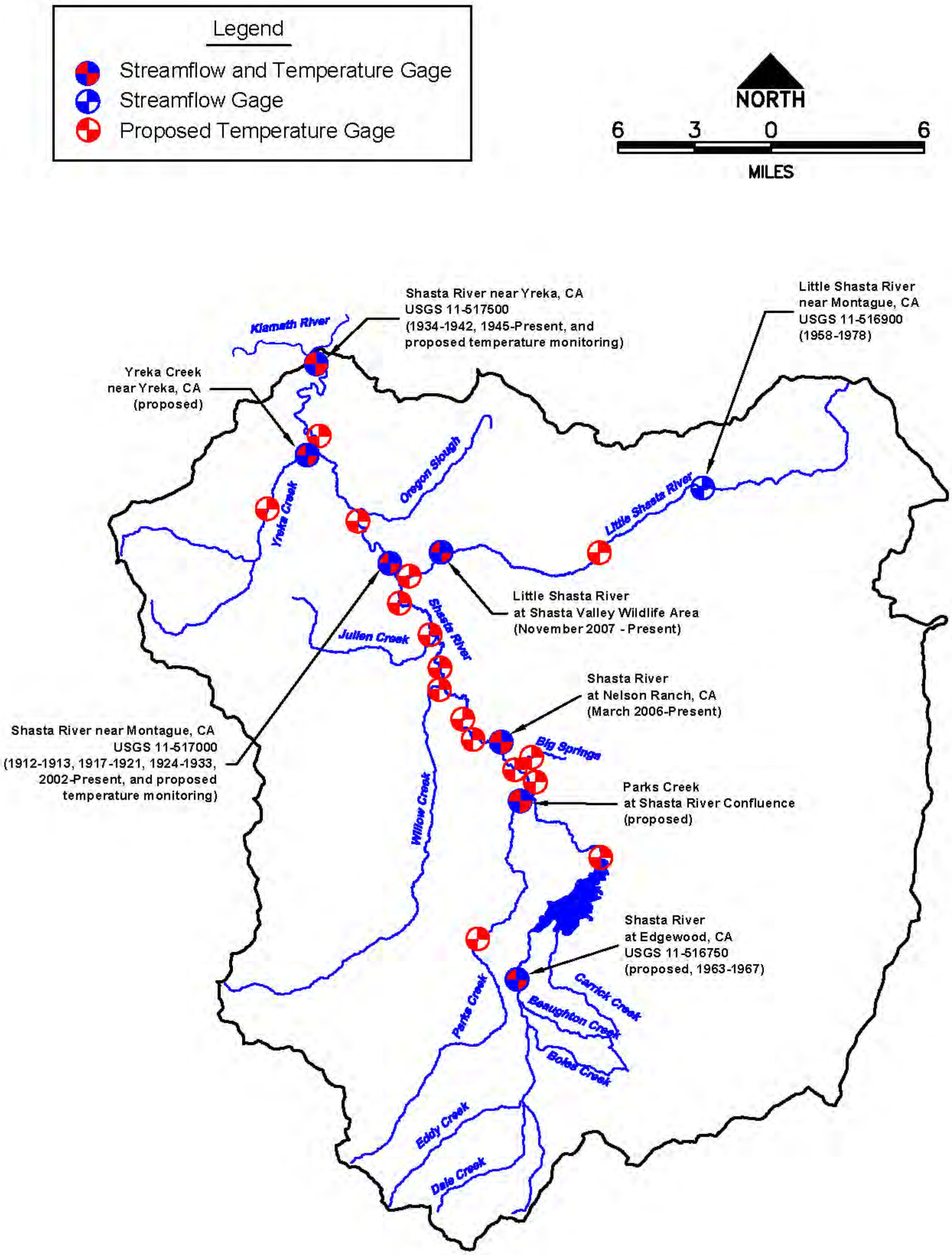

Figure 21. Existing and proposed streamflow gaging locations (blue) and proposed temperature monitoring locations (red). All existing and proposed streamflow gaging devices should be paired with a temperature logger (shown as blue and red).

- What is the current relationship between streamflow and habitat for various life stages of anadromous fish?
- How does the annual hydrograph affect where salmon, steelhead and lamprey spawn?
- What magnitude of streamflow is necessary to cleanse spawning gravels?
- What magnitude of streamflow "activates" side-channels, providing productive habitats for the target species and life stages?
- Do managed flows affect outmigration timing? If so, what flows would facilitate natural outmigration?
- What habitat features (depth, velocity, substrate, and cover components) do specific life stages use during different times of the year in the Shasta Basin?

Instream flow studies are a high priority in the Shasta Basin. The Coho Recovery Strategy (CDFG 2004) Task WM-9 stated:

> *CDFG and USFWS in cooperation with the community should seek funding to conduct instream flow studies on the Scott River and Shasta River to determine flow-habitat relationships. Establish a broad-based technical advisory group. Quantify how much, where, and when stream flow is needed for coho salmon rearing life stages… Use the best, scientifically valid method suitable for the analysis. Explore different instream flow assessment methods, including 1D and 2D modeling, microhabitat mapping, hydrologic modeling and others.*

Providing instream flow needs of the river ecosystem will be equally important as providing those that specifically fulfill physical salmonid habitat needs in high priority LHTs for restoring salmon populations in the Shasta Basin. River ecosystem IFNs will need to encourage high riffle benthic macroinvertebrate (BMI) productivity, periodically scour aquatic vegetation, transport coarse bed material, establish a dynamic woody riparian floodplain, open and maintain off-channel habitats, and restore a natural, variable annual thermograph. Many of these processes were historically achieved through the annual interaction of the snowmelt hydrograph with the Shasta River's structurally complex and diverse channel morphology.

Two general pathways are possible for implementing instream flow studies: a large-scale effort examining the entire watershed as a whole over a relatively discrete time-span (e.g., a 2 to 5 year intensive effort), or a phased approach treating different portions of the watershed somewhat independently in order of high to low priority (5 to 10 year effort). However, timely actions are needed. An important task for the TWG, and overseen by stakeholders/agencies/Tribes (see below), is to decide which actions/studies are needed now (e.g., establishment and implementation of interim instream flow recommendations).

This Study Plan and other reports cited herein describe the regulatory environment and recovery goals that recommend additional instream flow studies. The relationship between salmonid habitat abundance/quality and streamflow is one high priority task for this Study Plan that will require significant planning, integrated field data collection, and extensive analysis and modeling. Another will be establishing streamflows necessary to improve river productivity (e.g., IFNs for riffles providing productive BMI habitat). Ultimately, these studies will determine which LHTs have a high potential for recovery.

Task 2.1: Form a Technical Working Group

Section 4.1 of this Study Plan recommends that representatives from resource agencies, Tribes, and stakeholders form a Technical Working Group (TWG) for the Shasta River to coordinate regulatory and funding programs, and coordinate salmonid recovery efforts. This TWG should also be tasked with overseeing all phases of planning and implementation of instream flow studies, including the refinement of the work plan guidelines provided in this Study Plan.

Task 2.2: Develop HSC

Habitat Suitability Criteria (HSC) is one approach for describing a focal species' preferred physical habitat for a given life stage, including depth of water, velocity, substrate, and cover components. TWG scientists should meet to decide all methods and criteria appropriate for describing physical habitat and river productivity, and recommend necessary field studies or scientific literature reviews needed to provide HSC suitable for application to the Shasta River.

Study methods

Given the controversy and importance of recommending HSC, the methods for developing HSC criteria for use on the Shasta River are not proposed here. Instead, HSC criteria should be developed by the TWG and then peer reviewed, based on the best scientific methods applicable to the unique habitat characteristics of the Shasta Basin. Direct observational data used for coho and/or Chinook salmon should be collected over a range of flows and microhabitat types, utilizing defensible sampling methodologies (e.g., stratified random sampling, with equal effort and equal area). Given the scarcity of coho juveniles, their presence in any particular environmental setting may not be attributable to preference but lack of options; this could result in inaccurate HSC. HSC not derived completely from Shasta Basin-specific observations (e.g., as might be necessary for juvenile coho HSC) may need to be tested for transferability if recommended by the TWG.

Integration with other tasks

Ongoing fisheries studies on the Shasta River and tributaries can assist with collecting habitat information (e.g., collecting HSC data). When a flow event is anticipated to occur, additional effort for observational data collection could be implemented to increase the samples over the range of discharges expected under a natural hydrograph.

Task Deliverables

HSC for each target species and life stages that represent the habitat utilization of Shasta Basin.

Task 2.3: Quantify and Analyze Habitat-Flow Relationships

An Interim IFN assessment, funded by Ocean Protection Council under CDFG direction, is currently underway for the Big Springs Reach and Shasta Canyon. CDFG is initiating a more expansive IFN study that will incorporate the information provided by the Interim IFN assessments, and expand and improve those interim IFN recommendations.

Study methods

Similar to the HSC, the methods for developing flow-habitat relationships on the Shasta River are not proposed here. They should instead be developed by the TWG and then peer reviewed, based on the best scientific methods applicable to the unique habitat characteristics of the Shasta Basin. The analytical strategy and methods (how the flow-habitat relationships are used to quantify IFN's) should also be peer reviewed and approved by CDFG and the TWG before any fieldwork begins. Agreement on field data collection, analytical framework (including decision thresholds), and analytical methods will assure resource managers that the best scientific effort will be adapted to the unique environment of the Shasta Basin for identifying IFNs. However, these IFNs will not balance instream flow needs for the resource with other beneficial uses of water (i.e., irrigation, power generation, and urban uses), but will provide a baseline from which an informed decision-making process can proceed.

Integration with other tasks

Integration of microhabitat variables with macrohabitat variables (temperature, water quality, channel structure, woody riparian dynamics, and snowmelt runoff events) will be a challenging aspect of instream flow needs assessments in the Shasta Basin. For example, streamflows that improve coho juvenile rearing habitat area within the mainstem Shasta Canyon reach in summer months would have no value if water temperatures exceed rearing temperature thresholds and dissolved oxygen requirements.

Task Deliverables

An IFN Report identifying specific year-round instream flows for specific LHTs under variable water year conditions.

5.3. Study Plan Element #3: Water Quality Assessments

Priority Questions:

- How can a favorable temperature regime be obtained for fry and juvenile summer rearing (i.e., what actions are required to achieve maximum, minimum, and average temperature targets)?
- What is the relationship between streamflow and temperature, within context of: (a) complete riparian corridor recovery to baseline conditions, and (b) complete tailwater control to baseline conditions?
- What temperature(s) stimulate fry and juvenile salmonid emigration and/or movement into thermal refuge?
- Does temperature create barriers to fry and juvenile migration from the Shasta Canyon reach upstream or the Little Shasta River upstream into refugia areas above diversions?
- Do thermal refuges exist within the Big Springs Complex, upper Parks Creek, Willow Creek, Little Shasta River, Yreka Creek, and other tributaries for summer coho and steelhead rearing? Have thermal refugia been thoroughly inventoried along the entire mainstem? Are there temperature barriers preventing fish from reaching these thermal refuges?
- Are the salmonids that utilize summer thermal refuges surviving?
- Are water quality impairments resulting from high nutrient loads, pesticides and herbicides, or fish disease pathogens limiting salmonid production in the Shasta Basin?

The Coho Recovery Strategy (CDFG 2004) Task HM-5a suggested as a Tier-1 priority, "Continue to model the relationship of temperature and flow. Use that information and other habitat variables to plan water management and habitat restoration in the river." A flow and temperature model of the mainstem Shasta River from Dwinnell Dam to the Klamath River was developed for the SVRCD in 2003 with funding from CDFG (Deas et al. 2003). The modeling project used a one-dimensional hydrodynamic and water quality model to investigate effects of management actions on stream temperatures (Deas et al. 2003 and NCRWQCB 2006).

To implement recovery efforts and adaptive management and monitoring, resource managers will need a model capable of predicting unimpaired and impaired daily water temperatures at several locations along the mainstem to predict the outcome of planned implementation activities and then monitor the outcome of those activities. Recently the NCRWQCB requested an unimpaired flow and temperature simulation of the Shasta River based on the existing TVA-RMS flow and water quality model used in the Shasta River TMDL. WY2000 was simulated for unimpaired conditions and presented in a technical memo (Deas and Null 2007).

Task 3.1: Expand Water Temperature Data Collection and Develop Temperature Models

Additional water temperature data collection is needed to improve our field understanding of water temperatures at a variety of locations, meteorological conditions, and seasons, as well as provide data for calibrating and validating temperature models. Accordingly, the current water temperature model should be refined and expanded, calibrated, validated, and applied to different potential management scenarios to inform IFN's for various reaches within the Shasta Basin.

Timing and location of studies

We recommend continuously recording water temperature with data loggers set at 1-hr intervals along the mainstem Shasta River and tributaries at the following locations (Figure 21):

- *mainstem Shasta River at Edgewood USGS gage*
- *mainstem Shasta River below Dwinnell Dam*
- *mainstem Shasta River at confluence with Parks Creek*
- *Parks Creek at Edson-Foulke diversion, Hwy 99 bridge, I-5 bridge, and Shasta River confluence*
- *Big Springs Creek at the lake outlet, and confluence with Shasta River*
- *mainstem Shasta River at upstream boundary of TNC Nelson Ranch property*
- *mainstem Shasta River below GID diversion*
- *mainstem Shasta River at downstream boundary of TNC Nelson Ranch property*
- *Willow Creek at confluence with Shasta River*
- *mainstem Shasta River at Hwy A12*
- *mainstem Shasta River at Freeman Lane*
- *mainstem Shasta River at Shasta Water Users Association*
- *Little Shasta River at confluence, at SVWA, and below Hart diversion*
- *mainstem Shasta River at CDWR Montague Weir*
- *mainstem Shasta River at Yreka Ager Road*
- *Yreka Creek at Hwy 3 bridge and Shasta River confluence*
- *mainstem Shasta River at Anderson Grade Road (I-5 Bridge)*
- *mainstem Shasta River at USGS Shasta River near Yreka gage*

Locate and Monitor Water Temperature in coho salmon thermal refugia habitat

Once an inventory of thermal refugia locations has been completed, site-specific water temperature monitoring protocols should be developed. Water temperature monitoring probes in the mainstem channel are typically located between tributary confluences and may not be sufficient to evaluate thermal refugia, e.g., at diffuse springs, hyporheic flow locations at downstream ends of meander bend gravel bars (and side-channels), and below beaver ponds. Previous work should be consulted in developing this water temperature monitoring plan (e.g., Watershed Sciences LLC. (2003) and Chesney et al. (2009)).

Monitor water temperature, volume, and location of significant tailwater returns

In addition to identifying thermal refugia locations, tailwater returns from flood irrigation need to be identified and site-specific water temperature monitoring protocols developed. Previous work should be consulted in developing this water temperature monitoring plan (e.g., Watershed Sciences LLC. (2003) and Chesney et al. (2009)).

Study methods

Stream water temperature data and stage should be collected at the above listed monitoring locations using remote temperature and stage data loggers on at least an hourly basis. Data loggers should be checked for proper readings and downloaded at least quarterly, and after major storm events. Data should be compiled into an existing database and summarized to present daily and annual temperature statistics, utilizing protocols provided by the TWG.

Integration with other tasks

Water temperature and streamflow data will be used to calibrate and validate temperature and water balance models targeting reaches with high-priority LHTs.

Task Deliverables

Temperature files that followed the appropriate chain of custody and QA/QC protocol will be appended to a central database.

Task 3.2. Water Quality Assessment and Monitoring

In addition to temperature, there are several other water quality constituents that should be assessed in the Shasta River mainstem, its tributaries, and its distributary canals and ditches.

Dissolved Oxygen and Nutrients: Dissolved oxygen (DO) was listed as impaired by the NCRWQCB. Nutrient enrichment of nitrogen and phosphorous, the likely cause of DO impairment, is the primary target of the TMDL Action Plan (NCRWQCB 2006). The Shasta River has high nutrient loading from springs discharging to the river, with added nutrient loads from surrounding agricultural activities. The agricultural return flows (tailwater) are considered the primary anthropogenic source of nutrient enrichment to the river (A. Baker, personal communication). Additionally, pH should be listed as an additional parameter of concern. Although the Shasta River is not officially listed as pH-impaired, the pH objective of 8.5 is exceeded in portions of the Shasta River mainstem during the summer months (for example, see graphics in Appendix A of the Shasta TMDL). Sediment load also is a factor in nutrient and DO dynamics by providing a substrate for nutrient cycling. Several surrounding urban communities (Yreka and Weed) are attempting to address nutrient and sediment loading issues related to stormwater and sewage runoff. Research is needed regarding how pulse flows or other changes to the hydrologic regime could improve the scour of fine sediment and aquatic macrophytes, thereby improving water quality. This physical process, and anticipated macrophyte suppression, should be integrated into overall geomorphic/flood peak studies identified in this Plan. The role of changing grazing and irrigation management along the corridor (riparian fencing, reduced physical disturbance of macrophytes by grazing, reduced tailwater return flows) should be considered as well for their evolving role in DO, nutrients, and macrophyte problems.

Pesticides and Herbicides: As a result of a lawsuit filed under the Endangered Species Act against EPA (Washington Toxics Coalition, et al. v. EPA) a federal judge issued a ruling in 2004 to establish buffers adjacent to certain "salmon-supporting waters" in Washington, Oregon and California for applications of 34 pesticides with potential to harm salmon (http://www.epa.gov/espp/litstatus/wtc/maps.htm).

Use of pesticides and herbicides in farming and ranching operations is common. An initial step would be to query and summarize information available in the geo-referenced, publically-accessible pesticide use databases to determine which pesticides are used in the Shasta Basin that have potential toxicity to salmonids or aquatic macroinvertebrates. Then if any seem significant, further investigations such as the collection/analysis of water samples or farmer/applicator interviews would be warranted. A query of the California Department of Pesticide Regulation, California Pesticide Information Portal (http://calpip.cdpr.ca.gov/main.cfm) indicates that at least 11 of the 34 pesticides identified were applied in Siskiyou County in 2010 (Table 10). A web-based interactive map of pesticide usage is available at: http://www.ehib.org/tool.jsp?tool_key=18. Application of pesticides tends to focus on higher value crops than grown in the Shasta Valley, and the general County-wide pesticide application in Table 10 needs to be re-evaluated with respect to pesticide application along the Shasta river corridor.

Shasta Basin Water Quality Monitoring Program: A basin-wide water quality program should be developed and implemented to begin tracking temperature and dissolved oxygen levels, as well as non-point source nutrient inputs into the Shasta River and from the Shasta into the Klamath River. This program will be important for determining the success of the TMDL water quality standards and for tracking other important water quality constituents. The program's details should be developed with the NCWQCB and the Klamath Basin Monitoring Program (http://www.kbmp.net/about-us), with input from the TWG.

The SVRCD and AquaTerra have been implementing a monitoring plan (Aqua Terra 2011) as part of their tailwater assessment, with 13 tailwater sites monitored for streamflow, temperature, DO, and nutrients, on a monthly or more frequent sampling interval throughout the summer irrigation season. Continuous DO meters, D-opt Loggers, are now located in three locations: Nelson Ranch, Montague-Grenada Bridge, and the Araujo Dam site. Additional water quality monitoring should build upon this initial effort, and be implemented in the next phase of tailwater reduction projects.

Table 10. Pounds of pesticides applied in Siskiyou County in 2010 identified from a query of the California Pesticide Information Portal.

Chemical Name	Pounds Applied in Siskiyou County, 2010
Captan	5,793
Chlorothalonil	4,960
Metribuzin	3,862
Pendimethalin	1,982
Methomyl	777
Malathion	725
Chlorpyrifos	716
Diuron	575
Propargite	369
1,3-Dichloropropene	363
2,4-D	344

Timing and location of studies

Recommendations for a temperature monitoring infrastructure are detailed in Task 3.1 above. In addition, multi-probe data loggers deployed remotely for the continuous collection of temperature, DO, pH, pesticides, and conductivity are an option for several mainstem Shasta River locations (e.g., in the Big Springs Complex and mainstem Shasta River at USGS Shasta River near Yreka gage). Sites established by the SVRCD and Aqua Terra should continue to be monitored, with additional sites considered. The Karuk Tribe should continue collecting nutrient samples and running a continuous multi-probe data logger (temperature, DO, pH, and conductivity) at the mouth of the Shasta River. Presently, the Karuk Tribe's multi-probe is operated only between May and October; additional funding to keep the probe running year-round would keep the data compatible with other monitoring stations. These data are integral to implementation of the Shasta River TMDL and Klamath River TMDL. Study methods (empirical, modeled, expert opinion)

Basic empirical data on water temperature, DO, and nutrient loads must be collected within hydrologic reaches of the Shasta River and significant tributaries identified through the TMDL process. However, stringent protocols for calibration, deployment, data extraction, and post-processing must be developed and strictly followed in order to generate valid data. Working with the NCRWQCB in the TMDL process would be an obvious linkage for expanding current monitoring of other water quality constituents independent of the TDML program (e.g., coliform bacteria counts (Bogener 1990)).

Integration with other tasks

Water temperature, DO, and nutrient data collection and management should be coordinated with staff in the NCRWQCB and the Klamath Basin Monitoring Program. Of equal importance, recommended geomorphic and peak flow studies must contribute to a better understanding of how scour from flood peaks and high sustained spring snowmelt streamflows could be used to reduce macrophyte growth and to remove the accumulation of fine sediment in the mainstem as is occurring below Dwinnelle Dam and upstream of the Parks Creek confluence. Another potentially important water temperature monitoring task would be documentation of temperature stratification in the deepest adult holding pools within the Shasta Canyon (e.g., the big and deep pool upstream of the Pioneer Bridge known as an important holding habitat). This will help in evaluating instream flow needs for the earlier days of adult upstream migration and holding (i.e., in September and October).

Task Deliverables

Reports prepared by the NCRWQCB and Klamath Basin Monitoring Program.

5.4. Study Plan Element #4: Riparian Vegetation, Wood, and Beaver Management Studies

Priority Questions Pertaining to Natural Regeneration:

- What was the extent of historic and existing riparian vegetation, the dominant plant species, and canopy coverage of riparian vegetation along the mainstem and priority tributaries?
- What roles did different hydrograph components and water year types play in the successful initiation, establishment, and long-term sustainability of the riparian corridor?
- What was the historic channel morphology and flood disturbance frequency that promoted successful establishment of woody riparian vegetation?
- Which reaches have a high potential for natural woody riparian regeneration along the mainstem and priority tributaries?
- Does the current magnitude and timing of streamflows promote germination and establishment of riparian vegetation on floodplains along the mainstem Shasta River where riparian fencing has been installed?
- Do existing vegetation and land use practices inhibit establishment of woody riparian species (competition and water use/pumping) and, if so, where?
- Is there a sufficient seed supply of targeted woody riparian species close to sites where natural regeneration is desired?

Priority Questions Pertaining to Active Revegetation:

- What soil and groundwater characteristics have led to successful establishment of revegetated woody riparian plants in the past?
- What vegetation planting and maintenance methods have led to successful establishment of revegetated woody riparian plants in the past?
- What physical and hydrologic characteristics make a site suitable or unsuitable for woody riparian plantings?
- Where are existing soil and groundwater conditions suitable for riparian planting? Where are the priority sites for planting them along the mainstem and tributaries?
- What riparian corridor width is achievable and appropriate along the mainstem and priority tributaries?
- Are there assemblages of plant species that will indicate whether a site is suitable for woody riparian plantings?
- What target woody plant species will provide the best short and long-term wood recruitment?
- What are the target woody plant species and methods that can be used economically and successfully in revegetation efforts?
- What percent of the mainstem and priority tributaries can successfully support the establishment of a closed canopy woody riparian vegetation?
- Can areas with unsuitable soil types (anaerobic conditions caused by compaction, salt, dampness and buildup of hydrogen sulfide due to lack of drainage) be modified by treatments such as mechanical aeration or complete replacement?
- If native trees are no longer adapted due to irreversible changes in soil and hydrologic conditions, what guidelines could steer selection and planting of suitable non-native trees without presenting new problems?

Pertaining to Salmonid Habitat

- What was the role of the historic wood supply in creating salmon rearing habitat, and how has Dwinnell Dam and grazing affected large wood supply?
- For the supportable future riparian vegetation and canopy, how much benefit will be provided to reducing summer water temperatures?
- What is an appropriate level of woody material (including willow clumps) reintroduction that will improve aquatic habitat?
- Can flows and riparian vegetation be improved to support beaver reintroduction that would contribute to aquatic habitat improvement?
- Given that beavers affect channels differently based on scale, gradient, soils, and other factors (e.g., beaver dams and lodges versus bank dwelling), what reaches are more appropriate for encouraging beaver activity in a way that benefits fish rearing habitat while preserving migration opportunities?
- Were side-channels with canopy cover historically an important feature providing habitat and water temperature cooling effects on the mainstem? What about side-channels without canopy cover?

Long-term, sustainable habitat recovery for the Shasta Basin's anadromous salmonid populations will require woody riparian recovery (i.e., population recovery is not a streamflow issue only). Woody riparian recovery will provide multiple benefits to salmon/steelhead populations including (1) shading to reduce summer and fall water temperatures, (2) creating hydraulic resistance to induce sediment deposition for critical streambank building, (3) supplying woody material (coarse/large wood material greater than 0.2 mm in diameter and 1.5 m long (Beschta 1900)) to the channel, and (4) creating physical complexity capable of trapping woody material moving during storm events. A vigorous woody riparian corridor will provide bank stability and undercut banks and create in-channel wood structure (from input of woody material and willow clumps) essential for physical coho salmon habitat. The Shasta River TMDL (NCRWQCB 2006) identifies reduced stream shading, resulting from the loss of woody riparian vegetation, as one of several factors elevating water summer and early-fall water temperatures above salmon rearing tolerances. To achieve TMDL water temperature targets, woody riparian vegetation must substantially increase to achieve the 85% canopy cover requirement along the entire valley bottom mainstem (approximately 40 miles).

Riparian vegetation along the Shasta River valley bottom is primarily large wet meadows with patches of woody riparian vegetation. There is no consensus as to what historical riparian conditions were like, nor on the physical and hydrologic processes that once sustained them. Thus, there is no common vision and strategy for recovering the Shasta River riparian ecosystem or whether the historic riparian corridor supported woody and emergent riparian vegetation to the extent necessitated by the TMDL.

There is general consensus that past woody riparian planting efforts have been much less successful than expected. Future riparian vegetation goals must be realistic commensurate with the current understanding of the Shasta Basin's riparian vegetation potential. A working definition of 'riparian corridor' will be needed to set quantitative recovery targets for corridor width, canopy structure, and species composition. Significant woody riparian recovery will require natural recruitment and planting. Experimentation and monitoring should be incorporated into future woody riparian planting projects.

Several important issues must be addressed to develop realistic goals and objectives. Recovery efforts must first evaluate not only factors that have impaired or eliminated riparian vegetation (e.g., agricultural practices, loss of snowmelt hydrograph), but equally important, the factors necessary for woody riparian plant species to regenerate and establish naturally. Natural woody riparian vegetation recruitment is the result of nursery site availability and hydrologic conditions in the first year, and then survival through flood scour and inter-/intra-specific competition in subsequent years. Nursery sites are created through bank scour and deposition of coarse and fine sediment on suitable geomorphic surfaces. Nursery sites are generally created by larger magnitude floods (> 5-yr recurrence-interval flood). Generally, woody riparian plants growing within 150 ft of an available nursery site are required to ensure an adequate seed supply. Seed dispersal occurs at different times in the spring and summer for various woody riparian plants, which affects the quantity and distribution of each woody species along the river. Cottonwood and willow seeds are short lived and can successfully germinate up to 14 days after being released from the parent plant. Nursery sites must be moist, but not inundated, for a seed to successfully germinate. Gradually receding streamflows during the late spring and summer affect the shallow groundwater table adjacent to the stream. The groundwater table at a nursery site must recede slowly enough to allow seedling roots to grow fast enough to keep in contact with receding water and diminishing soil moisture.

A working definition of "riparian corridor" must be developed to set quantitative recovery targets for corridor width, canopy structure, and species composition. This quantitative definition of riparian corridor should be developed spatially based on the extent to which streamflows supply shallow groundwater laterally away from the river and temporally through the end of the growing season. A thoroughly documented description of historical riparian conditions within this riparian corridor is needed. The valley bottom mainstem of the Shasta River likely had an extensive riparian zone characterized by a mosaic of riparian hardwoods, grasslands, wetlands, beaver ponds or natural floodplain depressions, and springs. Recovery of this condition may not be feasible or desirable, but the scale of restoration, i.e., the desired future riparian corridor width, canopy structure, and species composition, needs to be clearly defined to provide goals for restoration planning to meet targeted beneficial conditions.

In many locations, natural riparian recovery may not be feasible and active riparian restoration through tree planting may be required instead. For revegetation efforts to succeed, plants may need protection from overgrazing by wildlife and cattle, and potentially irrigated in the first few years to facilitate root growth to the water table. Soil conditions and groundwater adjacent to the river also contribute to successful establishment of revegetated woody riparian plants. Although inadequately documented, past planting efforts have not met planting goals. Therefore, before any future large-scale planting efforts are implemented, there needs to be a concerted effort to assess past riparian planting projects to document success or determine likely causes of mortality. Evaluations at past revegetation sites should include a review of the plant species and planting methods that have been used to conduct revegetation, an assessment of plant material sources and how material have been prepared and stored before planting, and development of a list of criteria to assess future areas where revegetation is proposed. Future revegetation should be conducted with different methods and plant species using carefully controlled experimentation to test promising approaches. This assessment may require detailed investigations of groundwater, soil chemistry, plant phenology, and dependence of riparian recruitment on a more natural annual hydrograph (particularly winter floods and spring snowmelt hydrograph components).

Five initial tasks are recommended for riparian and woody material investigations: (1) establish riparian and woody material recovery goals and target conditions, including riparian corridor width, canopy structure, and species composition, along the mainstem and high priority tributaries; (2) assess the natural recovery potential of the Shasta River valley by identifying natural processes required to promote natural riparian regeneration of desired woody riparian and wetland species; (3) develop a revegetation strategy by assessing past planting projects to garner important lessons that can be applied to future efforts and developing a stratified experimental design to test planting success for varying soil and groundwater conditions, different plant stocks, and planting timing; (4) evaluate historic beaver use and probable role in providing coho salmon rearing habitat, and develop a beaver management strategy that benefits coho rearing habitat; and (5) develop a woody material management strategy by assessing historic wood loading, developing woody material short- and long-term management goals, determining desired geomorphic and habitat benefits, and identifying future wood recruitment sources.

Task 4.1: Establish Riparian and Woody Material Recovery Goals and Target Conditions

This task will use the interim and revised Riparian Protection Policy, the 100-yr flood boundary, and other objective criteria, to (a) map a proposed (future) riparian corridor boundary for the mainstem and tributaries, then (b) map the contemporary riparian vegetation stand structure, woody material, and beaver dams along the mainstem and selected tributaries, including Parks Creek, Big Springs Creek, Little Shasta River, and Yreka Creek. This effort may be conducted initially using aerial photo interpretation, but should also include field mapping for validation and integration with newly acquired LiDAR data. This task should search the available literature for historical descriptions of riparian vegetation, woody material, and beaver dams in the Shasta Valley. Vegetation mapping should identify reference sites with relatively healthy riparian structure and species composition, to model sites for establishing riparian recovery targets. Woody material mapping should provide reference sites for proposed wood loading and design elements. This task should also establish and sample vegetation monitoring transects to document baseline reference conditions for long-term monitoring.

The NCRWQCB has been developing a Stream and Wetland System Protection Policy that may provide, among other issues, riparian setbacks and buffer widths applicable to riparian restoration on the Shasta River mainstem and tributaries. However, this policy has still not been completed, and the completion date is currently unknown. In addition to NCRWQCB policy under development, the Shasta TMDL Action Plan Appendix E provides "Recommended Interim Riparian Reserve Widths for the Shasta River Watershed."

In areas where riparian expansion is feasible, a proposed riparian corridor boundary and the desired distribution of riparian vegetation and stand types should be assessed (i.e., fill in the blanks with the most appropriate vegetation and stand types). This proposed condition can guide the appropriate type of vegetation restoration. In addition to riparian expansion, areas where channel migration is feasible, addition of large wood elements should be evaluated for their geomorphic, riparian, and habitat benefits.

Timing and location of studies

A riparian corridor boundary should be defined for the Shasta River mainstem from Dwinnell Dam downstream to the Klamath River confluence, on Parks Creek from approximately Hwy 99 to the Shasta River confluence, on Big Springs Creek from the spring source downstream to the Shasta River confluence, on the Little Shasta River from the MWCD canal downstream to the Shasta River confluence, and on Yreka Creek from the Greenhorn Creek confluence downstream to the Shasta River confluence. Within these boundaries, historical (to the extent feasible) and contemporary riparian vegetation and habitat conditions should be described, and expected future conditions proposed. A historical literature search should be conducted as part of establishing riparian corridor boundaries. Field monitoring sites should be established at numerous selected reference locations, documented with permanent field markers for future reference, and monitored to inform descriptions of contemporary species composition and age-class structure.

Study methods (empirical, modeled, and expert opinion)

Study methods should: (1) provide a literature review, including historical accounts; (2) prepare a map of existing riparian vegetation; (3) establish a desired riparian corridor (The NCRWQCB scientists should be consulted for support of any riparian setbacks and buffer widths); and (4) identify monitoring cross sections.

Integration with other tasks

Riparian vegetation field studies, including mapping of contemporary riparian vegetation extent and composition, should also be compatible with water temperature modeling and physical habitat data needs.

Task Deliverables

Compile literature sources (if any) and photos describing historical riparian vegetation conditions. GIS layers describing the historical extent of the riparian corridor along the Shasta River mainstem and tributaries (as discussed above); GIS layers describing the contemporary extent of riparian vegetation, woody material, and beaver dams along the Shasta River mainstem and tributaries; and field data describing dominant woody riparian and wetland species offering the best prospects for natural recruitment and planting success, or alternatives should that not be feasible or desirable. Lastly this task should integrate all tasks (Tasks 4.1 – 4.4) to develop a riparian vegetation, woody material, and beaver management plan.

Task 4.2: Assess Natural Riparian Recovery Potential

This task will (a) assess the potential for natural riparian regeneration by evaluating available historical hydrographs and channel morphology in conjunction with any available, relatively less-disturbed reference conditions to "tell the story" of historical unimpaired riparian processes; (b) assess timing and density of seed release (phenology) for dominant woody riparian species (e.g., red willow, narrowleaf willow, cottonwood, water birch); (c) develop recommendations to improve physical and hydrologic conditions leading to increased natural riparian regeneration given current infrastructure and land management constraints; and (d) identify where natural regeneration is (i) likely to achieve TMDL goals, (ii) areas where a combination of natural regeneration and plantings can achieve TMDL goals, and (iii) locations where revegetation is the only likely way TMDL goals may be met. Alternatives to natural recruitment may be required if natural recruitment is unlikely to succeed. However, long-term sustainability of woody riparian vegetation may only be achieved through natural regeneration.

Timing and location of studies

Reference sites should be identified, based on results of historical and contemporary riparian vegetation mapping (Task 4.1), within several representative reaches of the mainstem Shasta River and high priority tributaries, including the reach below Dwinnell Dam, the Nelson Ranch, the Middle and/or Lower Shasta River, and the valley reaches of Parks Creek and the Little Shasta River.

Study methods (empirical, modeled, expert opinion)

This assessment should be primarily empirical. Within several reference sites, the distribution, abundance, age-class diversity, and natural recruitment of native species should be identified by vegetation mapping. Monitoring of seed release timing and distribution should employ sticky seed traps or other appropriate methods. At locations where native vegetation recruitment of desired species is successful, soil, streamflow, groundwater conditions, and other key factors promoting recruitment should be identified by developing stage-discharge and other relationships along transects, and by observing seasonal groundwater stage patterns.

Integration with other tasks

This task should be integrated with geomorphic evaluations recommended (and discussed) in Task 6, and should be designed to provide information to inform the identification of instream flow needs discussed in Task 2.

Task Deliverables

This task should establish several reference sites for long-term riparian monitoring studies, describe the specific riparian and geomorphic attributes that are capable of promoting natural riparian recruitment, and provide recommendations that will accelerate native vegetation recruitment. This information should be included in the riparian vegetation management strategy in Task 4.1.

Task 4.3: Develop revegetation management strategy

This strategy will (a) assess prior revegetation projects to determine the likely factors that contributed to plant survival or mortality, (b) summarize what information can be confidently garnered from past efforts, (c) identify issues of greater uncertainty, (d) identify specific additional information needs, and (e) develop a revegetation strategy. Evaluations at past revegetation sites will include a review of the plant species and planting methods that have been used to conduct revegetation, an assessment of plant material sources, and how materials have been prepared and stored before planting to develop of a list of suitability criteria to assess future areas where revegetation is proposed. Once completed, this assessment can be used to generate hypotheses and sampling plans for a next phase of active experimentation. Factors initially suspected to affect survival of planted riparian vegetation are: soil salinity and pH, groundwater and soil moisture conditions, type of stock used in planting, time of year planting is conducted, and irrigation methods. Experiments should also evaluate different species.

Timing and location of studies

The locations of previous riparian planting projects need to be identified, and the factors contributing to the success or failure at each site need to be identified (at a minimum subjectively with professional opinion) to determine if trends are evident in planting success/failure. For the next phase of riparian revegetation planting and experimentation, the two likeliest sites are on the mainstem Shasta River at the Nelson Ranch and on the Little Shasta River at the Shasta Valley Wildlife Area. Both sites have had previous riparian vegetation projects implemented. Other sites may be available and desirable in the Middle and Lower mainstem Shasta River at riparian fencing sites (Table 8).

Study methods (empirical, modeled, expert opinion)

An experimental design should be developed based on what is learned from the analysis of previous projects' successes/failures that incorporates this information to test new riparian planting hypotheses. Entities implementing riparian vegetation projects must incorporate experimental design and monitoring into projects. Until successful approaches are fully identified, survival expectations should be reflective of the experimental nature of the efforts.

Integration with other tasks

Riparian planting experimentation should be integrated into future revegetation and riparian fencing projects.

Task Deliverables

This task should provide a thorough description of factors causing success or failure of riparian planting projects, followed by concise recommendations on alternative planting methods to be implemented in subsequent revegetation projects.

Task 4.4: Develop woody material and beaver management strategy

This task should (a) provide a historical perspective of large wood and the role of beavers in providing coho salmon rearing habitat in the Shasta Basin, including different types of beaver use in different reaches (bank dwelling, beaver dams and lodges), (b) determine desired geomorphic effect of woody material and beaver dams on the reach and unit scale, (c) propose future salmonid habitat cover and complexity goals from large wood and beaver management, (d) recommend sort-term and long-term wood storage goals, including considering the effect of large wood and beaver dams on fish rearing habitat and migration opportunities, (e) prioritize wood loading locations and types of wood features, and (f) provide an integration element relating the revegetation strategy to a future source for wood recruitment. Evaluation of existing reference sites within the Shasta Basin or suitable reference rivers and the effectiveness of past restoration projects that incorporated wood into or adjacent to the channel, including bank stabilization projects is proposed. Locate and prioritize sites for wood loading, focusing on areas with existing thermal refugia or with potential for channel migration. Once completed, this information can be used to implement a wood strategy that incorporates experimental design elements increasing salmonid rearing habitat, geomorphic complexity, and/or channel migration.

Timing and location of studies

Along with the riparian corridor boundary described in Task 4.1, a channel migration boundary should be defined for the Shasta River mainstem and tributaries as described in Task 4.1. Within these boundaries, woody material loading and beaver habitat conditions should be described, and expected future conditions proposed. A historical literature search should be conducted as part of determining channel migration boundaries. Field monitoring sites should be established at numerous selected reference locations, documented with permanent field markers for future reference, and monitored to inform their effectiveness at meeting salmonid habitat and geomorphic objectives.

Study methods (empirical, modeled, expert opinion)

Study methods should: (1) provide a literature review, including historical accounts; (2) prepare a map of existing woody material and beaver dams; (3) establish a desired channel migration corridor; and (4) identify monitoring cross sections. An experimental design should be developed based on what is learned from the analysis of previous projects' (within or from reference basins) incorporating this information into each wood design and implementation project. Entities implementing wood habitat and/or geomorphic designs must identify habitat and geomorphic goals and objectives, incorporate experimental elements, and monitor each projects successes and/or failures.

Integration with other tasks

Wood habitat and geomorphic designs should be integrated into short-term and long-term riparian revegetation projects because wood augmentation may provide benefits to riparian planting success via improved soil moisture retention. Information from this task should be integrated into the riparian vegetation, wood material, and beaver management plan described in Task 4.1.

Task Deliverables

This task should provide a thorough description of potential coarse/large wood and willow clump designs, desired habitat and geomorphic goals, and evaluation criteria for determining success and/or failure of each project. This task should also include beaver management strategies for improving instream rearing habitat as well as considering management needs for avoiding impacts to agricultural infrastructure.

5.5. Study Plan Element #5: Juvenile and Adult Migration

Priority Questions:

- Do natural or artificial barriers impede adult migration to spawning habitat? If so, when, where and how?
- Do natural or artificial barriers impede juvenile coho and steelhead downstream and upstream migration from spawning grounds to access summer and winter rearing habitat?
- Are there dewatered reaches that inhibit successful juvenile upstream and downstream migration?
- Are there reaches with adverse water temperatures and/or low dissolved oxygen concentrations that impede the successful upstream and downstream migration of juvenile and/or adult salmonids and lamprey?

Viable LHTs require migratory pathways that allow salmonids to transition from one life stage to the next. Adults returning to spawn need unimpeded access to suitable spawning habitat throughout the basin. Emergent fry must be able to disperse widely from spawning grounds to fully seed viable rearing habitat. Juveniles commonly re-disperse in late-summer and fall to seek favorable overwintering habitat. Pre-smolt and smolt life stages must be allowed to migrate downstream at the appropriate time into high quality rearing habitat to promote good growth. Inadequate connectivity between any two life stages generally diminishes the success of a particular LHT.

Fish passage barriers may be categorized as: (1) natural features such as waterfalls, cascades, beaver dams, and transverse riffles that impede migration, or ephemeral stream reaches that have natural, seasonal, sub-surface flow; (2) non-natural, non-structural barriers such as dewatered stream reaches from irrigation withdrawals, and unsuitable water quality conditions (e.g., high temperature or dissolved oxygen); and (3) non-natural, structural barriers such as water diversion impoundments, culvert or bridge crossings, and dams that are partial or complete barriers to migration. The SVRCD and CalTrout have identified many structural barriers throughout the Shasta Basin (Table 11) and should be coordinated with statewide California Fish Passage Assessment Database (http://nrm.dfg.ca.gov/PAD/). CalTrout developed a GIS that includes all barriers that have been identified, and funding has also been allocated by CDFG and other entities to remediate major barriers.

This Study Plan element lends itself to prioritization by life history tactic, treating barriers that affect the highest priority tactics on the Shasta River mainstem and tributaries.

Table 11. Partial or full migration barriers, including those already removed or remediated.

Barrier Name	River Mile	Status
Shasta River Fish Counting Facility	0.5	Passable at most streamflows; narrow enough to potentially modify fish behavior.
Stewart Higgs Diversion Dam		Poorly known gravel dam installed each summer with dragline.
Dewey Smith Hydro – Old Prather Pump Dam	6.8	Hydro use ceased 1997 following winter damage, FERC license apparently either never issued or revoked. Ultimate status unknown.
Dewey Smith/old Oregon & Calif. Power Co Dam	7.1	Original hydro use abandoned ~1948.
CDWR Gage Weir	15.2	Partial upstream barrier to juveniles and adults at lower flows.
Novy-Rice Diversion Dam	25.9	No apparent removal action at present. Likely velocity barrier to upstream migration, possible increased risk of injury to downstream migrants. Fish screen for this diversion presents predation problems.
GID Diversion Dam/Huseman Diversion Dam	30.3	CDFG has prepared plans for removal of dam, construction of two new fish screens and replacement of GID pumps and moving the Huseman diversion downstream and converting it to pumps. Funding sought. Water efficiency issues.
Big Springs Creek waterwheel foundation	~1.6	TNC moving towards removal, no funding or permits. May be on Busk property.
Big Springs Lake outlet	2.2	No movement towards removal or passage; none likely.
Dwinnell Dam	40.2	Complete barrier. MWCD investigating fish passage options.
Mills Ranch Diversion	47	No movement towards removal, stream incision necessitating larger dam over time.
Mole Richardson Ranch Diversion	51.1	Concrete and rocks, no plan developed for removal or passage.
Edson-Foulke Diversion	52.6	Fish ladder and screen constructed. No plans to remove dam.
Parks Creek MWCD Diversion	12.2	Fish ladder in place, no screen. CDFG considers it a structural barrier. Further refinement may depend on defined bypass flow.
Parks Creek Cardoza Obstruction	1.8	No passage. Landowner considering options.
Parks Creek Low water crossing at I-5	8.2	Major fixes ~ 2006. CDFG investigating upgrading further.
Parks Creek at Stewart Springs Road Culvert	16.5	No plans for improvement.
Little Shasta Musgrave Diversion Dam	12	CDFG funded barrier removal design in 2009.
Hart Diversion	11.8	CDFG installed roughened channel ~ 2005, partially failed ~ 2006, CDFG seeking bids for repairs?
Hart Diversion II	13.1	Status unknown.
Greenhorn Dam, Yreka Creek	0.4	No plans for improvement at present.
Small Reservoir-Weed		No plans for improvement at present.—tributary to Boles Creek, probably Black Butte Spring Creek.
Nielsen-Willow Creek	5.4	Status unknown. [Reportedly from aerial photos.]
Giorgi-Willow Creek	7.4	Status unknown. [Reportedly 10 ft dam.]
Willow Creek at I-5	4.1	8 ft drop at Hwy I-5. No remediation planned at present.
Payot diversion on Oregon Slough	1	Very steep area just below diversion, plus diversion structure. Possibly remediated.
Kuck Diversion on Little Shasta	5	Concrete flashboard structure with fish ladder. Reportedly plugs frequently with debris.
CDFG Diversion on Little Shasta	6.2	Possible barrier when splashboards installed.

Task 5.1: Identify and Prioritize Migration Barriers

A reconnaissance-scale process should be implemented to review migration barriers throughout the basin for fry, juvenile, smolt, and adult life stages, and then prioritize each barrier for implementation to modify or remove barriers. Much of this effort is already underway, and has included treatment of the Fiock obstruction (1995), MWCD Parks Creek Diversion (2006), the Hole in the Ground diversion (2007), Araujo Dam (2007), and Shasta Water Association Dam (2008). The GID diversion structure is also slated to be removed. The Coho Recovery Plan (CDFG 2004) Task Shasta HM-2a identified the following fish passage barrier issues:

- There were six agricultural instream flashboard dams on the mainstem Shasta River that presented partial or complete blockage to passage. All but one have been removed or are in the design stage and scheduled for removal.
- Develop a working group to create a long-term strategy for Greenhorn and Dwinnell dams, including assessment of suitability of habitat upstream, options for passage or modification/removal.
- The Novy-Rice impoundment upstream of Highway 3 is a known water quality barrier due to periodic low dissolved oxygen. This impoundment is also a barrier during the summer months.
- Barriers have been identified by the CDFG Yreka Office on Parks Creek at I-5 [remediated], and at a diversion structure in the lower reaches of Parks Creek, along with several other barriers likely on springs feeding Parks Creek, at approximately three diversion structures in the Foothills reaches of the Little Shasta River [partially remediated], and at several dewatered reaches in summer on both Parks Creek and Little Shasta River.
- Other unidentified non-agricultural barriers likely exist in the watershed, and need to be explicitly identified and remedied.

Timing and location of studies

Several anthropogenic structures have been identified (and have long been known) on the mainstem Shasta River below Dwinnell Dam, several of which have been removed or are in the process of removal. Several tributaries may also need additional assessments of fish passage barriers. Assessments are thus needed in (from high to low priority): mainstem reaches from the Klamath River to Dwinnell Dam, including the upper mainstem Shasta River above Big Springs Creek and the Shasta Canyon reach, including natural barriers during late-summer and fall baseflows; Parks Creek upstream to the Stewart Springs Culvert where a road culvert with a 6 ft drop may be a natural migration barrier; the Little Shasta River from the confluence upstream to Dry Gulch; Yreka Creek upstream to at least Greenhorn Creek; and Willow Creek upstream to the Gazelle-Callahan Road Crossing.

Study methods (empirical, modeled, expert opinion)

Stream reaches not previously surveyed need to be surveyed on the ground with aerial photo maps and/or GPS units to map the location and coordinates of all barriers. Each barrier should be classified as a natural, non-structural, or structural barrier, given a flow range within which passage is problematic, and possible remedies suggested. Barriers should then be prioritized based on each LHT's recovery priority.

Integration with other tasks

Several non-structural, seasonal low-flow barriers may require instream flow analyses by CDFG to determine the minimum flow required to provide good migration condition (Table 12).

Task Deliverables

Barrier information should be catalogued in a GIS database, such as the database already developed by CalTrout and the SVRCD. This database should provide the barrier location, type, remedy, and priority. Flow thresholds that provide fish passage should be estimated for each barrier.

Table 12. Recommended priority life history tactics and instream flow needs for fish passage.

Tactic	Species	Life Stage	Information Needed
1	Chinook, coho, Steelhead	migration	estimate of streamflow threshold that provides unrestricted upstream migration into and through the Shasta Canyon reach
8	Chinook, coho, Steelhead	migration	estimate of streamflow threshold that provides unrestricted upstream and downstream migration to the Parks Creek Headwaters reach
11	Chinook, coho, Steelhead	migration	estimate of streamflow threshold that provides unrestricted upstream and downstream migration to the Little Shasta River Headwaters reach

5.6. Study Plan Element #6: Geomorphic Assessment

Priority Questions:

- What are natural geomorphic processes in the Shasta River mainstem, given the underlying geomorphology and geologic history of the Shasta Valley?
- To what extent have geomorphic processes and channel morphology of the mainstem Shasta River been impaired by the removal of riparian vegetation, grazing and other land uses, diking, and flow and sediment regulation by Dwinnell Dam and tributaries?
- Has reduction in magnitude and frequency of winter floods in the mainstem Shasta River reduced coarse and fine bedload transport rates and delivery to the Shasta Canyon reach and diminished alluvial storage features in the Shasta Canyon?
- To what extent have geomorphic processes and channel morphology of the tributaries been impaired by removal of riparian vegetation, grazing and other land uses, diking, and flow and sediment regulation?
- What actions could be implemented to protect mainstem and tributary reaches with functioning geomorphic process and enhance degraded reaches?
- How has channel degradation impaired salmonid habitat conditions relative to other habitat stressors (e.g., flow diversions, water temperature impairment, migratory barriers, etc.)?

The channel morphology of the mainstem Shasta River and numerous tributaries has been subjected to major and consequential impacts over the course of the past century and longer. Along the mainstem from approximately Yreka Creek (RM 8.6) to Dwinnell Dam (RM 40.6), and along several tributary reaches, cattle grazing and irrigation practices have caused the removal and suppression of riparian vegetation, altered bank stability, increased the input of fine sediment from eroded banks, altered channel migration rates resulting in a wider/shallower channel, reduced connectivity to floodplains and side channels, and reduced input of large wood into the channel (CDFG 2004). Historically, cattle grazing along the mainstem between the Shasta Canyon and Yreka Creek may have affected geomorphic processes and riparian vegetation (D. Webb, personal communication). Construction of Dwinnell Dam in 1928, along with the Parks Creek diversion, greatly diminished the supply of fine and coarse sediment to the Big Springs Complex, creating a new sediment supply and transport equilibrium, as well as eliminating many of the peak flow events that are required for channel, riparian, and macrophyte maintenance. The geomorphic processes that once formed and maintained the habitat components required by a balanced ecosystem are now in a new, smaller scale equilibrium, and likely a substantial factor affecting salmonid habitat, production, and potential for recovery. In the late 1800's and 1900's, portions of the Shasta Canyon were mined for gold, with most of the sediment removed from the channel (D. Webb, personal communication). The processes involved with mining greatly altered sediment supply and storage, floodplain soil composition, vegetation structure and composition, and the channel and floodplain features utilized by salmonids.

Task 6.1: Assess the Upper Mainstem Geomorphology

This task will evaluate the effects of Dwinnell Dam on geomorphic and habitat conditions between Dwinnell Dam (RM 40.6) and Big Springs Creek (RM 33.7). This task will (a) develop a detailed monitoring plan to assess the stream channel and floodplain characteristics; (b) assess current coarse and fine sediment storage volume, sources of sediment supply, and sediment transport rates within the reach; (c) evaluate the magnitude, duration, and frequency of historical and contemporary floodplain inundation and riparian vegetation regeneration; and (d) assess the historical and contemporary flood regime needed to form and maintain healthy channel conditions.

Timing and location of studies

The entire reach should be characterized to describe geomorphic conditions, and alterations compared to a control or reference condition.

Study methods (empirical, modeled, expert opinion)

Geomorphic assessments of historical and contemporary conditions should be conducted along the mainstem and tributaries, targeting specific questions and hypotheses related to channel morphology, salmonid habitat, and riparian vegetation (listed below). Initially, we recommend assessments in the following three priority reaches: (1) the upper mainstem from Dwinnell Dam to the Big Springs Creek confluence and (2) principal salmonid-bearing tributaries including Parks Creek, Little Shasta River, and Yreka Creek, and (3) the Shasta Canyon. These reaches have significant channel and floodplain degradation resulting from Dwinnell Dam, various diversions, gold mining, many land use practices, but also have a high potential for successful salmonid spawning and rearing habitat restoration.

Geomorphic assessments should: (1) research historical documents (e.g., CDWR and USGS records, aerial photographs, etc.), to the extent they are available, to shed light on historical conditions and assess major geomorphic and hydrologic changes that have occurred over the course of the past century of intensive land management; (2) delineate stream and floodway corridor boundaries based on flood records, topography, and contemporary floodplain and riparian vegetation extent; (3) identify fine sediment sources, locations and causes of aggradation, and remedies (see Study Plan Element 7); (4) identify reference reaches that are representative of unaltered river corridor conditions; (5) survey channel cross sections and longitudinal profiles to establish a contemporary baseline condition, and assess the degree of degradation; and (6) identify and prioritize reaches where channel degradation has occurred, and where physical restoration could improve channel morphology and instream habitat conditions. High resolution, orthorectified aerial photographs of the mainstem and tributaries, detailed topography and bathymetry of the flood corridor and channel, and hydraulic sediment transport models are common assessment tools to help guide restoration.

The reach evaluation should be based on available historical documents and field data, and include planform mapping of historic and contemporary geomorphic features, cross section and longitudinal profile surveys, stage-discharge relationships, sediment particle size distribution and identification of major sources of sediment, and integrate with riparian and fish habitat assessments.

Integration with other tasks

This task should be integrated with Task 4.2 riparian vegetation assessments and Element 7 Spawning Gravel Assessment.

Task Deliverables

The task would produce a written description of contemporary geomorphic conditions in the six mile reach between Dwinnell Dam and Big Springs Creek, supported with evidence of alterations from historical conditions, the effects on habitat, and the primary tasks and restoration actions needed to improve the geomorphic functions of this reach. The task would include the establishment of a long-term monitoring program (gaging locations, monumented cross sections, etc.) to evaluate the effectiveness of future management, restoration actions, and the evolution of the restored channel.

Task 6.2: Assess Geomorphic Conditions of Principal Tributaries

The task should assess major geomorphic alterations that are the consequence of streamflow diversions, grazing practices, and other land uses. In order of priority, this task should evaluate Parks Creek, the Little Shasta River, and Yreka Creek as high priority locations, and Willow and Julien creeks as a secondary priority (primarily as sources of gravel to the mainstem). The Parks Creek bottomlands reach downstream of Hwy I-5 has several geomorphically distinct reaches and several tributary springs that should be included in the geomorphic assessment. Sediment supply blockage on Parks Creek resulting from the MWCD diversion structure and from elimination of winter floods should be assessed. Lack of riparian vegetation recruitment in lower reaches of Parks Creek (downstream of Bridgefield Springs) should also be evaluated. The Little Shasta River has several geomorphically distinct reaches that should be evaluated, including three sub-reaches that approach reference conditions (upstream of the Hart Diversion, the Cowley Ranch that has been fenced for 10+ years, and the CDFG Wildlife Area that has had recent riparian vegetation projects and little or no cattle grazing). The Little Shasta River also has beaver dams that should be evaluated for beneficial water temperature effects and provision of high quality coho salmon habitat, as well as for their potential to prevent adult migration in the fall. Yreka Creek offers excellent habitat potential in the lower reach downstream of Hwy 3, but is heavily confined and needs major floodway reconstruction to restore sediment transport and storage processes, floodplains, and aquatic habitat. Actions related to the *Yreka Creek Aquatic Needs Assessment* (NRG et al. 2010) should be supported. The lower three miles of Yreka Creek has potential to be a source of large volumes of coarse sediment suitable for gravel augmentation in Yreka Creek and the Shasta Canyon (McBain & Trush 2010).

Timing and location of studies

Landowner collaboration will be essential for a successful implementation of this task and any restoration efforts identified through these analyses. Geomorphic assessments within Big Springs Complex (upper Shasta River and Parks Creek) are a high priority, but the timing of studies will be based upon access.

Study methods (empirical, modeled, expert opinion)

The reach evaluations should be based on available historical documents and field data, including planform mapping of historical and contemporary geomorphic features, cross section and longitudinal profile surveys, stage-discharge relationships, sediment particle size distribution and identification of major sources of sediment. Significant restoration actions developed from this effort (habitat structures, channel reconstruction, etc.) would include conceptual designs for stakeholder and agency review.

Integration with other tasks

This task should be integrated with Task 4.2 riparian vegetation assessments.

Task Deliverables

The task would produce a written description of contemporary geomorphic conditions in each priority reach, supported by evidence of the alterations from historical conditions, the alterations' effects on habitat, and the primary management and restoration actions necessary to improve the geomorphic functions and associated habitat. The task would include the establishment of a long-term monitoring program (gaging locations, monumented cross sections, etc.) to evaluate the effectiveness of future management and restoration actions and the evolution of the new channel. Significant restoration actions developed from this effort (habitat structures, channel reconstruction, etc.) would include conceptual designs for stakeholder and agency review.

Task 6.3: Assess the Shasta Canyon Reach Geomorphology

This task would determine the extent of coarse sediment alteration from historical conditions and evaluate the effects on salmonid habitat, describe the changes in morphology and vegetation composition and structure, and evaluate sediment supply and transport processes to determine the potential for restoration in the Shasta Canyon reach.

Timing and location of studies

This task is not strongly dependent on timing, except for the possibility of gathering a sufficient range of stream stage data.

Study methods (empirical, modeled, expert opinion)

The reach evaluation would be based on historical documentation and field data, and include planform mapping of historic and contemporary geomorphic features, cross section and longitudinal profile surveys, stage-discharge relationships, sediment particle size distribution and identification of major sources of sediment input (from bank erosion, etc.).

Integration with other tasks

This task may be integrated with the assessment of fish barriers, riparian vegetation assessment, and instream flow studies.

Task Deliverables

The task would produce a written description of contemporary geomorphic conditions in the Shasta Canyon reach, supported by evidence of alterations from historical conditions, the alterations' effects on habitat, and the primary tasks and restoration actions needed to improve the geomorphic functions of this reach. The task would include the establishment of a long-term monitoring program (gaging locations, monumented cross sections, etc.) to evaluate the effectiveness of future management and restoration actions and evolution of the new channel.

5.7. Study Plan Element #7: Spawning Gravel Assessment

In earlier drafts of this Study Plan, a Spawning Gravel Evaluation and Enhancement Plan was recommended as a priority Study Plan Element. As this Study Plan was developed, the Spawning Gravel Evaluation and Enhancement Plan was completed in November 2010 (McBain & Trush 2010), with funding provided by the Pacific States Marine Fisheries Commission and CDFG. This study focused on spawning gravel availability and quality for coho salmon and Chinook salmon. Reaches having known spawning in the mainstem Shasta River and its tributaries were prioritized. Primary study components were:

1. A spawning gravel supply evaluation to provide understanding of historic and contemporary spawning gravel source areas;
2. Monitoring and modeling spawning gravel dynamics to link geomorphic processes of bed mobility and bed scour to streamflow thresholds;
3. A spawning gravel inventory to identify and document the amount of available spawning gravel within primary reaches; and
4. Strategic plans for enhancing spawning gravel supplies and spawning habitat conditions for specific coho and Chinook salmon life history tactics.

Priority Questions

Based on input from and discussion with CDFG and the SVRCD, the Spawning Gravel Evaluation and Enhancement Plan prioritized the following five questions:

- Is spawning gravel available at strategic locations in the watershed that allows emergent fry access to suitable rearing habitat?
- Is coarse sediment being delivered to spawning reaches in the Shasta River mainstem (upper river and Shasta Canyon reach) and in tributaries at rates that do not limit spawning habitat availability at current and future projected population targets?

- Is the quality of spawning gravel impaired by excessive fine sediment and lack of channel maintenance flows?
- Will gravel augmentation encourage Chinook and coho salmon to spawn in the Shasta Canyon at the expense of spawning in the upper mainstem reaches where emergent fry have access to more suitable rearing habitat?
- Will additional spawning gravel availability increase juvenile and smolt production from the Shasta Basin?

Additional priority questions may include:

- Have the spawning gravel amounts and distribution within the Shasta Canyon reach changed from historical conditions? Can historical gravel storage conditions be quantitatively estimated?
- Is the quality and quantity of spawning gravel impaired? If so, how much and where should gravel augmentation be prioritized for Chinook and coho salmon?

The first additional question will likely be impossible to address in a quantitative way. The Spawning Gravel Evaluation and Enhancement Plan addressed the first additional question in a qualitative way, and made recommendations that address the second additional question.

Key Findings of Spawning Gravel Evaluation and Enhancement Plan (McBain & Trush 2010)

Based on the field investigations of contemporary coarse sediment supply and spawning gravel abundance, the following key findings were reported:

- The primary sources of contemporary coarse sediment supply to the Shasta River are from tributaries on the west side of the watershed, downstream of Dwinnell Dam, primarily Parks Creek and Yreka Creek (historically these sources also included Julien Creek, Willow Creek, Dale Creek, and Eddy Creek). The natural coarse sediment supply to the Shasta River has been reduced due to Dwinnell Dam, flow diversions on tributaries, and sediment trapping in tributaries. Reduced coarse sediment supply and flows, particularly immediately downstream of Dwinnell Dam, has reduced channel size and dynamics, and reduced coarse sediment storage available as spawning habitat. Locations closer to Dwinnell Dam and other diversions are impacted more than downstream locations where flow and sediment supply are greater.
- Prior to the gold mining era, the Shasta Canyon naturally had a small coarse sediment supply, limited primarily to Julien Creek, Yreka Creek, ravel and landslides from the canyon walls, and to a lesser extent, coarse sediment routed in from upstream Shasta River reaches. Loss of coarse sediment supply from Julien Creek and upper Yreka Creek (Greenhorn Dam) may result in lower contemporary coarse sediment supply compared to the pre-gold mining era. Although sediment supply to the Shasta Canyon was higher compared to contemporary (highly regulated) supply immediately below Dwinnell Dam, sediment delivery in the Shasta Canyon appears to occur infrequently and episodically, primarily as rockfall, rockslides, and dry ravel, which supply angular rocks to the channel that are initially less suitable as spawning gravel. The overall result has likely been reduced upstream coarse sediment supply to the Shasta Canyon reach, thereby reducing the overall volume of coarse sediment stored in the channel, which can result in (1) increased boulder and bedrock exposure, and (2) reduced spawning gravel quality and quantity as less rounded fluvial sediment enters the reach, shifting the distribution of stored coarse sediments to being more angular. In addition, land use within the Shasta Canyon (mining, diversions, grazing) may have removed much of the riparian vegetation that would have trapped both coarse and fine sediment, built floodplains, and contributed to a channel morphology that provided more diverse salmonid habitat than what is present today. The coarse sediment storage may be limiting Chinook salmon fry production during high escapement years due to superimposition losses.

- The lower mainstem Shasta River from the Little Shasta River confluence to the head of the Shasta Canyon may contain abundant spawning gravel, but lack of access to inventory this reach prevented a more thorough assessment. Because of the low slope and sand-bedded reach upstream of the Little Shasta River confluence, spawning gravel quality in this reach may be poor.
- The low gradient, middle mainstem from Little Shasta River to approximately the GID diversion on the Nelson Ranch contains very little spawning gravel, which is probably representative of unimpaired conditions due to the naturally low slope through this reach.
- The Big Springs Complex contains several significant spawning reaches, each with variable quantity and quality, and in some cases accessibility. Big Springs Creek has abundant spawning gravel with a good particle size distribution, but is laden with a high fine sediment load that may translate to reduced egg survival-to-emergence (Tappel and Bjornn 1983). Additional gravel quality sampling is recommended to better understand overall gravel quality, as well as spatial variation in gravel quality. Ongoing restoration actions may improve spawning gravel quality in the near future. The mainstem Shasta River from Big Springs to Parks Creek also has abundant, high quality spawning gravel, and if provided suitable streamflows during the fall spawning season, would also provide abundant, good quality spawning habitat.
- Two critically important reaches, the Shasta River below Dwinnell Dam and Parks Creek downstream of Hwy I-5, are currently impaired by lack of streamflow during the fall spawning season, lack of consistent coarse sediment delivery from the watershed, and by grazing practices that adversely affect the quality of spawning gravels. With improvements in streamflow, sediment supply processes (or augmentation), and land management, these reaches could provide abundant and high quality spawning habitat for Chinook and coho salmon, and steelhead.
- Substantial spawning gravel likely exist in reaches above Dwinnell Dam and on Parks Creek above Hwy I-5 that were historically important spawning locations for Chinook and coho salmon, but that are currently inaccessible. Field surveys were not conducted in these reaches; instead, aerial photographs and anecdotal information was used to estimate the extent of spawning gravel availability.
- Based on current and projected coho salmon population estimates by CDFG, spawning gravel inventory results suggest that existing spawning gravel quantity can sustain current (and support projected) populations. During higher escapement years, spawning gravel quantity may be limiting for Chinook salmon fry production in certain reaches depending on spawner distribution.

Key Recommendations of Spawning Gravel Evaluation and Enhancement Plan (McBain & Trush 2010)

Spawning gravel supply, storage, and quality within mainstem and tributary spawning areas (i.e., the reaches prioritized for this study) have different implications for Chinook and coho salmon fry production; therefore, an enhancement strategy is proposed that first focuses on coho salmon habitat (due to a significantly reduced population) and then on Chinook salmon habitat. Although current spawning gravel quantity will support current and projected coho salmon populations, gravel quality in the Big Springs reach may limit coho fry production and potential Chinook salmon fry production. Therefore, the Spawning Gravel Evaluation and Enhancement Plan recommended:

- additional gravel quality sampling in the Big Springs Reach and Dwinnell Reach to better quantify overall gravel quality in the reaches, as well as spatial differences;
- a pilot gravel augmentation project in Big Springs Creek to evaluate whether clean, augmented gravel can be sustained (retain good quality over time given fine sediment supply and hydrology);
- Dwinnell Dam pulse flow releases to flush fine sediment and organic material accumulated in pools and mobilize (cleanse) spawning gravel patches on pool-tails (particularly if instream flows can be improved between Dwinnell Dam and Parks Creek confluence);

- Dwinnell Reach sediment sampling and gravel augmentation to investigate current sediment conditions in the reach from Dwinnell Dam downstream to the Parks Creek confluence, and determine if gravel augmentation may be needed to increase spawning habitat (particularly if instream flows can be improved between Dwinnell Dam and Parks Creek confluence);
- Parks Creek sediment routing assessment to restore sediment transport continuity past the MWCD Parks Creek diversion structure and allow sediment to route naturally downstream in Parks Creek.

For Chinook salmon, the Spawning Gravel Evaluation and Enhancement Plan recommended additional gravel quality sampling in the Big Springs Reach and Dwinnell Reach to better quantify overall gravel quality in the reach, as well as spatial differences. The recommended sampling will satisfy information needs for coho and Chinook salmon. Although spawning gravel quantity is sufficient for most escapement years, the Plan also recommended consideration of gravel augmentation in the Big Springs, Dwinnell, and Shasta Canyon reaches to increase spawning gravel quantity to support spawners during high escapement years. However, gravel augmentation in the Shasta Canyon may encourage coho salmon to spawn there instead of colder upstream reaches, and that a 0+ or 1+ coho salmon LHT that includes spawning in the Shasta Canyon may have lower survival rates in most years due to poor water quality in the lower Shasta River and Klamath River.

5.8. Study Plan Element #8: Salmonid Population Studies

Priority Questions:

- What are annual population estimates for juvenile and adult salmonids, and recent abundance trends in the Shasta Basin for all salmonid species?
- Where is critical spawning and rearing habitat in the Shasta Basin?
- What proportion of adult salmonids migrates to the upper mainstem Shasta River to spawn?
- Based on rotary screw trapping data, otoliths, and other sources of information, which life history strategies are most successfully producing abundant juveniles in the Shasta Basin?
- To what extent do individual tributary sub-basins have identifiable signatures recorded in their scale or otolith microchemistry/microstructure that will allow analysis of life history strategies?
- What is the relationship between size and age of juvenile coho and steelhead emigrating from the Shasta River, and probability of survival to return as adult to the Shasta Basin?
- What factors trigger young-of-year salmonid emigration from the Shasta River?
- What is the fate of young-of-year emigrants to the Klamath River?
- What percentage of young-of-year Chinook salmon emigrating from the Shasta River as fry or as juveniles survive to smolt? To what extent does timing of entry into the Klamath River affect survival related to disease infection and Klamath River habitat constraints?
- Do young-of-year coho salmon and steelhead emigrating from the Shasta River as fry or as juveniles survive in the mainstem or tributaries and later smolt, do they return to the Shasta River in fall/winter to rear, or do they die? Do they return to the Shasta River as adults?
- What is the proportion of annual juvenile production from the Shasta River that rear in the upper Shasta River mainstem versus other locations?
- What are average growth rates for juveniles captured while emigrating from the upper mainstem in spring, and recaptured at the SRFCF (i.e., how much growth occurs while migrating down the mainstem Shasta River)?
- Does excessive fine sediment impair spawning gravel and reduce egg-to-emergence survival of spawners?

Information Gaps:

- Empirical data demonstrating successful life history strategies, habitat requirements, distribution and abundance of suitable habitat, and factors constraining survival and abundance for all salmonid species.

The CDFG Northern California North Coast Region (NCNRC) Fisheries staff developed a long-term monitoring plan for salmonids in the Shasta and Scott river watersheds (Chesney et al. 2007). Population monitoring will assess the current status and future trends in salmonid populations and the success of various recovery efforts. This is a large and diverse study component. Selection of specific study designs must weigh the costs and data/knowledge benefits against numerous other information needs. Monitoring objectives are:

- Estimate annual juvenile salmonid production within each basin;
- Estimate the number and distribution of adults returning to each basin, annually;
- Determine various juvenile life history elements important in determining population limiting factors;
- Determine the location of critical spawning and juvenile rearing areas;
- Develop improved monitoring techniques.

The CDFG study plan for the Shasta River and Scott River basins contains tasks to address high priority objectives, and should be implemented as described. Monitoring objectives were prioritized by CDFG into A and B priorities. In this Study Plan, we suggest "Recommended Considerations" which may be included in the implementation of these monitoring tasks. These additional objectives and suggestions are presented following a summary of each CDFG study plan element. The NCNRC Monitoring Plan included detailed information and recommendations on the timing and location of studies, study methods, and task costs. This information is not repeated here.

Priority projects for the Shasta River, using the CDFG study plan (Chesney et al. 2007) Task numbers are:

Task 8A1: Continue Monitoring Juvenile Salmonid Outmigrant Abundance

This task will continue operation of a rotary screw trap (RST) near the mouth of the Shasta River to estimate juvenile/smolt Chinook salmon, coho salmon, and steelhead outmigrants. The study also proposes to begin screw trap operations earlier in the season (beginning October 1) to determine if 0+ coho salmon are leaving the Shasta River in the fall. Although a lower priority, an upstream juvenile migrant trap should also be considered in conjunction with the downstream trap to determine if juvenile coho salmon are entering the Shasta River from the Klamath River.

Recommended Considerations:

Evidence from several past (Shapovalov and Taft 1954 and Kabel and German 1967) and recent studies (Bond 2006 and Ricker 2002) indicates that size of fish at ocean entry (or as a proxy, at emigration from the Shasta Basin) may determine survival success. Juvenile outmigrant monitoring should determine the relationship between fish size and survival success by developing smolt-to-adult return curves from scale and adult otolith microstructural analyses. This information, coupled with information on (1) stream origin of juveniles, (2) successful life history tactics and recruitment success, and (3) growth rates (a measure of productivity) will prove critical in guiding recovery efforts.

In addition, combining downstream migrant trapping with PIT tagging or other marking experiments in tributaries would: (a) estimate growth rates from the time of marking to recapture at the RST (i.e., to evaluate rearing productivity in the lower tributary and the mainstem reaches), (b) estimate juvenile survival from specific marking locations to the Shasta River mouth, (c) analyze effects of environmental conditions or cues (e.g., onset of irrigation season, water temperatures, etc.) on emigration timing and rates, and (d) obtain growth and health conditions as the fish migrate through the Klamath River and estuary for captured individually identifiable outmigrants.

Task 8A2-2: Continue Adult Escapement Counts at the Shasta River Fish Counting Facility

This task will maintain the fish weir and video counting station in the Shasta River to count upstream migrating adult Chinook salmon, coho salmon, steelhead, and lamprey, and develop seasonal escapement estimates.

Task 8B1: Assess Coho Rearing in the Shasta River

This study should continue operation of a RST at the TNC Nelson Ranch to trap and PIT tag rearing juvenile coho salmon, estimate their range of rearing habitat use in the upper Shasta River during spring and summer (March 1 to August 30), attempt a smolt production estimate, then compare upper river and lower river production estimates to determine the percentage of smolt production from the upper river, and evaluate if early emigrant 0+ coho salmon from the lower Shasta River later return and rear in the lower Shasta River. An upstream migrant trap may be required to evaluate upstream movement and non-natal rearing (e.g., Klamath River juveniles moving into the Shasta River).

Recommended Considerations:

The Coho Recovery Plan (CDFG 2004) recommends task HM-1a as a Tier-1, near-term Priority to: "Identify existing areas successfully used for rearing and potential rearing areas by conducting entire mainstem channel-length survey [of]: 1) water temperature refugia and 2) habitat suitability based on slope and water velocity. Estimate carrying capacity and fish utilization of rearing habitat. Identify spawning areas and determine accessibility to rearing areas."

If access is granted from private landowners, a survey of summer juvenile coho salmon rearing habitat along the entire mainstem and tributaries should be a high priority, including thermal refugia (including rearing habitat at beaver dams) inventoried in the tributaries and along the mainstem channel. The survey should employ seining, direct observation and traps at regular intervals (e.g., every mile) or at strategic locations along the mainstem (e.g., at bridges, diversion dams, tributary confluences) to determine presence of rearing coho salmon.

If juvenile abundance is sufficiently high, habitat use data should be collected (water depth, velocity, cover components, substrate, and water temperature) to broaden the range of sampled habitat. The temperature data collection plan (Task 3.1) addresses general temperature trends along the mainstem, but will not provide data on the availability of local temperature refugia and temperature stratification (addressed in Task 3-1).

In addition to focusing on production estimates from upstream and downstream RST sites, the study should evaluate survival and individual fish growth rates for PIT tagged fish (not just the size class distribution) during migration in the mainstem between trapping sites. This information should be evaluated in light of temperature conditions during pre-smolt and smolt downstream migration, and also compared to survival and growth estimates (if available) for the mainstem Klamath River. The objective would be to determine if better spring smolt growth conditions are needed in the Shasta River mainstem to offset mainstem Klamath River conditions, or conversely, if smolt emigration from the Shasta River could be encouraged sooner, knowing that rearing and growth conditions in the Klamath River are suitable.

Task 8B2: Track Adult Coho with Radio-telemetry

This study will use the SRFCF weir station to capture adult coho salmon, install radio tags, and then track their migration onto spawning grounds to observe spawning distribution, relative abundance, migration behavior, and timing.

Recommended Considerations:

If possible, the radio-telemetry study should attempt to determine to what extent known instream diversion structures block or impede the upstream migration of adult coho salmon.

Consider the effects of the weir operation, especially during low-flow periods, in disrupting upstream migration and distribution of adult spawners.

Task 8B4: Install a Resistance Board and Adult Video Weir at the Nelson Ranch

This study will install a floating resistance board weir and video fish counting facility in the upper Shasta River in the TNC Nelson Ranch reach to count adult salmonids returning to spawn in the upper river and observe the run timing.

Recommended Considerations:

The proposed weir will count the number of spawners using the upper mainstem, Big Springs, and Parks Creek. Combined with escapement estimates from the SRFCF, researchers can then estimate the proportion of the total adult escapement using the upper river. Researchers should also determine if adult spawners migrate into Yreka Creek or the Little Shasta River, either through collection of anecdotal information during the period of upper weir operation, or through more rigorous sampling methods (e.g., repeat carcass surveys). This task should be integrated with assessment of flow-related accessibility.

Scale samples, tissue samples, and otoliths should be collected from all (or a representative subset of) adult coho salmon encountered during the study, for potential use later to determine the origin and migratory patterns of successful LHTs.

Task 8B6: Study Fish Scale and Otolith Microstructure and Microchemistry of Juvenile and Adult Salmonids

This proposed pilot study for the Shasta River will attempt to identify successful LHTs for coho salmon and quantify recruitment success of early out-migrating age 0+ coho salmon from the Shasta River. The study will collect scale samples from coho salmon collected at the SRFCF to determine age and growth rates, then compare this information to population and environmental variables to make inferences on factors influencing recruitment (year class strength). The study should also examine otolith and scale chemistry to establish predictable chemical signatures for individual hatching and rearing areas used by fish.

Recommended Considerations:

Using scales and otoliths collected in Task B4, a high priority for this task should be to identify the stream origin of returning adults, juvenile growth rates of those fish, and the fish size and age at exit from the Shasta River (and at ocean entry check) (i.e., answer the question: how big were successful recruits when they left the Shasta River and when they left the Klamath River to enter the ocean). Juvenile fish size of successfully returning adults should then be compared to the size class distribution of juveniles trapped at the SRFCF weir to determine the proportion of emigrating juveniles that are attaining the size of successfully returning adults, and the origin of those fish.

- Consider using microstructural analysis to determine rearing areas with good rearing conditions.
- Collect tissue samples for future genetic analysis for harvest and disease management.
- Collect adult otoliths to evaluate successful life history strategies.

Task 8C: Assess Other Fishes, Amphibian and Reptile Species and their Habitats

The primary focus of this Study Plan is anadromous salmonid populations and their habitat within the Shasta Basin. However, for salmonids to recover and thrive, the river must function as an ecosystem. Consideration must be given to all members of the aquatic community. This does not imply all members of the aquatic community must be studied, but there are several non-salmonid species that warrant additional attention. Native non-salmonid fishes that may warrant individual assessment include Pacific lamprey (*Lampetra tridentata*) and Klamath River lamprey (*Lampetra similes*), of which little is known in the Shasta River. Several non-native species present in the Shasta River are piscivorous centrarchids (Moyle 2002) that prey on juvenile salmonids in other river systems (e.g., the Sacramento and San Joaquin River basins, and the Bay-Delta). An assessment of the distribution and abundance of these native and non-native fish species, and potential for predatory impacts on juvenile salmonids, is recommended. In addition to salmonids, native and non-native amphibians, western pond turtles, and some indicator avian species should be included as key indicators of a healthy ecosystem.

5.9. Study Plan Element #9. Develop Population Model

Priority Questions:

- Given the low abundance of coho salmon, and the numerous alternative restoration actions that could improve productivity, carrying capacity, and survival, which actions would most benefit salmonids while simultaneously reducing the risk of greater population impairment?
- Which LHTs are capable of producing the most juveniles and smolts?
- What is the current and reasonably attainable carrying capacity for coho salmon rearing in the mainstem Shasta River and in tributaries during the summer irrigation season, particularly in Big Springs Creek, Parks Creek, and the Little Shasta River?

Eventually, a population model should be developed for coho salmon and Chinook salmon that quantifies the relationships between physical habitat, carrying capacity, and fish production well enough to simulate production benefits of alternative recovery scenarios, habitat variable targets (e.g., water temperature), and water management scenarios. However, many high priority LHTs do not require a model to justify taking restoration actions, including prescribing interim instream flows. The model should include the entire mainstem Shasta River up to Dwinnell Dam, Parks Creek, Big Springs Creek, Little Shasta River, and Yreka Creek. The population model should be integrated with results from water balance modeling, instream flow studies, temperature monitoring and modeling, and fish population studies, to allow water managers the tools necessary to balance competing water demands. The model should be used to evaluate the extent of feasible population recovery with and without provision of fish migratory access above Dwinnell Dam and the MCWD diversion on Parks Creek or Dwinnell Dam removal.

This Study Plan has the goal of recovering LHTs, which is essential to basin-wide population recovery. The recovery of several key coho salmon and Chinook salmon LHTs will contribute significantly to future population abundance and stability. Population modeling is not necessary to justify recovery of priority LHTs. For example, our understanding is sufficient to know that recovery of the Big Springs Complex 1+ coho LHT is essential to coho salmon recovery. However, there is no guarantee that the TWG will identify and prioritize all the recoverable LHTs necessary to sustain healthy basin-wide populations. The Coho Recovery Plan (CDFG 2004) ultimately will need predicted (i.e., modeled) numerical population goals to inform tradeoffs between recoverable LHTs.

Expectations for what a population model could provide are often considerably greater than what a population model can actually do. Most population models require many assumptions. The compounding error of multiple, interactive model parameters often can generate population estimates with error margins too wide to be useful. Therefore, the TWG must decide, early in the process, what modeling error will be tolerable. Given the urgency for immediately improving annual coho salmon runs, the Recovery Plan can/should proceed as population modeling for the Shasta Basin is being developed. A critical parameter for population modeling and IFN studies is development of smolt-to-adult return probabilities for each anadromous species. A study should be considered for identifying where, within each high priority LHT, smolt mortality is/could be greatest.

In addition to evaluating tradeoffs between LHTs, a population model that quantifies the relationships between physical habitat, carrying capacity, and fish production well enough to simulate production benefits of alternative recovery scenarios, habitat variable targets (e.g., water temperature), and water management scenarios would be extremely valuable to guide the Recovery Plan. The model should include the entire mainstem Shasta River up to Dwinnell Dam, Parks Creek, Big Springs Creek, Little

Shasta River, and Yreka Creek, and be integrated with results from water balance modeling, instream flow studies, temperature monitoring and modeling, and fish population studies, to allow water managers the tools necessary to balance competing water demands.

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7. APPENDICES

7.1. Appendix A: Primary documents reviewed during preparation of this Study Plan.

California Department of Fish and Game (CDFG). 2004. *Recovery Strategy for California Coho Salmon*. Report to the California Fish and Game Commission, Species Recovery Strategy 2004-1. California Department of Fish and Game, Native Anadromous Fish and Watershed Branch. Sacramento, CA.

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7.2. Appendix B. General Descriptions of Salmonid Life Histories

The generalized life histories, historical and contemporary fish distributions, and population decline of anadromous salmonids in the Klamath and Shasta basins have been researched and documented in numerous published reports and books, and is not repeated for this Study Plan. For the reader's convenience, sections describing the general life histories of Chinook, coho, and steelhead were excerpted from the CDFG Biological Needs Assessment (CDFG 1997), the Coho Salmon Recovery Strategy (CDFG 2004), and [spring run] and presented here. Detailed reviews and descriptions can be found in the following documents:

California Department of Fish and Game (CDFG). 2004. *Recovery Strategy for California Coho Salmon*. Report to the California Fish and Game Commission, Species Recovery Strategy 2004-1. California Department of Fish and Game, Native Anadromous Fish and Watershed Branch. Sacramento, CA.

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7.2.1. Fall-run Chinook Salmon

From Biological Needs Assessment (CDFG 1997):

"Adult fall Chinook salmon begin entering the Klamath River in late July, ascending the Klamath River and its tributaries between August and December, depending on the tributary and its location in the drainage. Chinook salmon begin entering the Shasta River in [August and] September with adult immigration continuing into November. The majority of spawning occurs during October and November. The period of egg incubation begins as soon as spawning occurs and is usually completed before March (Leidy & Leidy 1984). Emergence, the period in which developing fish swim up through the gravel and enter the stream, takes place late January through March. Three Chinook salmon early life history phases involving the timing of emigration have been identified within the Klamath River basin (KRBFTF 1991). The three phases or life history "types" are outlined below.

Type I: Outmigration occurs in spring within several months of fry emergence.

Type II: Juveniles spend their first spring and summer in stream and emigrate in the fall.

Type III: Juveniles spend an entire year in the stream and emigrate in the spring of the following year.

Juvenile salmon ready to descend their natal streams and enter the estuary and ocean are called "smolts". Smoltification is a process involving chemical/hormonal changes in the body that prepare the fish for a saltwater environment. Young-of-the-year (YOY) smolts from the Shasta River system generally emigrate between February and mid-June (Type 1 life history phase) (Leidy and Leidy 1984). Through the use of fyke traps, Jong (1994) found YOY Chinook leaving the Shasta River as early as January through and as late as late-June.

In recent years CDFG has observed juvenile Chinook residing in the Shasta River beyond June. This indicates that not all juvenile Chinook are following the "Type I" emigration pattern. A relatively smaller emigration of juvenile Chinook salmon smolts has been noted in the fall. "Type II" or "Type III" emigration tendencies may exist among Shasta River Chinook or environmental conditions and irrigation diversion structures cause fish to remain in the upper portion of the river beyond their normal tendency to do so. Additional studies are needed to evaluate Shasta River Chinook salmon rearing and emigration patterns.

After descending the Shasta River, fall-run Chinook salmon enter the Klamath River en route to the estuary and ultimately the Pacific Ocean. In the ocean, Chinook salmon normally mature at three to five years of age, although a small portion of each year's brood return are sexually mature two-year old males known as “jack“ or "grilse" salmon.”

7.2.2. Coho Salmon

From Coho Salmon Recovery Strategy (CDFG 2004):

> *“Adult Coho Salmon enter fresh water from September through January in order to spawn. In the short coastal streams of California, migration usually begins between mid-November and midJanuary (Baker and Reynolds 1986). Coho Salmon move upstream after heavy rains have opened the sand bars that form at the mouths of many California coastal streams, but may enter larger rivers earlier. On the Klamath River, Coho Salmon begin entering in early to mid-September and reach a peak in late September to early October. On the Eel River, adult Coho Salmon return four to six weeks later than on the Klamath River (Baker and Reynolds 1986). Arrival in the upper reaches of these streams generally peaks in November and December. Timing varies by stream and/or flow (Neave 1943; Brett and MacKinnon 1954; Ellis 1962) (Figure 2-5).*
>
> *Generally, Coho Salmon spawn in smaller streams than do Chinook Salmon. In California, spawning occurs mainly from November to January, although it can extend into February or March if drought conditions are present (Shapovalov and Taft 1954). In the Klamath and Eel rivers, spawning occurs in November and December (USFWS 1979). Shapovalov and Taft (1954) note that females usually choose spawning sites near the head of a riffle, just below a pool, where the water changes from a laminar to a turbulent flow and there is a medium to small gravel substrate. The female digs a redd (nest) by turning partly on her side and using powerful, rapid movements of the tail to dislodge the gravels, which are transported a short distance downstream by the current. Repeating this action creates an oval-to-round depression at least as deep and as long as the fish. Eggs and milt (sperm) are released into the redd, where, because of the hydrodynamics of the redd, they tend to remain until they are buried. Approximately one-hundred or more eggs are deposited in each redd. The fertilized eggs are buried by the female digging another redd just upstream. The flow characteristics of the redd location usually ensure good aeration of eggs and embryos, and the flushing of waste.*
>
> *Larger Coho Salmon produce more eggs and there is a definite tendency for fecundity to increase from California to Alaska (Sandercock 1991). Average Coho Salmon fecundities, as determined by various researchers working on streams in British Columbia, Washington, and Oregon, range from 1,983 to 2,699 and average 2,394 eggs per female (Sandercock 1991). The fecundity of Coho Salmon in Washington streams ranged from 1,440 to 5,700 eggs for females that were 44 cm to 72 cm in length (Scott and Crossman 1973).*

In California, eggs incubate in the gravels from November through April. The incubation period is inversely related to water temperature. California Coho Salmon eggs hatch in about forty-eight days at 48°F, and thirty-eight days at 51.3°F (Shapovalov and Taft 1954). After hatching, the alevins (hatchlings) are translucent in color (Shapovalov and Taft 1954; Laufle et al. 1986; Sandercock 1991). This is the Coho Salmon's most vulnerable life stage, during which they are susceptible to siltation, freezing, gravel scouring and shifting, desiccation, and predation (Sandercock 1991; Knutson and Naef 1997; Pacific Fisheries Management Council [PFMC] 1999). Alevins remain in the interstices of the gravel for two to ten weeks until their yolk sacs have been absorbed, at which time their color changes to that more characteristic of fry (Shapovalov and Taft 1954, Laufle et al. 1986, Sandercock 1991). The fry are silver to golden with large, vertical, oval, dark parr marks along the lateral line that are narrower than the spaces between them.

Fry emerge from the gravel between March and July, with peak emergence occurring from March to May, depending on when the eggs were fertilized and the water temperature during development (Shapovalov and Taft 1954). They seek out shallow water, usually moving to the stream margins, where they form schools. As the fish feed heavily and grow, the schools generally break up and individual fish set up territories. At this stage, the fish are termed parr (juveniles). As the parr continue to grow and expand their territories, they move progressively into deeper water until July and August, when they inhabit the deepest pools. This is the period when water temperatures are highest, and growth slows (Shapovalov and Taft 1954). Food consumption and growth rate decrease during the winter months of highest flows and coldest temperatures (usually December to February). By March, parr again begin to feed heavily and grow rapidly.

Rearing areas used by juvenile Coho Salmon are low-gradient coastal streams, lakes, sloughs, side channels, estuaries, low-gradient tributaries to large rivers, beaver ponds, and large slackwaters (PFMC 1999). The most productive juvenile habitats are found in smaller streams with low-gradient alluvial channels containing abundant pools formed by large woody material (LWD). Adequate winter rearing habitat is important to successful completion of Coho Salmon life history.

After one year in fresh water, smolts begin migrating downstream to the ocean in late March or early April. In some years emigration can begin prior to March and can persist into July (Shapovalov and Taft 1954; Sandercock 1991). Weitkamp et al. (1995) indicate that peak downstream migration in California generally occurs from April to early June. Factors that affect the onset of emigration include the size of the fish, flow conditions, water temperature, dissolved oxygen (DO) levels, day length, and the availability of food. In Prairie Creek, Bell (2001) found that a small percentage of Coho Salmon remain more than one year before emigrating to the ocean. Low stream productivity, due to low nutrient levels or cold water temperatures, can contribute to slow growth, potentially causing Coho Salmon to postpone emigration (PFMC 1999). There may be other factors that contribute to a freshwater residency of longer than one year, such as late spawning, which can produce fish that are too small at the time of smolting to migrate to sea (Bell 2001).

The amount of time Coho Salmon spend in estuarine environments is variable, and the time spent there is less in the southern portion of their range (PFMC 1999). Upon entry into the ocean, the immature salmon remain in inshore waters, congregating in schools as they move north along the continental shelf (Shapovalov and Taft 1954; Anderson 1995). Most remain in the ocean for two years; however, some return to spawn after the first year, and these are referred to as grilse or jacks (Laufle et al. 1986). Data on ocean distribution of California Coho Salmon are sparse, but it is believed that the Coho Salmon scatter and join schools from Oregon and possibly Washington (Anderson 1995)."

7.2.3. Steelhead

From Biological Needs Assessment (CDFG 1997):

"Runs of steelhead identified in the Klamath River basin are spring run (better known as summer steelhead), fall-run, and winter-run. The runs are classified based on the season of the year they enter the Klamath River as adults. Spring-run, or summer steelhead, do not presently occur in the Shasta River. Because of their very similar life histories, the fall-run and winter-run steelhead are discussed together.

The initial stages of the fall-run begin with the movement of small migrants called "half-pounders" during August through October. Half-pounders spend one to three years in a freshwater environment and less than a year in the ocean. These small, immature fish spend several months in the Klamath River and its major tributaries, tending to remain primarily in the lower portion of the Klamath River basin below the confluence of the Scott River. The half-pounder run is unique in that it occurs in large numbers in only two river systems in California (Klamath and Eel rivers) and in Oregon's Rogue River (Rankel 1978).

The arrival of greater numbers of larger, sexually mature steelhead in October and November marks the start of the fall-run. The winter-run steelhead migration overlaps the fall-run, with winter run fish beginning to enter the Klamath River in December. The majority of the winter-run steelhead enter their natal streams to spawn from December through April. Steelhead spawning takes place in the Shasta Basin beginning around mid-December, and continues through April (Leidy and Leidy 1984). It is uncertain whether fall-run and winter run steelhead spawn at different times or select different locations for spawning within the Shasta basin. Steelhead may spawn more than once during their life, generally returning to the ocean after spawning.

Steelhead eggs incubate in the Shasta River from midDecember through mid-June (Leidy and Leidy 1984). The actual incubation period is dependent on water temperature. Cold water temperatures impede egg development and delay hatching. Emergence of Shasta River steelhead alevins generally occurs between March and June (Leidy and Leidy 1984). Based on CDFG trapping results in the Shasta River during the winter and springs of 1986-1989 and 1992 (Jong 1994 and CDFG files, Yreka), steelhead emergence can occur as early as the first week of February.

Juvenile steelhead usually spend one to three years (most two years) in their nursery stream environment before emigrating to the ocean. Size appears to be a determining factor for smoltification and emigration. Smoltification generally occurs when fish reach approximately six inches in length (Lanse 1972 as reported in Leidy and Leidy 1984). Outmigration of steelhead smolts is known to occur between February and June. After one to four years in the ocean, steelhead enter the Klamath River system for their first spawning with the possibility of additional runs in subsequent years (Leidy and Leidy 1984)."

7.2.4. Spring-run Chinook Salmon

Spring run Chinook salmon enter the Klamath River from late March through June (Snyder 1931, Leidy and Leidy 1984). In the Klamath River Basin, this run timing allows(ed) spring-run Chinook salmon to migrate into headwater and upper tributary reaches that are less accessible to fall-run Chinook salmon because of low flows and high temperatures in the lower reaches during fall (Moyle 2002). Adults typically enter freshwater before their gonads are fully developed, migrate to their upstream destinations, and aggregate in deep pools, where they hold for 2-4 months before spawning. Temperatures below 16°C generally are regarded as necessary for spring-run Chinook salmon because susceptibility to disease and other sources of mortality and loss of viable eggs increase as temperature increases (McCullough 1999). In the Salmon River, however, temperatures of holding pools often exceed 20°C (West 1991, Moyle et al. 1995). Spawning begins in mid-September and is typically completed by late-October in the Salmon River. Leidy and Leidy (1984) suggest spawning extends into November. West et al. (1990) found that spring-run Chinook salmon in the North and South Fork Salmon River selected low gradient riffles for spawning. Egg incubation is lengthy as a result of cold winter water temperatures typically found in the upper basins. Leidy and Leidy (1984) suggest that emergence begins in December and continues through February for spring-run Chinook salmon in the Klamath system. In other systems supporting spring-run Chinook salmon, the onset of emergence is often delayed until March, and may extend until early June.

Like coho, spring-run Chinook salmon have a stream type of life history, which means that juveniles may remain in streams for up to a year or more before moving to the sea (Healey 1991). Because most of the streams in which they reside are also likely to be used by juvenile coho salmon, interactions between the two species are likely (see O'Neal 2002 for information specific to the Klamath). As described for fall-run Chinook salmon, three distinct juvenile life history patterns are observed in the Klamath River:

Type I: Outmigration occurs in spring within several months of fry emergence.

Type II: Juveniles spend their first spring and summer in their natal stream and emigrate in the fall.

Type III: Juveniles spend an entire year in their natal stream and emigrate in the following spring.

Sullivan (1989) found Type II and III fish were most common to the Salmon and Scott rivers, possibly indicating the presence of spring-run Chinook salmon in either or both of those systems. Snyder (1931) reported that spring-run Chinook salmon were present only in upper Klamath tributaries (Oregon), the Shasta River, and the Salmon River, and had mostly been extirpated by the late 1800's.

7.3. Appendix C: Salmonid Habitat Requirements

7.3.1. Physical Habitat Requirements for Salmonids

The habitat requirements of anadromous salmonids are probably the most studied aspect of salmonid ecology. Extensive research has been conducted over several decades and across nearly the entire geographic distributions of the species. Much of the literature focuses on documenting mesohabitat types used by salmonids (pools, riffles, and runs etc.), and measuring a small subset of microhabitat parameters – water depth, velocity, stream substrate type and size distribution, the presence and types of cover, volume of large wood accumulations in streams occupied by juvenile salmonids, and water temperatures – suitable during the various life stages for each species. This Study Plan briefly summarizes the general habitat requirements for the freshwater life stages of Chinook, coho, and steelhead. The reader is also referred to several comprehensive summaries and literature reviews for more information:

Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pp. 83-138 *in* W.R. Meehan, ed. *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*. American Fisheries Society, Special Publication 19, Bethesda, MD.

Groot, C. and L. Margolis (eds.). 1991. *Pacific Salmon Life Histories*. University of British Columbia Press, Vancouver, BC.

Lestelle, L.C. 2007. *Coho Salmon (Oncorhynchus kisutch) Life History Patterns in the Pacific Northwest and California, March 2007*. Prepared for the U.S. Bureau of Reclamation, Klamath Office. Biostream Environmental, Poulsbo, WA.

Moyle, P.B. 2002. *Inland Fishes of California*. University of California Press, Berkeley, CA.

7.3.2. Water Temperature Requirements for Salmonids

Water temperature influences the development and survival of salmonids by affecting different physiological processes such as growth and smoltification. Water temperature also affects migration timing, ability to cope with predation and disease, and exposure to contaminants.

As with salmonid general life history patterns and habitat requirements and water temperature requirements for salmonids have been well documented, and is not repeated for this Study Plan. The most authoritative documentation of water temperature requirements for anadromous salmonids in the Shasta Basin is Shasta River TMDL Staff Report (NCRWQCB 2006), and specifically Appendix 28Ae (Carter 2005). Pertinent excerpts of this report are reproduced below; additional in-depth reviews and descriptions are in the following documents:

CDWR. 1988. *Water Temperature Effects on Chinook Salmon (*Oncorhynchus tshawytscha*) with Emphasis on the Sacramento River: A Literature Review*. California Department of Water Resources, Northern District Office. Red Bluff, CA.

Myrick, C.A. and J.J. Cech, Jr. 2001. *Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations*. Bay-Delta Modeling Forum Technical Publication 01-1. Published electronically by the Bay-Delta Modeling Forum at http://www.sfei.org/modelingforum/.

U.S. Environmental Protection Agency (USEPA). 2003. *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*. Report EPA 910-B-03-002. U.S. Environmental Protection Agency, Region 10, Office of Water. Seattle, WA.

From Shasta River TMDL Temperature Appendix 4 (Carter 2005):

Introduction and Purpose

Temperature is one of the most important environmental influences on salmonid biology. Most aquatic organisms, including salmon and steelhead, are poikilotherms, meaning their temperature and metabolism is determined by the ambient temperature of water. Temperature *therefore influences growth and feeding rates, metabolism, development of embryos and alevins, timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration, and the availability of food. Temperature changes can also cause stress and lethality (Ligon et al. 1999). Temperatures at sub-lethal levels can effectively block migration, lead to reduced growth, stress fish, affect reproduction, inhibit smoltification, create disease problems, and alter competitive dominance (Elliott 1981, USEPA 1999). Further, the stressful impacts of water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival (Ligon et al. 1999).*

*A literature review was performed to evaluate temperature needs for the various life stages of steelhead trout (*Oncorhynchus mykiss*), Coho Salmon (*Oncorhynchus kisutch*), and Chinook Salmon (*Oncorhynchus tschawytscha*). The purpose of this review was to identify temperature thresholds that are protective of salmonids by life stage, as a basis for evaluating Klamath River basin stream temperatures.*

This review included USEPA temperature guidance, Oregons' and Washingtons' temperature standards reviews, reports that compiled and summarized existing scientific information, and laboratory and field studies. When possible, species-specific needs were summarized by the following life stages: migrating adults, spawning and incubation/emergence, and freshwater rearing and growth. Additionally, the effects of temperature on disease and lethality are also discussed. Some of the references reviewed covered salmonids as a general class of fish, while others were species specific.

Temperature Metrics

In considering the effect of temperature on salmonids, it is useful to have a measure of chronic (i.e. sub-lethal) and acute (i.e. lethal) temperature exposures. A common measure of chronic exposure is the maximum weekly average temperature (MWAT). The MWAT is the maximum seasonal or yearly value of the mathematical mean of multiple, equally spaced, daily temperatures over a running seven-day consecutive period (Brungs and Jones 1977, p.10). In other words, it is the highest single value of the seven-day moving average temperature. A common measure of acute effects is the instantaneous maximum. A third metric, the maximum weekly maximum temperature (MWMT), can be used as a measure of both chronic and acute effects. 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 over a running seven-day consecutive period. The MWMT is useful because it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day.

Much of the information reported in the literature characterizes temperature needs with terms such as "preferred" or "optimum". Preferred stream temperatures are those that fish most frequently inhabit when allowed to freely select temperatures in a thermal gradient (USEPA 1999). An optimum range provides suitable temperatures for feeding activity, normal physiological response, and normal behavior (without symptoms of thermal stress) (USEPA 1999). Optimal temperatures have also been described as those temperatures at which growth rates, expressed as weight gain per unit of time, are maximal for the life stage (Armour 1991).

Salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. The USEPA (2001) in their Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids makes the case that there is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards.

Climate conditions vary substantially among regions of the State and the entire Pacific Northwest. …Such [varying climatic] conditions could potentially have led to evolutionary

> *adaptations, resulting in development of subspecies differences in thermal tolerance. …[However,] the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (Mathur & Silver 1980, Konecki et al. 1993, both as cited in USEPA 2001).*

Additionally:

> *There are many possible explanations why salmonids have not made a significant adaptation to high temperature in streams of the Pacific Northwest. Temperature tolerance is probably controlled by multiple genes, and consequently would be a core characteristic of the species not easily modified through evolutionary change without a radical shift in associated physiological systems. Also, the majority of the life cycle of salmon and steelhead is spent in the ocean rearing phase, where the smolt, sub-adults, and adults seek waters with temperatures less than 59°F (15°C) (Welch et al. 1995, as cited in USEPA 2001).*

As a result, literature on the temperature needs of coho salmon, Chinook salmon and steelhead stemming from data collected in streams outside Northern California are cited in this document

<u>Selection of TMDL Temperature Thresholds</u>

As a result of this literature review [presented in its entirety in Appendix C], Regional Water Board staff has selected chronic and acute temperature thresholds for evaluation of Klamath River basin stream temperatures. Chronic temperature thresholds (MWMTs) were selected from the USEPA document EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards (2003), and are presented in Table C-1. The Region 10 guidance is the product of a three-year interagency effort, and has been reviewed by both independent science review panels and the public. Acute lethal temperature thresholds were selected based upon best professional judgment of the literature, and are presented in Table C-2.

Table C-1. Temperature thresholds from USEPA 2003.

Life Stage	MWMT (°C)
Adult Migration	20
Adult Migration plus Non-Core[1] Juvenile Rearing	18
Core[2] Juvenile Rearing	16
Spawning, Egg Incubation, and Fry Emergence	13

1 Non-Core is defined as moderate to low density salmon and trout rearing usually occurring in the mid or lower part of the basin (moderate and low not defined).
2 Core is defined as areas of high density rearing (high is not specifically defined).

Table C-2. Lethal temperature thresholds (from USEPA 2003).

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

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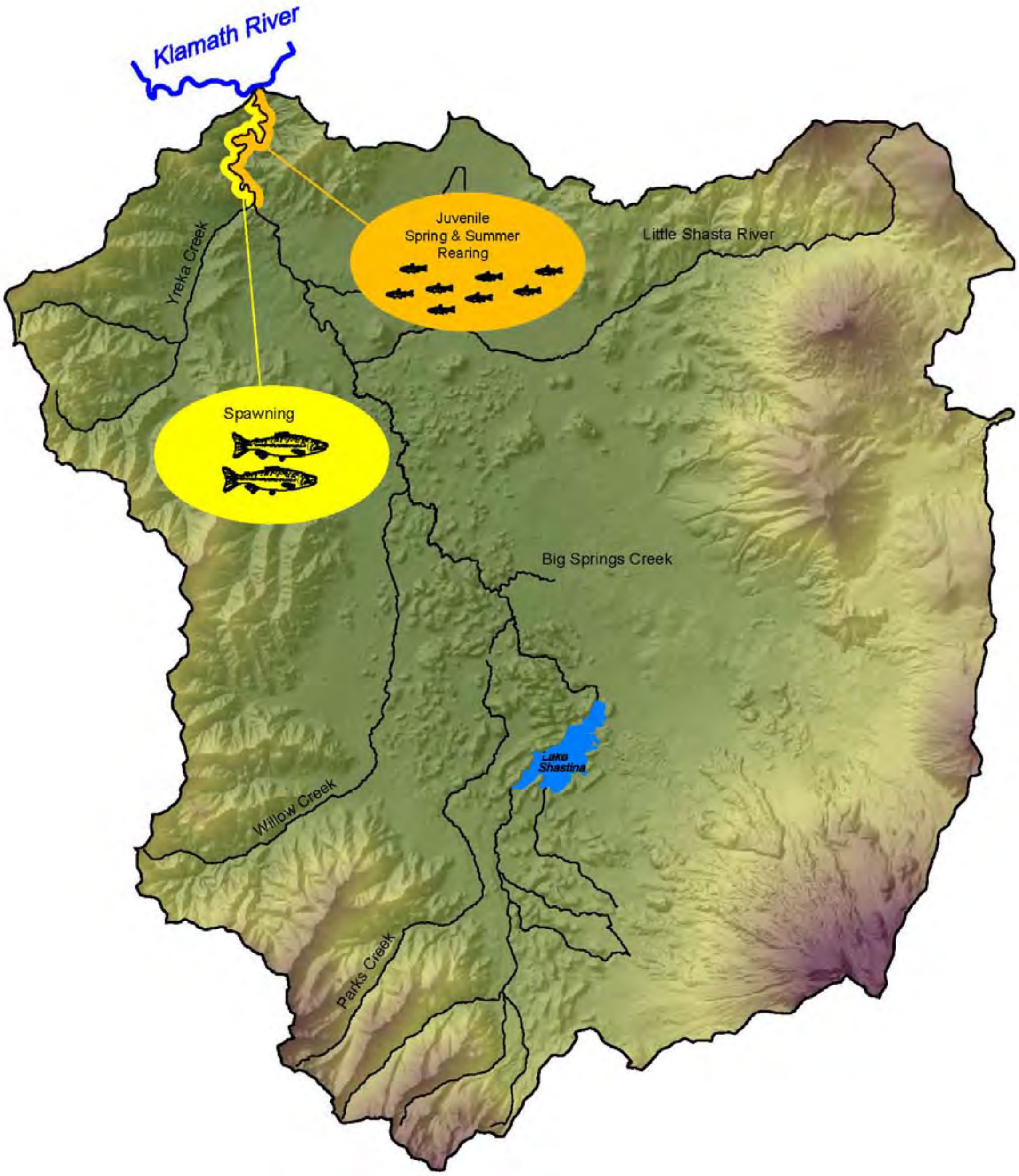
7.4. Appendix D: Shasta Basin High Priority Life History Tactics Important for Salmonid Recovery

	Life History Tactics	Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
		Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
1	Fall Chinook Canyon 0+ Tactic	Canyon	→	0+ ENTER KLAMATH	
2	Fall Chinook Big Springs Complex 0+ Tactic	Big Springs Complex	→	0+ ENTER KLAMATH	
3	Coho Big Springs Complex 1+ Tactic	Big Springs Complex	→	→	Mainstem/Canyon
4	Coho Big Springs Complex 0+ Tactic	Big Springs Complex	→	0+ ENTER KLAMATH	
5	Steelhead Big Springs Complex 1+ and 2+ Tactics	Big Springs Complex	→ (1 or 2 years)	→	Mainstem/Canyon
6	Steelhead Little Shasta River Headwaters 1+ Tactic	Little Shasta Headwaters	Little Shasta Foothills	→ Bottomlands	Mainstem/Canyon
7	Steelhead Little Shasta River 2+ Tactic	Little Shasta Headwaters	→	Lower Shasta Mainstem (1 yr)	Mainstem/Canyon
8	Coho Parks Creek Headwaters Tactic	Parks Headwaters	→	→	Mainstem/Canyon
9	Coho Parks Creek Foothills/Bottomlands Tactic	Parks Headwaters	Parks Foothills	→	Mainstem/Canyon
10	Coho Parks Creek Foothills/Big Springs Complex Tact	Parks Foothills	Big Springs Complex	→	Mainstem/Canyon
11	Coho Canyon Tactic	Canyon	→	→	→
12	Coho Little Shasta River Foothills Tactic	Little Shasta Foothills	→	→	Little Shasta Bottomlands/ Mainstem/ Canyon
13	Coho Little Shasta River Foothills/Bottomlands Tactic	Little Shasta Foothills	→	Little Shasta Bottomlands	Mainstem/Canyon
14	Coho Little Shasta River Bottomlands Tactic	Little Shasta Foothills	Little Shasta Bottomlands	→	Mainstem/Canyon
15	Fall Chinook Yearling Tactic	Canyon	→	0+ ENTER KLAMATH	
16	Coho Below Dwinnell Tactic	Below Dwinell	Below Dwinnell, Big Springs Complex	→	Mainstem/Canyon
17	Spring Chinook Tactic	Below Dwinnell, Big Springs Complex	→	0+ ENTER KLAMATH	

7.4.1. Tactic 1: Fall-run Chinook Salmon Canyon 0+ Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Canyon →	0+ ENTER KLAMATH		

Tactic 1: Fall-run Chinook Salmon Canyon 0+ Tactic

Description of life history tactic:

Fall-run Chinook salmon are the most abundant salmonids currently in the Shasta Basin (CDFG 1997). Their "ocean-type" strategy allows an early exit from the Shasta River, and they rely on additional growth in the Klamath mainstem and estuary before entering the ocean. Snyder (1931) recognized this tactic from analysis of adult Chinook salmon scales: "the individual from which it [scale] was taken, hatched from an egg deposited in the fall or early winter, passed down stream in time to arrive in the estuary in the following summer, remained in the estuary until growth… was complete, perhaps late fall, and then migrated to the sea." The fall-run Chinook salmon Canyon tactic utilizes the Canyon reach for its entire Shasta River life history, spawning in the fall, emerging in winter and early spring, and then emigrating to the Klamath between February and June. Fall-run Chinook salmon begin arriving at the SRFCF in September, and peak in September and October of most years. CDFG estimates most fall-run Chinook salmon currently spawn in the lower 8 to 10 miles of the Shasta River. Additional spawning habitat utilized by other Chinook salmon tactics is available upriver. Winter floods of 1,000 to 1,850 cfs (and occasionally higher) are common downstream of Yreka Creek and may occasionally scour Chinook salmon redds. CDFG estimates the average 2001 to 2005 Chinook salmon fry production from the Shasta River was 2.34 million annually (Chesney et al. 2007), and that over 89% of the total 0+ Chinook salmon emigrated between mid-February and early April, potentially avoiding summer rearing and poor mainstem Klamath water quality. The contemporary peak emigration timing (April to May) may also correspond with abruptly reduced streamflows from irrigation diversions and concurrent increases in water temperatures, whereas historically, snowmelt floods ranged from 400 to 700 cfs persisted through April and May, and later in wetter years. Snowmelt runoff provided cold water, access to floodplain and side-channel rearing habitat, and highly productive invertebrate food resources. Historically, some Chinook salmon juveniles probably remained in the Canyon reach through summer and emigrated as larger juveniles and smolts in the fall, winter, or following spring (i.e., other tactics).

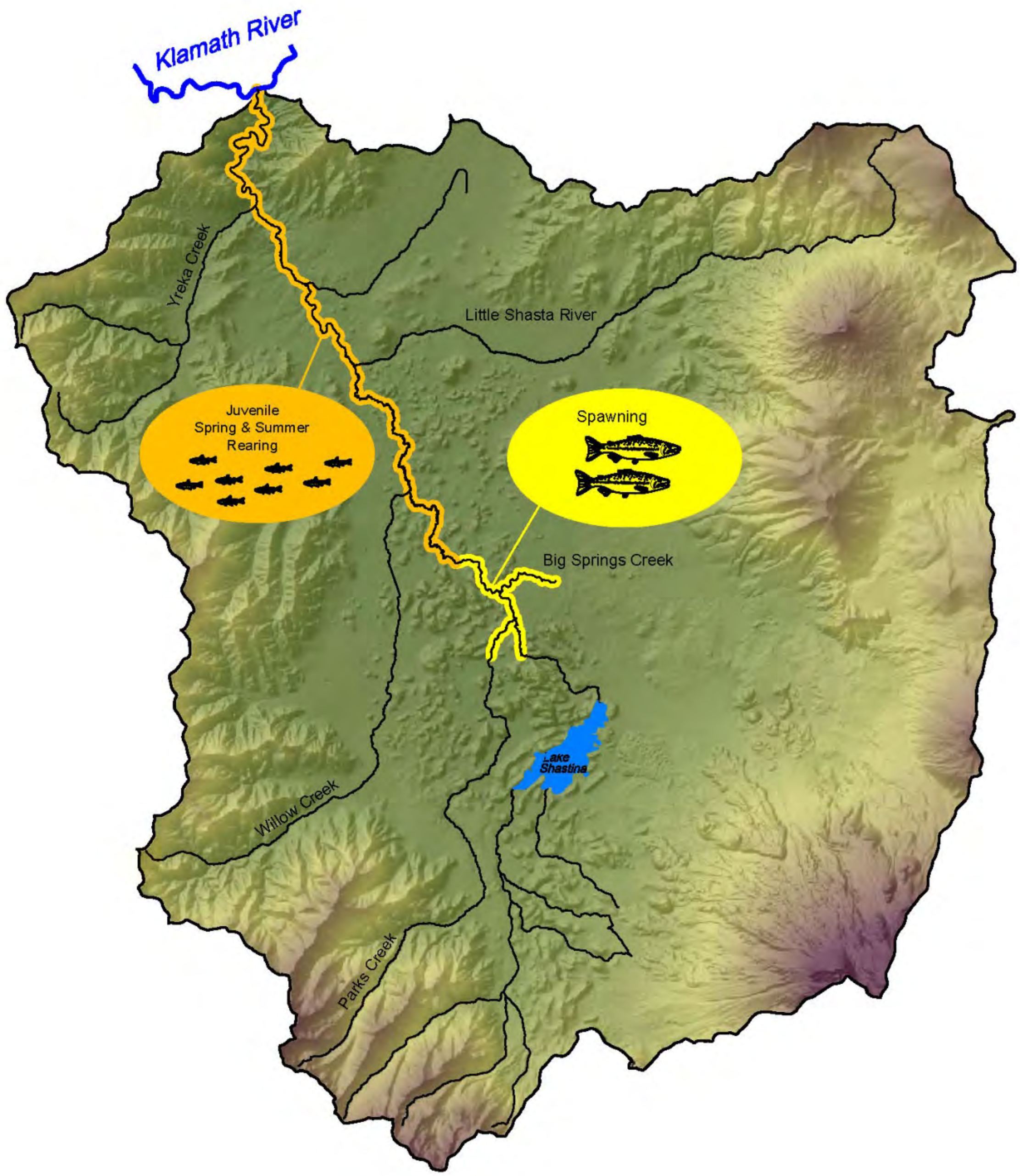
Current status of tactic and habitat conditions

Fall-run Chinook salmon spawning habitat in the Canyon reach is heavily utilized. Ricker (1997) suggests high levels of fines in spawning gravels may reduce fry emergence. Poor gravel supply to the canyon resulting from reduced winter floods below Dwinnell Dam may limit spawning habitat quantity and quality (CDFG 2004 Coho Recovery Plan). Fry and juvenile rearing habitat appears abundant in the Canyon reach at typical winter/spring baseflows (200 to 300 cfs) that persist up until the irrigation season begins. But reduced spring flows, instead of the unimpaired snowmelt flows, reduces habitat abundance in backwaters, side channels, and floodplains of the Canyon reach. Water temperatures in spring also can approach or exceed the tolerable limits for juveniles, and may promote earlier than optimal emigration. Fry and juvenile growth and survival in the Klamath River are poorly understood, particularly given the effects of disease. Early emigration may potentially promote higher survival.

High priority data and information needs

- estimate of streamflow threshold that provides unrestricted upstream migration into and through the Canyon reach (applies to all Tactics henceforth);
- assessment of potential natural and anthropogenic migration barriers that impede or slow migration through the Canyon reach, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration through the Canyon;
- relationship between streamflow and Chinook salmon spawning habitat abundance in the Canyon reach estimate of the current distribution and abundance of spawning gravels in the Shasta Canyon, including spawning gravel sources, transport rates and mobility, and assessment of the need for gravel augmentation to replenish coarse sediment supply and spawning gravel abundance;
- relationship between streamflow and Chinook salmon fry and juvenile rearing habitat abundance in the Canyon reach, including habitat on floodplain and side-channel features assessment of the survival and recruitment of fry entering the mainstem Klamath in late-winter and early-spring, relative to juveniles and smolts entering the Klamath in late spring and early summer;
- estimates of Chinook salmon fry growth rates (relative to water temperature) in the Canyon reach, compared to growth estimates in the mainstem Klamath River;
- relationship between size of Chinook salmon smolts at ocean entry, and survival to adult returns to the Shasta River;
- comparison of unimpaired and impaired water temperature conditions in the Canyon reach in fall and spring; evaluation of the effects of elevated fall water temperatures on fecundity; evaluation of the effects of elevated spring water temperatures on fry growth rates and emigration;
- assessment of harvest management practices and potential impacts on early returning fall-run Chinook salmon;
- role of Canyon salmon in providing for genetic mixing and re-colonization.

7.4.2. Tactic 2: Fall-run Chinook Salmon Big Springs Complex 0+ Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Canyon →	0+ ENTER KLAMATH		

Tactic 2: Fall-run Chinook Salmon Big Springs Complex 0+ Tactic

Description of life history tactic:

The fall-run Chinook salmon Big Springs Complex tactic is the second of two tactics that dominate contemporary fall-run Chinook salmon runs (complementing the Shasta Canyon 0+ tactic). The Big Springs Complex tactic exhibits similar spawner migration timing up the Klamath and into the Shasta River. But given adequate streamflow and water temperatures, some fall-run Chinook salmon continue their migration above the canyon to spawn. Mainstem barriers and high water temperatures may delay upstream migration in some years. Fall-run Chinook salmon spawn in the mainstem Shasta River from approximately river mile 32 to Big Springs Creek, in lower Big Springs Creek, lower Parks Creek, and in the Shasta River upstream of Parks Creek (Chesney et al. 2007). These reaches cover approximately 13 river miles. Mainstem reaches above Dwinnell Dam likely supported this tactic historically. Fall-run Chinook salmon eggs incubate through fall and into winter, and are likely less vulnerable to scour from winter floods than redds constructed in the Shasta Canyon reach because of the unconfined channel morphology and attenuated flood peaks below Dwinnell Dam. This tactic could buffer the Chinook salmon population from threat of large winter floods. Fry emerge in late-winter and spring, likely rear briefly near the spawning grounds, then slowly migrate downstream through the Middle and Lower Mainstem reaches, through the Canyon reach, and into the Klamath River. CDFG biologists estimate a large proportion of fall-run Chinook salmon progeny from the Shasta Canyon leave the Shasta River by early April, whereas downstream migrants from the upper mainstem river arrive at the SRFCF through late spring (end of June). Emigrants from the Big Springs Complex are likely larger than Canyon progeny, but at present may be at greater risk of mortality due to Klamath River disease/parasite problems.

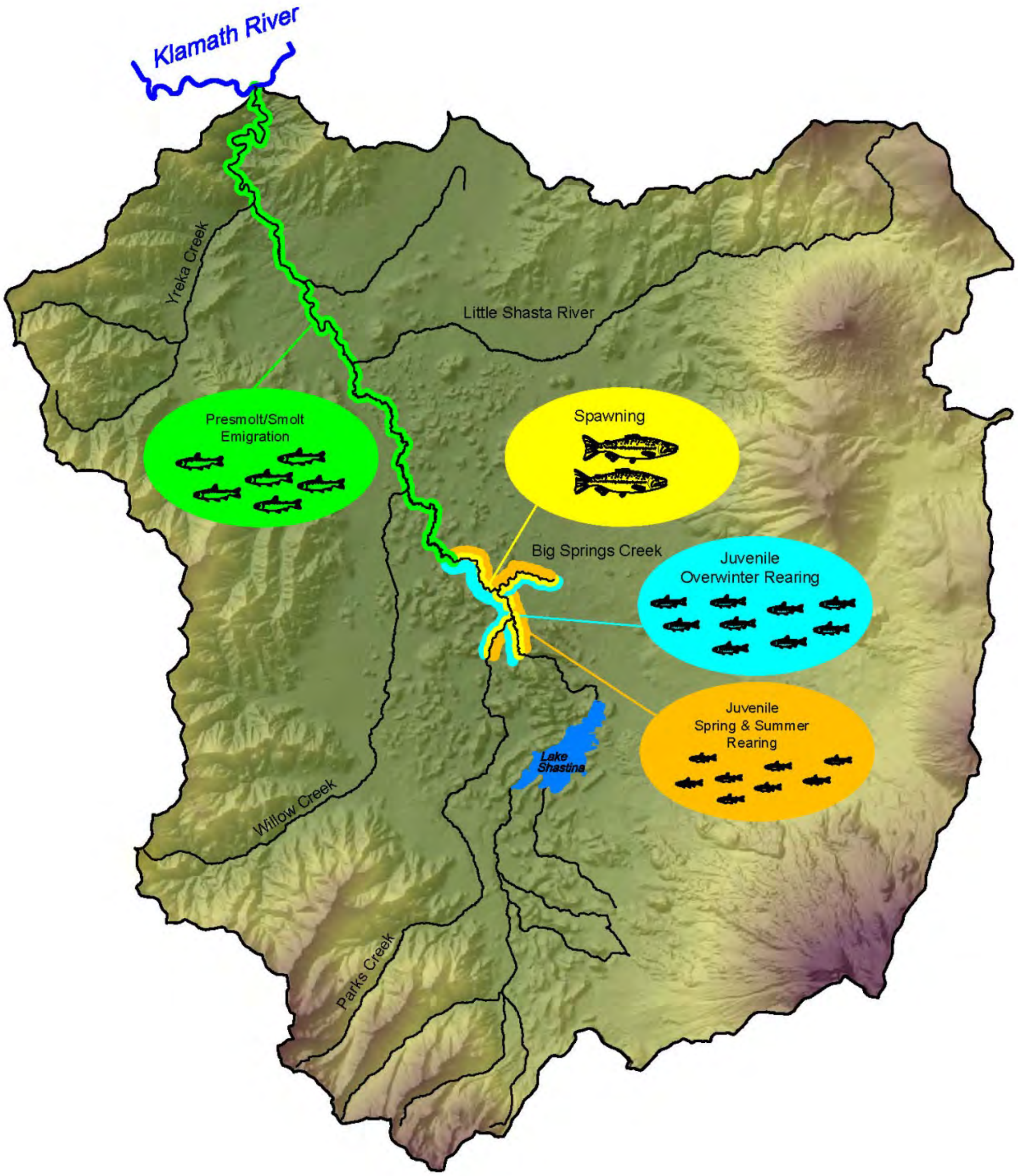
Current status of tactic and habitat conditions

Overall, given healthy habitat conditions in the mainstem Shasta and the Klamath River, this would be a highly productive tactic. This tactic appears to persist under contemporary conditions, at least for adult migration, spawning location and timing, and early emergent rearing in the general vicinity of the spawning grounds. However, irrigation diversions beginning April 1 may force Chinook salmon fry to emigrate from the Big Springs Complex earlier than would be optimal, likely by early May. Given more suitable water temperatures and access to migrate upstream to find more favorable habitat, the rearing period for Chinook salmon fry could extend later into spring and result in larger downstream migrants. However, delayed emigration to the Klamath River may increase the risk of mortality from disease and parasites.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration to the Big Springs Complex, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration to the Big Springs Complex;
- relationship between streamflow and Chinook salmon spawning habitat abundance in the Big Springs Complex
- estimate of the distribution and abundance of spawning gravels in the Big Springs Complex; assessment of spawning gravel sources, transport rates, and mobility; and assessment of the need for gravel augmentation to replenish coarse sediment supply and spawning gravel abundance below Dwinnell Dam;
- relationship between streamflow and Chinook salmon fry and juvenile rearing habitat abundance in the Big Springs Complex estimates of Chinook salmon fry rearing densities within suitable water temperature conditions;
- estimate of water temperature threshold or other environmental cues that encourage emigration of Chinook salmon fry from the Big Springs Complex in spring;
- estimates of Chinook salmon fry growth rates (relative to water temperature) in the Big Springs Complex, compared to growth estimates in the Canyon reach, and in the mainstem Klamath River;
- evaluation of existing and potential riparian vegetation coverage in the Big Springs Complex, and assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Big Springs Complex required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;
- evaluation of geomorphic conditions, potential habitat availability, and actions required for restoration of channel morphology and salmonid habitat (particularly spawning) in the Dwinnell reach;
- evaluation of bank erosion and channel migration rates, and geomorphic processes maintaining channel confinement in the Below Dwinnell and Nelson reaches;
- evaluation of the relative importance of growth incurred during emigration down the mainstem Klamath River, and survival during ocean entry and eventual adult return.

7.4.3. Tactic 3: Coho Salmon Big Springs Complex 1+ Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Big Springs Complex	→	→	Mainstem/Canyon

Tactic 3: Coho Salmon Big Springs Complex 1+ LHT

Description of life history tactic:

Dwinnell Dam blocked the upper mainstem and several headwater tributaries/springs that once provided abundant spawning and rearing habitat. The mainstem immediately downstream of Dwinnell Dam (to just above Big Springs Creek confluence), its springs, and lower Parks Creek are now the destination for adult coho salmon migrating through the Shasta River's valley bottom. Coho salmon population recovery will need a Big Springs Complex LHT annually producing large and abundant smolts from their spawning efforts. Early emergent fry can utilize shallow/slow habitat along stream margins or within dense beds of aquatic vegetation. But as springtime air temperatures warm and the irrigation season begins, water temperatures can rise rapidly. To reside within the Big Springs Complex through summer, 0+ coho salmon juveniles must locate habitat with sufficiently cool water temperatures. Summertime juvenile rearing habitat capacity will not be limiting given the instream flow requirements for cooler water temperatures. If they can thrive, this LHT would produce abundant and large 1+ pre-smolts and smolts outmigrating the following spring beginning early-March. Smolts produced by the Big Springs Complex LHT would not completely rely (though desirable) on good growing conditions through the valley bottom or Canyon. An early outmigration into the Klamath River would, at least partially, avoid serious disease issues. A productive Big Springs Complex LHT, therefore, would buffer variable annual smolt abundance/size originating elsewhere in the Shasta Basin.

Depending on juvenile rearing densities, some fry probably disperse upstream and downstream in search of cooler habitat (different tactics). But given suitable water temperatures, the Big Springs Complex would likely remain densely populated through summer and winter. The water surface elevation (not necessarily streamflow) and water temperature appear to dominate habitat quality in these reaches; abundant food and cover appear well suited for coho salmon rearing. Recent observations of densities and growth rates of juvenile steelhead rearing in these reaches suggest similar rearing conditions exist for coho salmon. This tactic could produce abundant and large 1+ pre-smolts and smolts by early-March. Assuming that more adults return from larger smolts, this tactic would likely produce abundant adult coho salmon returns. Scattered pockets of water temperature refugia may support a few fish remaining through summer in the Big Springs Complex, although migratory access into these cold-water springs may be difficult.

Current status of tactic and habitat conditions

Coho salmon spawning likely occurs in isolated patches throughout the Big Springs Complex, given emergent fry have recently been observed (C. Jeffres, personal communication). During the WY2005 to WY2007 spring/summer seasons, CDFG and UC Davis researchers did snorkel surveys and operated a rotary screw trap near the downstream end of the Big Springs Complex on the Nelson Ranch. They observed 0+ coho salmon rearing in the Big Springs Complex reaches until water temperatures in spring exceeded suitable ranges (~68°F) for juvenile coho salmon. Presumably these juvenile coho salmon emigrated or succumbed to temperature induced mortality. If water temperatures were suitable, and other habitat requirements suitable, this coho salmon LHT could thrive with modestly improved conditions.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration to the Big Springs Complex, their cumulative effects on migration over a range of flows, and estimate of a streamflow threshold that provides unrestricted migration to the Big Springs Complex;
- relationship between streamflow and coho salmon spawning habitat abundance in the Big Springs Complex
- estimate of the distribution and abundance of spawning gravel in the Big Springs Complex; assessment of spawning gravel sources, transport rates, and mobility; and assessment of the need for gravel augmentation to replenish coarse sediment supply and spawning gravel abundance below Dwinnell Dam;
- relationship between streamflow and coho salmon fry and juvenile spring and summer rearing habitat abundance in the Big Springs Complex;
- estimate of water temperature threshold or other environmental cues that encourage emigration of coho salmon juveniles from the Big Springs Complex in spring;
- quantitative estimates of coho salmon fry and juvenile growth rates under different water temperature regimes;
- evaluation of existing and potential riparian vegetation coverage in the Big Springs Complex, and assessment of hydrograph components available to promote natural riparian vegetation recruitment;

- assessment of a minimum corridor width throughout the Big Springs Complex required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;
- evaluation of geomorphic conditions, potential habitat availability, and actions required for restoration of channel morphology and salmonid habitat (particularly spawning) in the Dwinnell reach;
- evaluation of the relative importance of growth during emigration down the mainstem Klamath River, and survival following ocean entry and eventual adult return;
- estimate of the size class distribution of 0+ coho salmon at ocean entry from scale and otolith analysis of returning adults.

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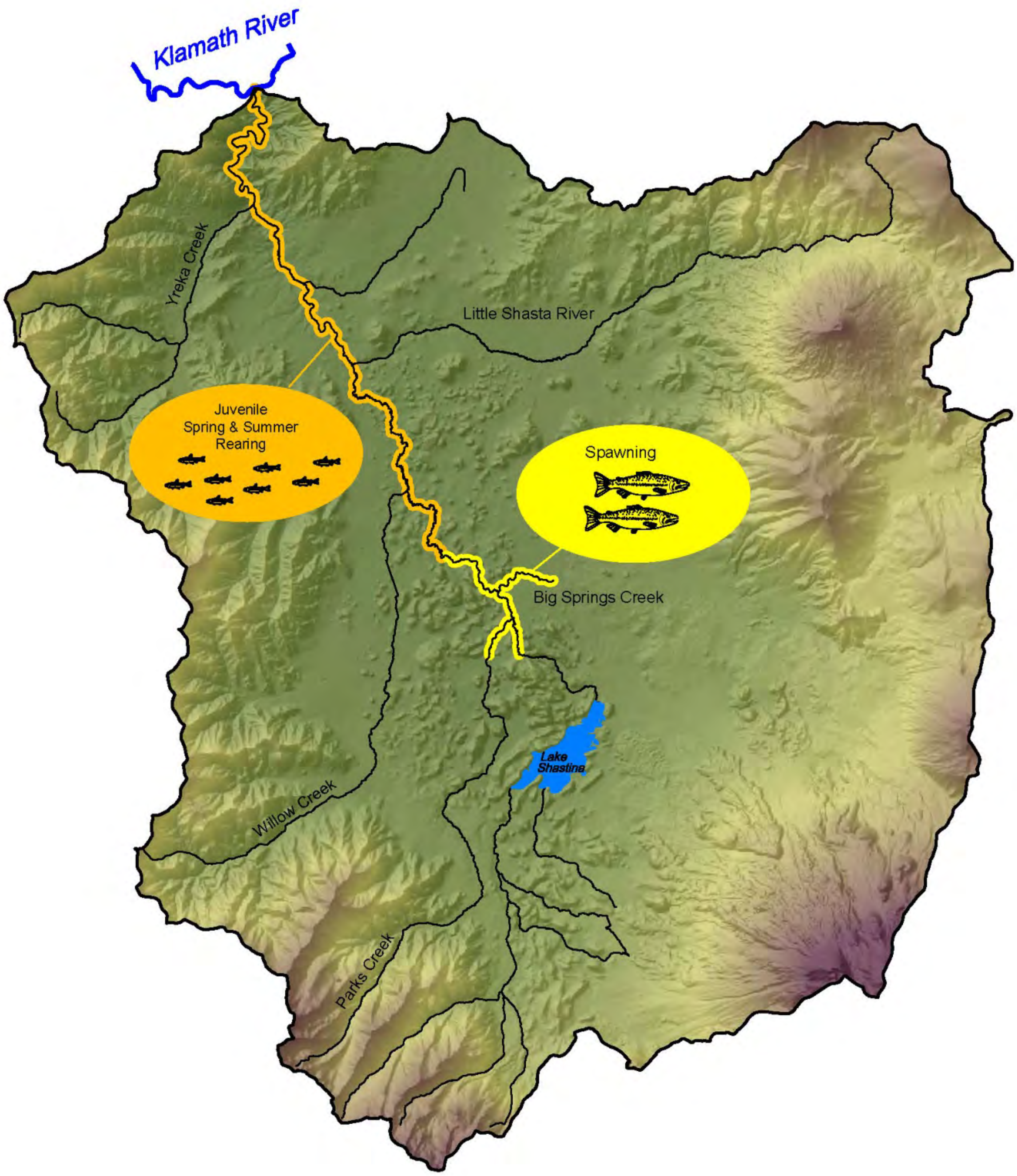
7.4.4. <u>Tactic 4: Coho Salmon 0+ Big Springs Complex LHT</u>



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Big Springs Complex →	0+ ENTER KLAMATH		

Tactic 4: Coho Salmon 0+ Big Springs Complex LHT

Description of life history tactic:

In addition to the more typical coho salmon life history pattern of rearing 12 to 18 months in freshwater, some coho salmon in the Shasta River have smolted as 0+ juveniles. While there is no historical documentation of this tactic, the unique habitat conditions and spring-dominated hydrology of the mainstem Shasta River has unusually high productivity that could have enabled 0+ coho salmon juveniles to smolt and emigrate their first year. Accelerated growth likely began with spawning: abundant discharge from Big Springs may have enabled adult coho salmon to spawn earlier than in other Klamath River tributaries. Snyder (1931) observed "The time of arrival of salmon in the tributaries appears to differ markedly… and their degree of maturity varies also. For example, during the week beginning October 16 (1927), relatively small numbers of the [Chinook salmon] held between the Klamathon racks were ripe. In Shasta River large numbers were actively spawning [likely Chinook salmon], while many spent and a few dead fish were seen." Egg incubation may also have been accelerated by relatively warmer spring-fed water temperatures. By early-spring, snowmelt runoff provided abundant, high quality rearing habitat along stream margins, within dense beds of aquatic vegetation and on submerged floodplain surfaces, all producing abundant food. As streamflows receded in summer, aquatic vegetation in the mainstem continued to provide excellent food production and cover. Recent growth studies by CDFG and UC Davis researchers document high summer growth rates in the Big Springs Complex. Chesney (2006) estimates approximately 870 0+ coho salmon left the Shasta during the 2006 sampling period, representing 7.4% of juvenile coho salmon emigrants. The 0+ emigration peaked in early June, six weeks later than the peak emigration of 1+ coho salmon. But these juveniles were approaching 100 mm by mid to late-June. Suitable water temperatures in this reach likely would allow extended rearing through the summer, enabling juvenile coho salmon to emigrate in the fall by growing their way downstream through the mainstem Shasta and Klamath rivers to enter the Pacific Ocean as large as 130 to 140 mm long.

Current status of LHT and habitat conditions

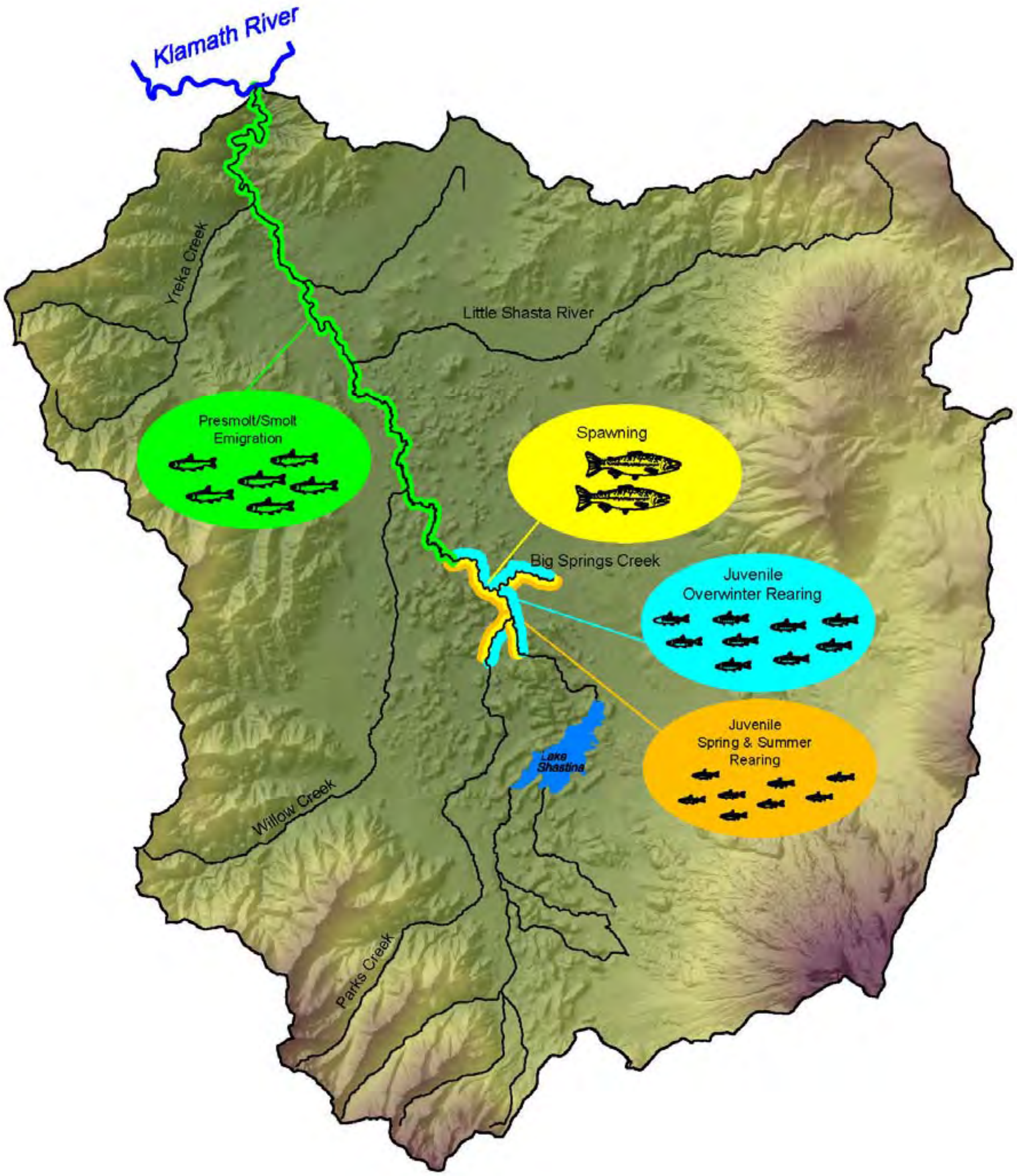
This tactic persists under current partially-regulated streamflows. However, elevated water temperatures likely force coho salmon to emigrate from the Big Springs Complex by early-June. The fate of 0+ coho salmon rearing in the mainstem Klamath is unclear: they may rear in non-natal tributaries through the summer and fall, enter the ocean, or succumb to temperature-induced mortality. Although currently diminished, late-winter and spring baseflows still inundate small floodplains and stream edges along the mainstem, oxbow ponds with emergent wetland vegetation, and side channels. These features provide good rearing habitat and high growth rates into spring (C. Jeffres, personal communication).

High priority data and information needs

[same data and information needs as Tactic #3]

- identification of anthropogenic sources of elevated water temperatures in the Big Springs Complex;
- estimate of water temperature threshold or other environmental cues that encourage emigration of 0+ coho salmon juveniles from the Big Springs Complex in spring;
- survival of 0+ coho salmon in the Klamath River in June, July, August, and September;
- evaluation of growth incurred during emigration down the mainstem Klamath River;
- estimate of the size class distribution of 0+ coho salmon at ocean entry from scale and otolith analysis of returning adults;

7.4.5. Tactic 5: Steelhead 1+ and 2+ Big Springs Complex LHT



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Big Springs Complex	⟶ (1 or 2 years)	⟶	Mainstem/Canyon

Tactic 5: Steelhead 1+ and 2+ Big Springs Complex LHT

Description of LHT:

Without access to their ancestral spawning grounds higher in the watershed, winter steelhead utilizing Shasta River mainstem are constrained to the Big Springs Complex where their habitat needs overlap considerably with coho salmon. Microhabitat partitioning between these two sympatric species may be unique because of the spring creek morphology (near absence of a pool-riffle morphology), and because aquatic plants provide spatial separation, abundant food, and possibly less competition. Historically, the annual hydrograph was dominated by cold baseflows, fed by springs and snowmelt. Winter steelhead entered the Shasta River beginning in October, and spawned between December and May. Steelhead spawning habitat was historically abundant in the upper watershed, particularly in the Shasta River and Parks Creek headwaters reaches. In addition to successful Headwater LHTs, a Steelhead 1+ and 2+ Big Springs Complex LHT would have been historically productive. CDFG and UC Davis researchers observed steelhead (primarily 0+ and 1+ fish) rearing on shallow, low velocity floodplain benches during spring. As stage dropped, juveniles moved to main channel habitat (dominated by submerged aquatic macrophytes) to rear through summer. Because of their ability to tolerate warmer water temperatures summer rearing in the Big Springs Complex may now favor steelhead. Recent research has shown that, despite water temperatures in the upper end of their suitability range, steelhead growth rates can be exceptionally high. Abundant prey and slightly higher temperature tolerances may be the key to this tactic. Steelhead probably inhabit these reaches year-round for one season (1+ tactic) or two seasons (2+ tactic), although winter migration into other stream reaches cannot be ruled out. Following one or two years of rearing, juvenile steelhead emigrate through the lower mainstem reaches, the Shasta Canyon, and down the Klamath River.

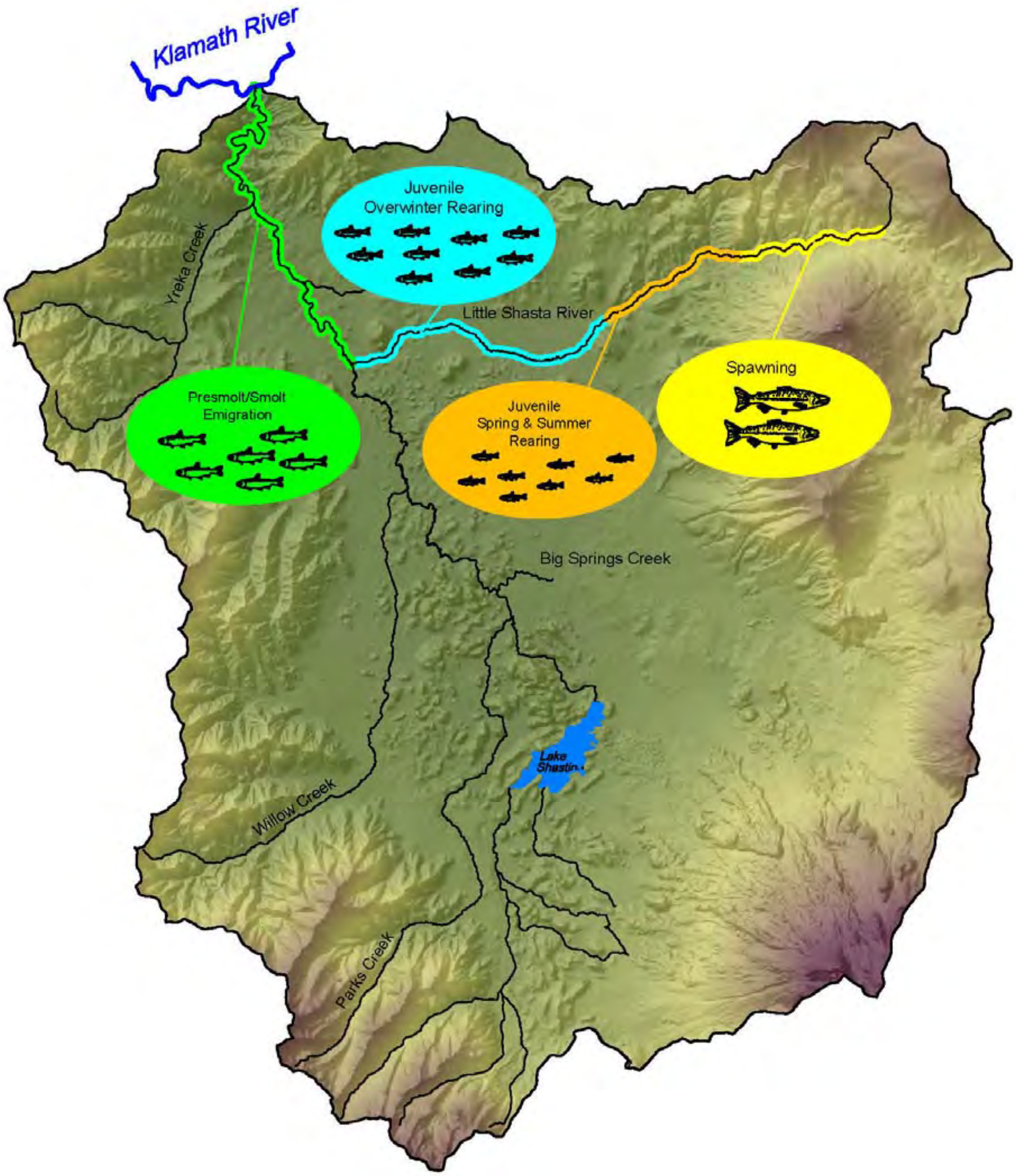
Current status of tactic and habitat conditions

UC Davis researchers have been observing abundant juvenile steelhead in the Nelson reach. Despite warm water temperatures during the summer months, current habitat conditions appear suitable in the Big Springs Complex to sustain a steelhead LHT. While spawning is notoriously elusive to observe, the presence of 0+ steelhead in spring strongly suggests successful spawning occurs in the Big Springs Complex.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration to the Big Springs Complex, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration to the Big Springs Complex (for Summer steelhead);
- relationship between streamflow and steelhead spawning habitat abundance in the Big Springs Complex ;
- estimate of the distribution and abundance of spawning gravel in the Big Springs Complex; assessment of spawning gravel sources, transport rates, and mobility; and assessment of the need for gravel augmentation to replenish coarse sediment supply and spawning gravel abundance below Dwinnell Dam;
- relationship between streamflow and steelhead fry and juvenile spring and summer rearing habitat availability in the reach below Big Springs;
- estimates of fry and juvenile steelhead rearing densities within suitable water temperature conditions;
- empirical estimate of water temperature threshold that triggers emigration of juvenile steelhead from the Big Springs Complex in spring and summer;
- quantitative relationship between water temperature and juvenile steelhead growth rates;
- evaluation of existing and potential riparian vegetation coverage in the Big Springs Complex, and assessment of hydrograph components available to promote natural woody riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Big Springs Complex required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;
- analysis of bank erosion and channel migration rates, and processes maintaining channel confinement in the Upper Mainstem and Nelson reaches;
- evaluation of geomorphic conditions, potential habitat availability, and actions required for restoration of channel morphology and salmonid habitat (particularly spawning) in the Dwinnell reach;
- relative importance of growth incurred during mainstem rearing and timing of emigration to survival during emigration and ocean entry.

7.4.6. Tactic 6: Steelhead Little Shasta River Headwaters 1+ Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Little Shasta Headwaters	Little Shasta Foothills →	Bottomlands	Mainstem/Canyon

Tactic 6: Steelhead 1+ Little Shasta River Headwater LHT

Description of life history tactic:

Steelhead exhibit the most complex life history traits of any Pacific salmonid: juveniles rear in the watershed for one, two, or more years before emigration, or can residualize in freshwater if downstream passage is not feasible. Adults return to sea after spawning. In the Shasta Basin, steelhead also had an advantage over salmon by preferring to spawn in higher gradient headwaters reaches (above contemporary diversions), accessed in fall and winter during higher baseflows and storm events (~50 cfs to 200 cfs). This enabled fry and juveniles historically to rear where summer water temperatures remained cold. Steelhead can also thrive better in higher velocity streamflows, an advantage if overwintering in headwater streams. The Little Shasta River Headwaters 1+ tactic likely took advantage of these benefits, and was a primary steelhead tactic. Adults accessed as much as 10 miles of headwaters habitat above Dry Gulch to spawn. After emerging in spring in the Headwaters, steelhead fry began a slow descent into the Foothills reach where late-spring and summer conditions provided a good balance between water temperatures conducive to rapid growth and plentiful prey stimulated by the moderate snowmelt runoff. Habitat conditions remained good in the Foothills reach for juvenile steelhead, where they stay through the fall and winter. By early to mid-spring, the 1+ steelhead cohort began a second slow downstream descent, through the valley bottom of the Little Shasta and Shasta River mainstems, lasting 1 to 2.5 months before entering the Klamath River in mid-April to early-July, measuring from ~140 mm to 180 mm mean fork length (Chesney et al. 2007 Chart 14). Additional growth in the Klamath River mainstem and estuary before ocean entry would have guaranteed a strong smolt-to-adult survival in many years.

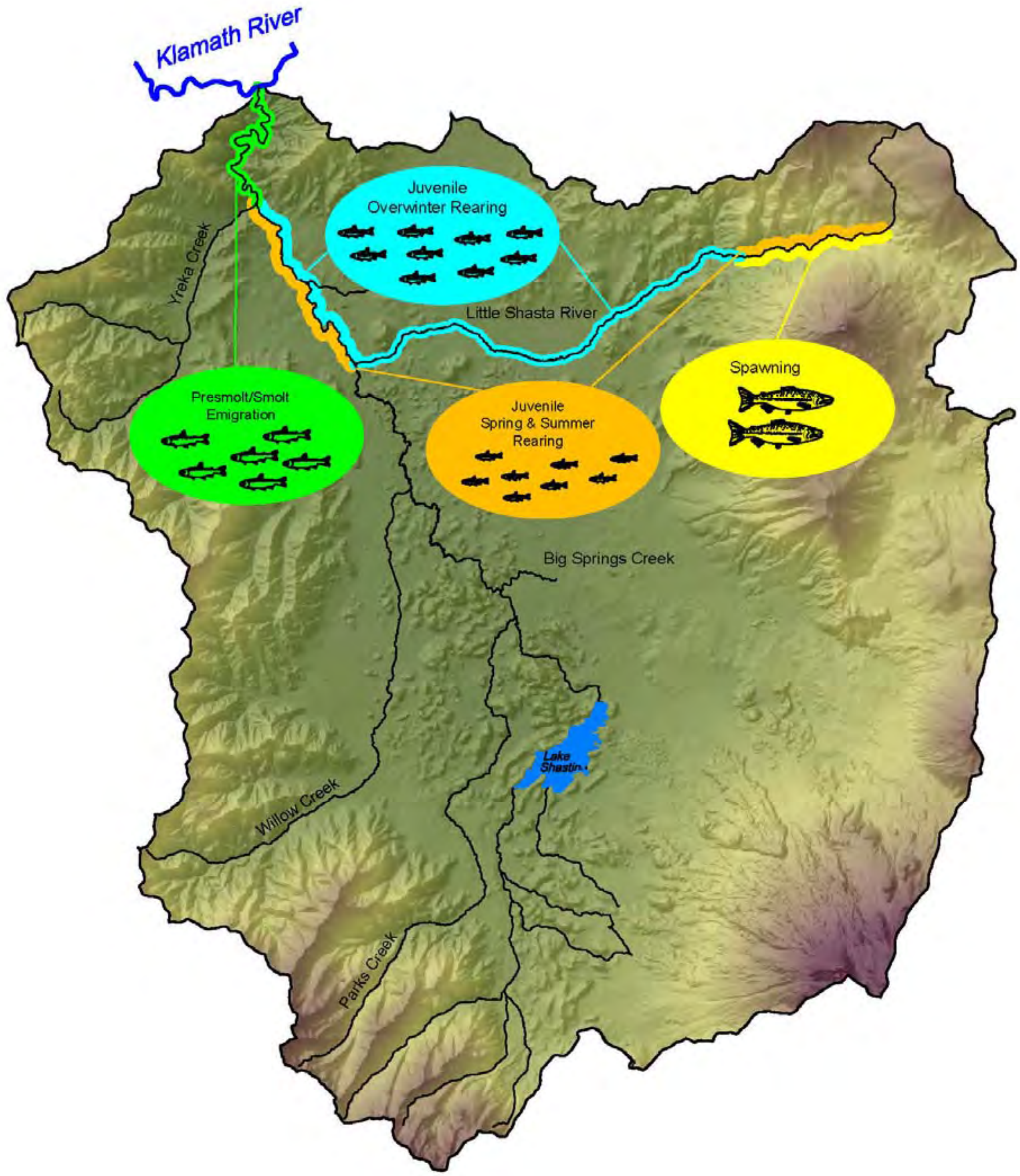
Current status of tactic and habitat conditions

Juvenile steelhead have been observed in the Little Shasta River under limited sampling by the CDFG Wildlife Area biologist (M. Farmer, personal communication). Suitable habitat appears available in the Headwaters reach to support spawning, early emergent rearing, and over-summer rearing, although data are not available to confirm summer water temperature suitability. Summer and winter rearing may also be feasible in the Foothills reach and winter rearing habitat may also be available in the Bottomlands reach, although flows in this reach are more variable. Primary constraints on this LHT are adequate streamflows in fall during the adult migration period, summer rearing habitat capacity in the Foothills reach, and adequate streamflows for downstream pre-smolt/smolt migration in spring. Steelhead survival may also be affected by Klamath River disease pathology. Despite this LHT's promise, annual estimates of steelhead 1+ leaving the Shasta Basin are considerably lower than that of 2+ outmigrants.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration from the mainstem Shasta River confluence to the Little Shasta River Foothills and Headwaters reaches, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration to these reaches;
- reach-scale survey of steelhead habitat availability from the mainstem Shasta River confluence to the Little Shasta River Foothills and Headwaters reaches, to determine (1) extent of spawning habitat, (2) extent of rearing habitat, and (3) location of natural and anthropogenic migratory barriers;
- relationship between streamflow and steelhead fry and juvenile winter rearing habitat availability in the Little Shasta River Foothills and Bottomlands reaches (below diversions), relationship between streamflow and ephemeral steelhead rearing habitat in side-channels and on floodplains in the Little Shasta River Bottomlands reach, or minimum flow threshold providing rearing habitat in these features;
- streamflow and water temperature data for the Headwaters and Foothills reaches;
- evaluation of existing and potential riparian vegetation coverage in the Foothills and Bottomlands reaches, and an assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Foothills and Bottomlands reaches required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;
- estimate of timing and size class distribution of 1+ steelhead downstream migrants (if any) from the Little Shasta River to the mainstem Shasta River in spring;
- direct observation or electrofishing surveys in the Headwaters and Foothills reaches to determine presence/absence and age class distribution of steelhead juveniles;
- analysis of winter rearing habitat abundance and food availability in the Bottomlands reach following seasonal dewatering.

7.4.7. Tactic 7: Steelhead 2+ Little Shasta River LHT



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Little Shasta Headwaters	→	Lower Shasta Mainstem	→	→	Mainstem/Canyon

Tactic 7: Steelhead 2+ Little Shasta River LHTs

Description of life history tactic:

The steelhead 2+ life history tactics was likely a mainstay in the historic Shasta Basin steelhead population, with three potentially LTH's that dominated 2+ production from the on the Little Shasta River: (1) Stay in Headwater reach until 2+, (2) move into the foothill reach and rear until 2+, or (3) move into valley bottom and rear until 2+. The 2+ LHT's are desirable because extended residence allowed fish grow large and have higher smolt-to-adult survival than 0+ or 1+ LHTs. The Little Shasta River (among several other tributaries in the Shasta Basin) provided ideal conditions for steelhead 2+ LHTs, thus improving 2+ production from the Little Shasta River would provide population stability by creating some independence from mainstem habitat conditions (primarily related to poor water temperature). Able to ascend high into the watershed, steelhead would have spawned in the Little Shasta River Headwaters reach beginning in late-fall and continuing late into winter (December to March). Eggs required 50 days to 80 days before fry emerged in spring and early-summer. Early-emergent fry then distributed throughout the Headwaters reach and descended into the Foothills reach to rear through spring and summer. The Headwaters reach had low summer baseflows (~15 cfs to 25 cfs) but suitable water temperatures. Several different ages of rearing juveniles occupied available rearing habitat, but densities were moderate to low. In winter, perhaps stimulated by winter flood conditions, juvenile steelhead descended through the Bottomlands reach and into the Shasta River mainstem where winter rearing was good. These 1+ steelhead then remained in the mainstem to rear through an entire second year, becoming strongly territorial, piscivorous, and growing large as a result. By late-winter and early-spring (early by typical emigration timing), the 2+ steelhead began exiting the Shasta mainstem and Canyon into the Klamath River. Recent data (Chesney et al. 2007) indicate an extended emigration period for 2+ steelhead, beginning mid-February and continuing through June. The 2+ steelhead were larger than the 1+ tactic, measuring (and increasing through their emigration) from ~160 mm to 200 mm mean fork length. An important variation on this tactic could have been for 1+ juveniles to rear in lower gradient reaches during winter, then return to colder Headwaters and Foothills reaches to rear in summer. Snowmelt runoff provided good rearing conditions through the lower mainstem and Shasta Canyon.

Probably the strongest 2+ LHT (producing the most smolts annually over 170 mm) within the Little Shasta River was: (1) spawning in Headwaters, (2) early-emergent rearing in Headwaters, (3) 0+ rearing in Headwaters and Foothills, (4) over-wintering in the Foothills, (5) 1+ spring/summer rearing in Foothills and Bottomland, (6) over-wintering in Foothills and Bottomland, (7) leaving Little Shasta River early-spring as 2+, (8) migrating/growing downstream through the valley bottom and canyon before entering Klamath River 1 to 2 months after leaving the Little Shasta River.

Current status of tactic and habitat conditions

Within the Shasta Basin, the steelhead 2+ life history appears to be a dominant tactic. The 2006 CDFG outmigrant studies estimated 32,616 (40%) of steelhead migrants were 2+ fish (another 57% were 0+ migrants). CDFG hypothesizes that the high abundance of 2+ relative to 1+ steelhead may result from the Shasta functioning as a winter refugia for steelhead not of Shasta River origin (B. Chesney, personal communication). As with the steelhead 1+ tactic, suitable spawning habitat are available in the Headwaters reach. Summer and winter rearing may also be feasible in the Foothills reach; winter rearing habitat may also be available in the Bottomlands reach. The primary constraints on this tactic are streamflows in fall during the adult migration period and summer rearing habitat in the Bottomlands and Lower Shasta mainstem.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration from the mainstem Shasta River confluence to the Little Shasta River Foothills and Headwaters reaches, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration to these reaches;
- reach-scale survey of steelhead habitat availability from the mainstem Shasta River confluence to the Little Shasta River Foothills and Headwaters reaches;
- relationship between streamflow and steelhead fry and juvenile winter rearing habitat availability in the Little Shasta River Foothills and Bottomlands reaches (below diversions, discharge providing suitable temperature and rearing habitat for steelhead 1+ and 2+ in the Bottomlands and Lower Mainstem reaches;
- streamflow and water temperature data for the Headwaters and Foothills reaches;

- evaluation of existing and potential riparian vegetation coverage in the Foothills and Bottomlands reaches, and an assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- estimate of timing and size class distribution of 1+ steelhead downstream migrants (if any) from the Little Shasta River to the mainstem Shasta River in spring;
- direct observation or electrofishing surveys in the Headwaters and Foothills reaches to determine presence/absence and age class distribution of steelhead juveniles;
- analysis of winter rearing habitat abundance and food availability in the Bottomlands reach following seasonal dewatering.

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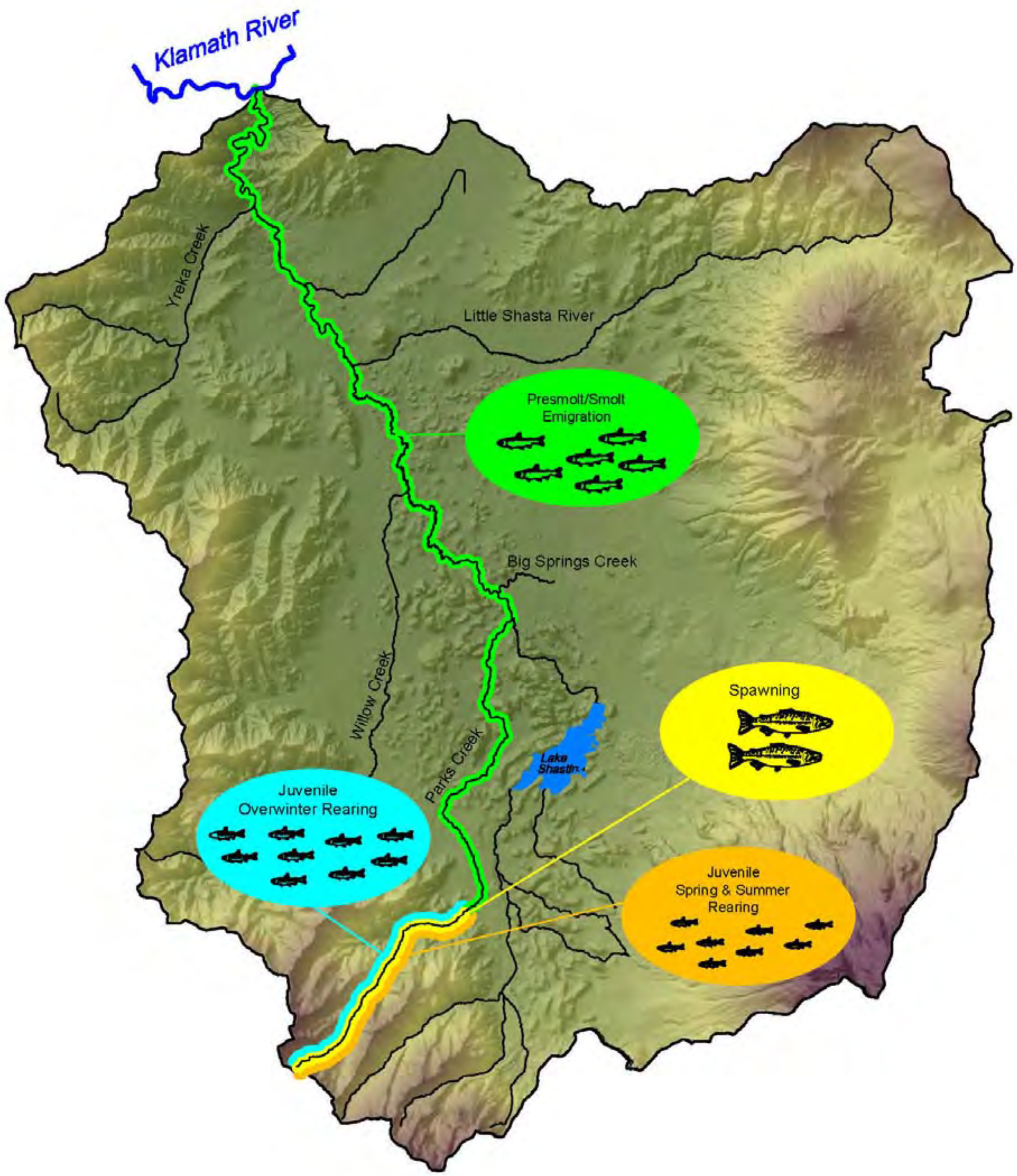
7.4.8. Tactic 8: Coho Salmon Parks Creek Headwaters Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Parks Headwaters	→	→	Mainstem/Canyon

Tactic 8: Coho Salmon Parks Creek Headwaters Tactic

Description of life history tactic:

Given a pool-riffle channel morphology, winter flood hydrology, and moderate spring snowmelt, the Parks Creek Headwaters tactic was probably more typical of coho salmon life histories throughout their distribution, and similar to other headwaters tactics in the Shasta and Scott basins. Seasonal runoff patterns in the Parks Headwaters reach were probably similar to the Shasta Headwaters reach as depicted in the Edgewood gage (see Section 2.2). This tactic utilized spawning habitat at the upper end of the coho salmon's stream elevation/gradient preference, where spawning gravel deposits were plentiful. Spawning higher in the watershed often depended on late-fall and early-winter freshets to allow upstream migration. Emerging from the gravels in spring, many fry remained in the Headwaters reach where cold water rearing habitat persisted through the spring and summer. Spring snowmelt brought a pulse of early season productivity, rapid growth, and some downstream dispersal of displaced fry. Rearing habitat would have depended on a healthy riparian canopy, deep pools, and complex physical structure to provide shade, cover, and suitable water temperatures. Summer rearing densities and growth rates were probably lower than in the mainstem. In dry years and at the lower elevations in the Foothills reach, summer rearing may have become unsuitable, or at least had extremely low habitat availability, with temperature refugia confined to deep pools. Stewart Springs and possibly other springs may have provided cold summer baseflows in the Headwaters reach. Winter rearing habitat probably depended on habitat areas with abundant instream cover or off-channel rearing as protection against winter floods, otherwise juveniles were forced to emigrate to lower gradient reaches. Productivity in the Headwater reach probably peaked in the spring during or after the snowmelt, which enabled rapid growth before emigration to the mainstem and Klamath River.

Current status of tactic and habitat conditions

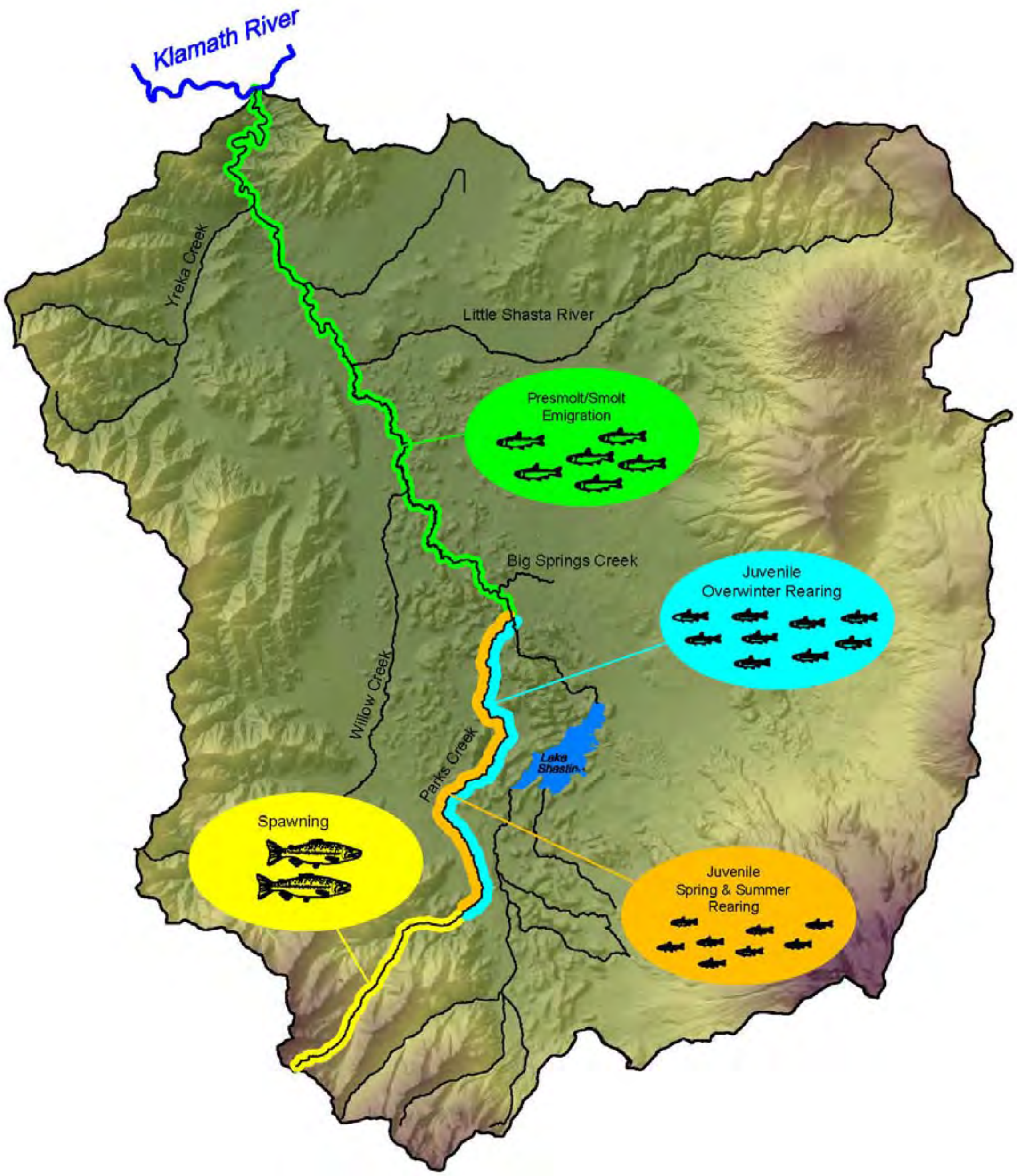
The current status of this tactic is unknown. Streamflows in Parks Creek are diverted in summer for irrigation and in winter to fill Lake Shastina. Streamflow may not be sufficient in many years to allow upstream migration. Fry rearing habitat, juvenile spring/summer rearing habitat, and juvenile overwintering rearing habitat have not been documented in the Headwaters reach. The reach is currently not accessible to agency or private researchers. However, if flows were provided in the fall to allow adult migration to the Headwaters reach, then spawning habitat, fry rearing habitat, summer juvenile rearing habitat, and overwinter juvenile habitat could be available. Juveniles would then require adequate flows in spring to reach the mainstem Shasta River.

High priority data and information needs

- assessment of potential natural and anthropogenic migration barriers that impede or slow migration to Parks Creek Headwaters reach, their cumulative effects on migration over a range of flows, and estimate of streamflow threshold that provides unrestricted migration to Parks Creek Headwaters;
- reach-scale reconnaissance survey of coho salmon spawning and rearing habitat in Parks Creek from the confluence to the historical limit of anadromy;
- direct observation or e-fishing surveys in the Headwaters reach to determine presence/absence and age class distribution of juvenile coho salmon;
- estimate of streamflow threshold that provides unrestricted upstream coho salmon migration to the Parks Creek Headwaters reach;
- estimate of the distribution and abundance of spawning gravels in Parks Creek;
- relationship between streamflow and coho spawning habitat abundance in Parks Creek Headwaters reach;
- relationship between streamflow and coho salmon fry and juvenile summer and winter rearing habitat availability in Parks Creek Middle and Headwaters reaches;
- flow and water temperature data (above diversions) for Parks Headwaters reach;
- estimate of timing and size class distribution of downstream migrants from the Parks Creek to the mainstem Shasta River in spring;
- relationship between streamflow and ephemeral coho rearing habitat in side channels and on floodplains in the Parks Creek Bottomlands reach, or minimum flow threshold providing rearing habitat in these features;
- evaluation of the impacts of sediment transport into the Parks Creek diversion channel on the mainstem Parks Creek channel morphology.
- evaluation of existing and potential riparian vegetation coverage in Parks Creek Bottomlands reach, and assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Parks Creek Foothills and Bottomlands reach required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;
- evaluation of geomorphic conditions, potential habitat availability, and actions required for restoration of channel morphology and salmonid habitat in the Parks Creek Foothills and Bottomlands reach;

- evaluation of bank erosion and channel migration rates, and geomorphic processes maintaining channel morphology in the Parks Creek Bottomlands reach.

7.4.9. Tactic 9: Coho Salmon Parks Creek Foothills/Bottomlands Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Parks Headwaters	Parks Foothills →	→	Mainstem/Canyon

Tactic 9: Coho Salmon Parks Creek Foothills/Bottomlands Tactic

Description of life history tactic:

The Parks Creek Foothills/Bottomlands tactic was probably a dominant historical coho salmon tactic in Parks Creek, but is absent under present water management practices primarily because of lack of summer streamflows in Parks Creek. Seasonal runoff patterns in Parks Creek were probably similar to the Shasta River as depicted in the Edgewood gage (see Section 2.2), with spring-fed baseflows, moderate winter floods, and a distinct snowmelt hydrograph. Fall freshets and springs provided baseflows for adult migration. Spawning habitat was probably abundant and of high quality in the moderate gradient, alluvial Foothills reach. The early life history (migration, spawning, incubation, and early fry rearing) may have been indistinguishable from the coho salmon Headwaters tactic, but the two tactics diverged when many fry of both tactics redistributed in spring and summer to the lower-gradient Bottomlands reach. Upstream dispersal of fry and juveniles was likely a key feature of this tactic, allowing access to cold-water mainstem and spring habitat. In the Bottomlands reach, juvenile coho salmon would have thrived. Historical summer rearing conditions based on cold summer flows in this reach have not been confirmed, but given the presence of an historical snowmelt, springs, and groundwater recharge, suitable rearing conditions were likely prevalent throughout the summer. In dry water years, streamflows and water temperatures may have become marginal if not entirely inhospitable, but most years likely provided abundant habitat. Historical conditions in the Parks Creek Bottomlands reach include the presence of ephemeral wetlands, beaver impoundments, and a meandering, low gradient stream channel, all contributing to rich, complex habitat. Once summer passed, temperatures cooled and coho salmon remained in the Bottomlands to rear throughout the winter. If springs moderated winter water temperatures, fish could have continued rearing and growing. The following spring, juveniles were sufficiently large to emigrate to the mainstem Shasta River and Klamath River before and during the snowmelt runoff.

Current status of tactic and habitat conditions

This tactic is not present under current water management practices. Parks Creek flows are among the most regulated in the Shasta Basin. Summer flow diversions dewater the channel for several months of the summer in most water years. Winter flow diversions to Lake Shastina have eliminated the winter baseflows, winter floods, and the spring snowmelt. In addition, fish passage is uncertain at the MID Diversion and the Cardoza obstruction. The channel morphology may also be heavily degraded from loss riparian habitat, cattle grazing, and other human activities.

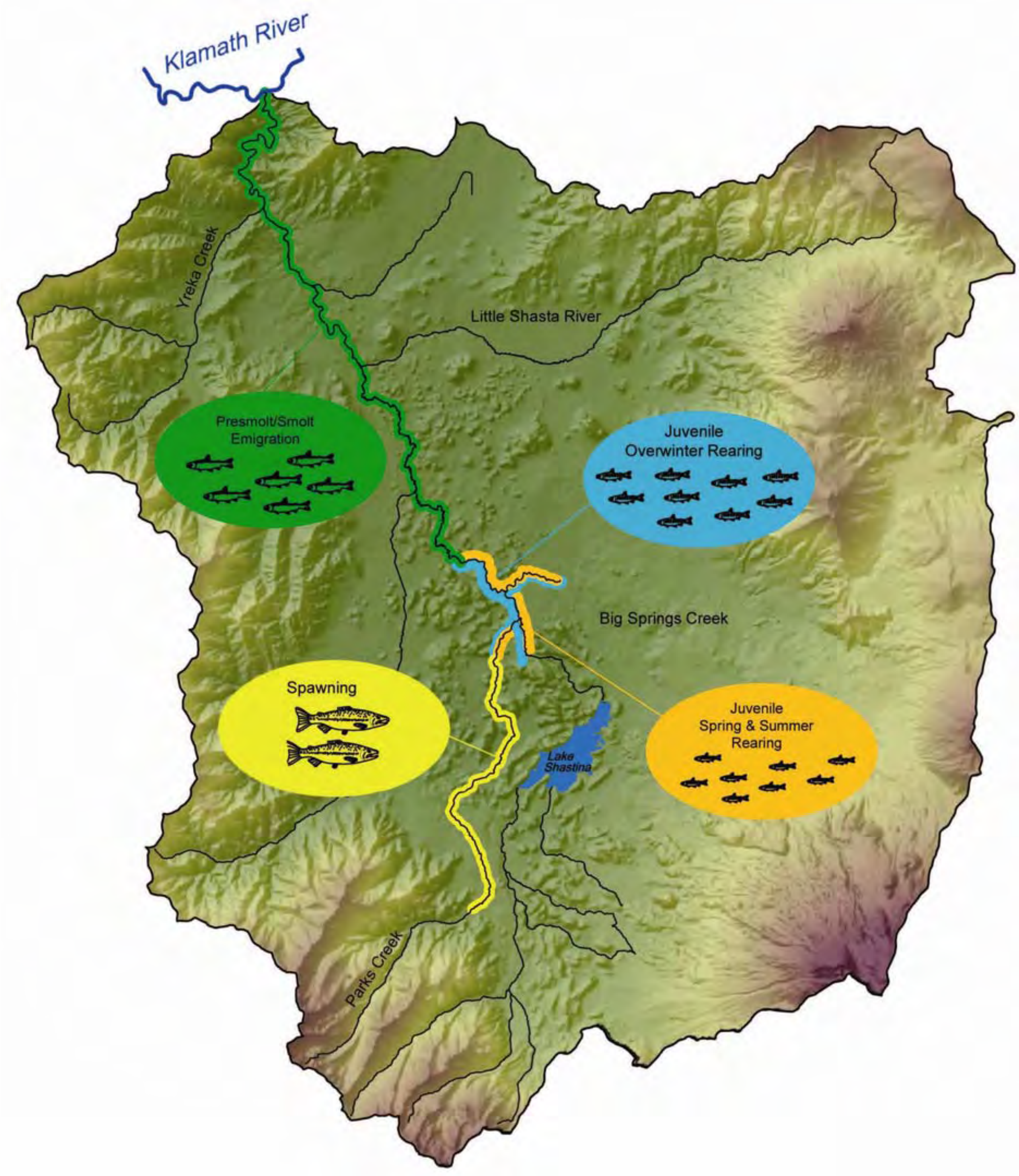
Overwinter rearing habitat may also be available in the Middle Parks and Headwaters reaches, but this is unconfirmed.

High priority data and information needs

[same data and information needs as Tactic #8]

- relationship between streamflow and coho salmon fry and juvenile spring and summer rearing habitat abundance, in the Parks Creek Foothills and Bottomlands reaches;
- estimate of water temperature threshold or other environmental cues that encourage emigration of coho salmon juveniles from the Parks Creek Foothills and Bottomlands reaches in spring;
- evaluation of existing and potential riparian vegetation coverage in the Parks Creek Bottomlands reach, and assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Parks Creek Bottomlands reach required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;

7.4.10. Tactic 10: Coho Salmon Parks Creek Foothills and Big Springs Complex Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Parks Creek Foothills	Big Springs Complex	→	Mainstem/Canyon

Tactic 10: Coho Salmon Parks Creek Foothills and Big Springs Complex Tactic

Description of life history tactic:

The mainstem Shasta River requires restoration of two critical habitat components to make several coho salmon 1+ tactics thrive: adult access to abundant spawning habitat in fall, and cold water summer rearing habitat. Investigations conducted by the NCRWQCB (2006) and UC Davis researchers (Deas et al. 2004; Jeffres et al. 2008) at the TNC's Nelson Ranch indicate that suitable summer water temperatures in the Nelson Reach and more broadly throughout the Big Springs Complex are eminently attainable with modest increases in instream flow, riparian vegetation recover, and a robust tail-water management program. The Parks Creek Foothills could provide an abundant source of spawning habitat and thus abundant fry cohorts to seed summer rearing in the Big Springs Complex. There are as much as eight miles of potential spawning reach with moderate gradient, gravel-bedded channel, from below the I-5 Bridge upstream to the MWCD Diversion dam, and possibly upstream to the Edson-Foulke diversion. Recent CDFG radio-tagging studies have tracked adult coho salmon into Parks Creek. Winter flows are required to protect incubating eggs and newly emergent fry. Spring streamflows through April would also be required, with a well-timed pulse flow to mimic snowmelt runoff. These streamflow components would stimulate benthic invertebrate productivity and to allow fry to grow and redistribute to the mainstem and Big Springs Complex where high quality summer rearing habitat would be abundant. Upstream dispersal of fry and juveniles was likely a key feature of this tactic, allowing access to cold-water mainstem and spring habitat. Fry migration upstream to summer habitat above points of diversion might also be an important consideration. With streamflow management, the coho salmon Parks Creek – Big Springs Complex tactic could produce a large and robust size-class of juvenile coho salmon.

Current status of tactic and habitat conditions

This tactic is not present under current water management practices. Parks Creek flows are among the most regulated in the Shasta basin. Summer flow diversions dewater the channel for several months of the summer in most water years. Winter flow diversions to Lake Shastina have eliminated the winter baseflows, winter floods, and the spring snowmelt. In addition, fish passage is uncertain at the MID Diversion and the Cardoza obstruction. The channel morphology may also be heavily degraded from loss riparian habitat, cattle grazing, and other human activities.

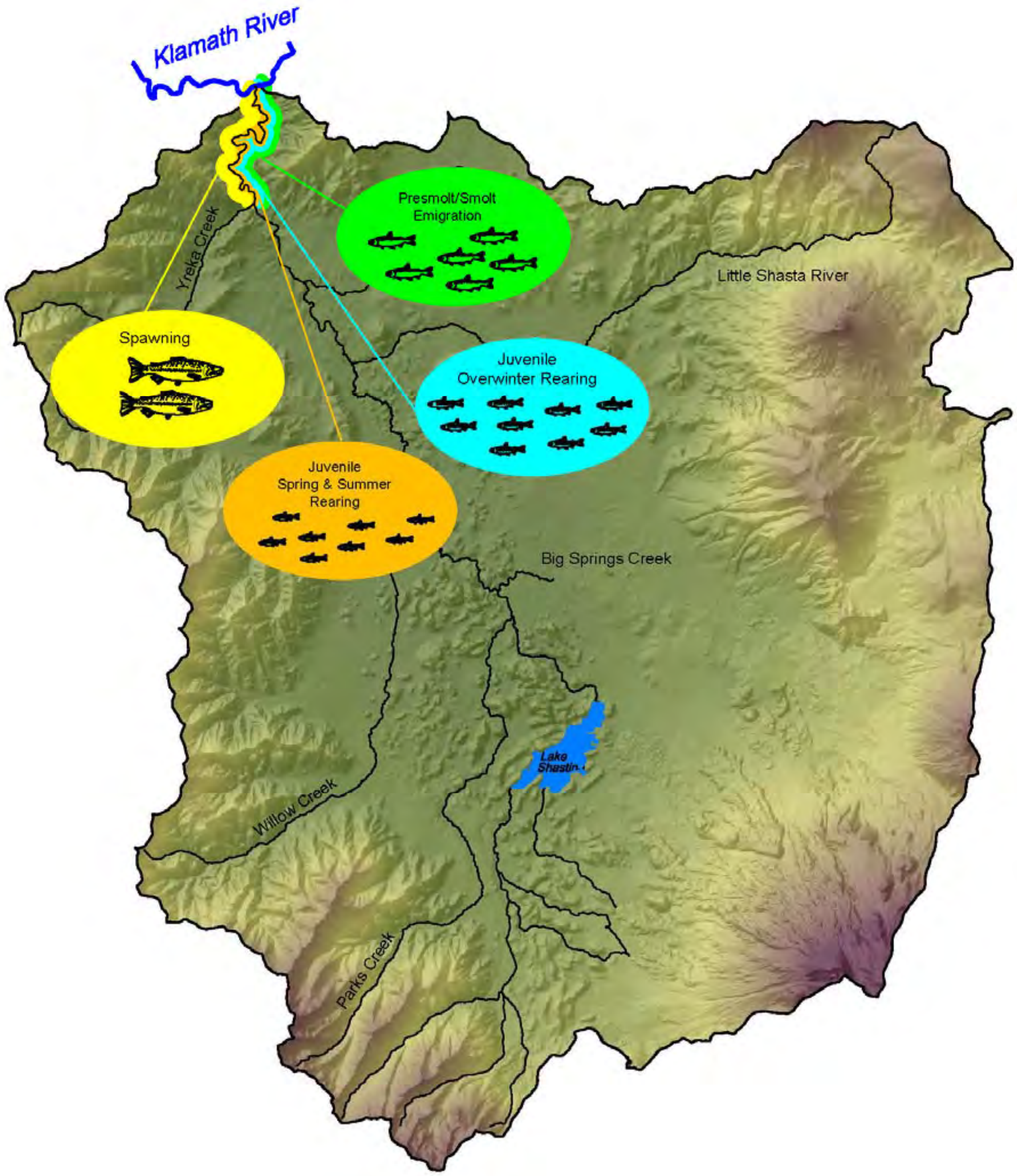
Overwinter rearing habitat may also be available in the Middle Parks and Headwaters reaches, but this is unconfirmed.

High priority data and information needs

[same data and information needs as Tactic #8]

- relationship between streamflow and coho salmon fry and juvenile spring and summer rearing habitat abundance, in the Parks Creek Foothills and Bottomlands reaches;
- estimate of water temperature threshold or other environmental cues that encourage emigration of coho salmon juveniles from the Parks Creek Foothills and Bottomlands reaches in spring;
- evaluation of existing and potential riparian vegetation coverage in the Parks Creek Bottomlands reach, and assessment of hydrograph components available to promote natural riparian vegetation recruitment;
- assessment of a minimum corridor width throughout the Parks Creek Bottomlands reach required to protect stream banks, floodplains, emergent wetland, and riparian vegetation;

7.4.11. Tactic 11. Coho Salmon Canyon 1+ Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Canyon	→	→	→

Tactic 11: Coho Salmon Canyon 1+ Tactic

Description of life history tactic:

The Shasta Canyon reach, extending 7.8 miles from Yreka Creek to the Klamath confluence, was perhaps the most challenging reach of the Shasta Basin within which to produce a coho salmon smolt. With the combined unimpaired hydrograph of all the headwaters, tributaries, and springs, the coho salmon of this tactic first competed with the huge historical Chinook salmon runs that dominated the mainstem, and were immediately at a competitive disadvantage by spawning later, emerging later, and generally preferring lower velocity water and abundant cover for rearing. Incubating eggs and early emergent fry were also vulnerable to scour and downstream displacement by winter storm peaks in December through March. Abundant habitat appears available in the Canyon for early emergent fry to escape at least moderate winter floods. And while the snowmelt runoff in April and May produced abundant juvenile rearing habitat, young-of-year coho salmon that survived the winter were subjected to waves of displaced fry and juveniles from upstream reaches, and pre-smolts and smolts emigrating through the Canyon. Many of the progeny of Canyon spawners may have joined the chorus of winter and spring early–immigrant fish (these fry emigrated to the Klamath River where their survival is currently speculative). Then came the summer season and warm water temperatures, possibly the warmest in the basin given this reach’s location at the bottom of the watershed. Upstream dispersal of fry and juveniles was likely an important feature of this tactic, allowing access to cold-water mainstem and tributary habitat. Finally, there appears to have been abundant juvenile steelhead rearing habitat in the canyon, though predation on young-of-year coho salmon fry could have been substantial. Nevertheless, habitat was available in the Shasta Canyon for all life stages of coho salmon, and some likely persevered to emigrate to the Klamath River.

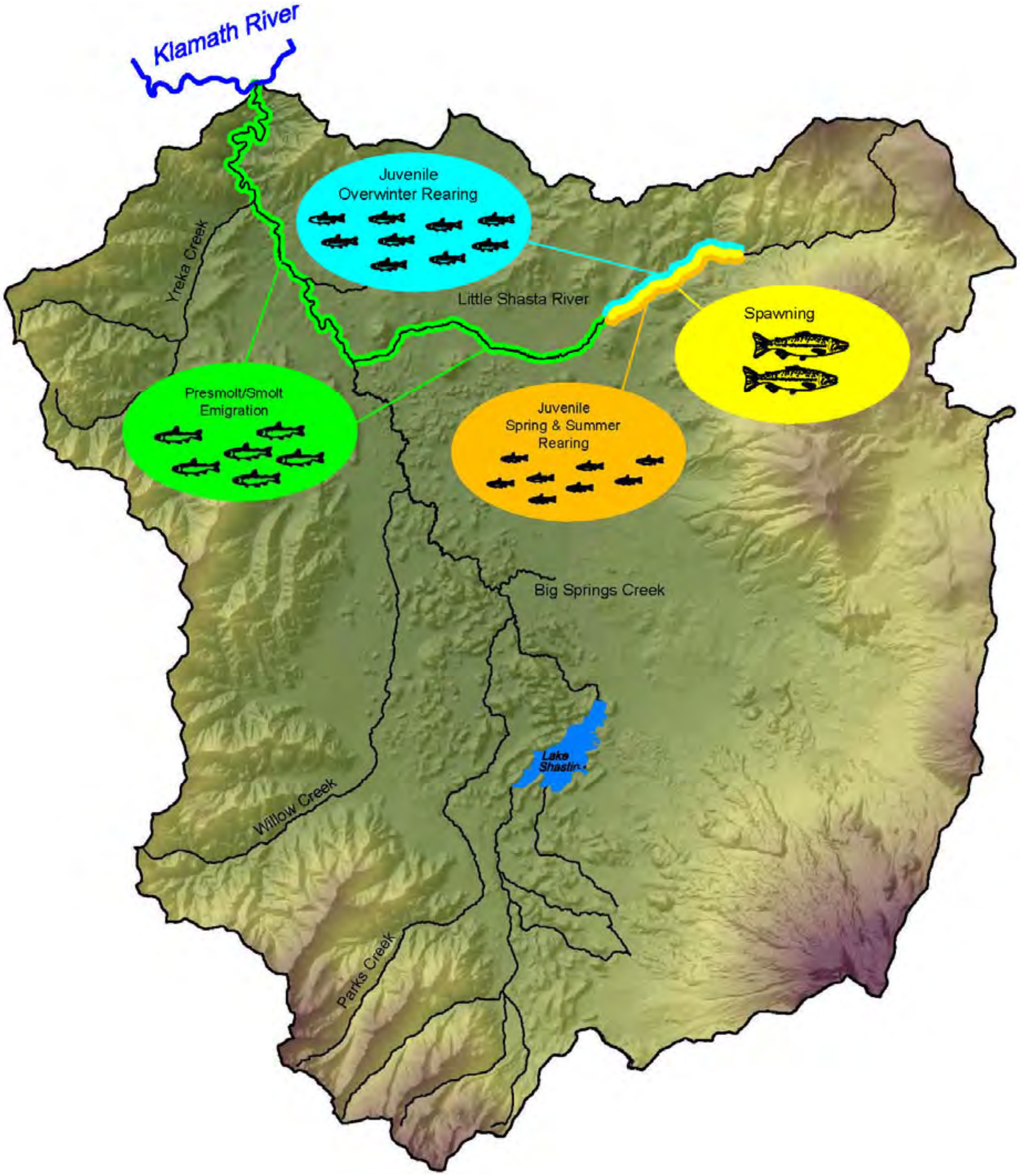
Current status of tactic and habitat conditions

Anecdotal observations and radio-tracking studies by CDFG have identified adult coho salmon spawning in the Canyon. CDFG biologists estimate that currently approximately half of all coho salmon spawning occurs in the Canyon (Chesney et al. 2007). This tactic may be one of only a few contemporary tactics still producing fry and juveniles that reach the Klamath River. Adult passage is likely not an issue, nor is the availability of spawning habitat at the low contemporary escapements. Rearing habitat remains suitable until water management practices cumulatively reduce instream flows, and water temperatures become unsuitable in all years. Because the Dewey Smith Obstruction appears impassable to juvenile upstream migration, fry are assumed to migrate to the Klamath where their survival is currently speculative. Agency and tribal biologists have observed coho salmon rearing in cold-water refugia in Klamath tributaries, many of which are assumed to be non-natal juveniles.

High priority data and information needs

- relationship between streamflow and coho salmon spawning habitat availability in the Canyon reach;
- relationship between streamflow and coho salmon fry and juvenile spring rearing habitat availability in the Canyon reach;
- evaluation of the effects of spring and summer water temperatures on fry growth rates and emigration;
- estimate of the current distribution and abundance of spawning gravels in the Shasta Canyon reach, including spawning gravel sources, transport rates and mobility, and assessment of the need for gravel augmentation to replenish coarse sediment supply and spawning gravel abundance;
- estimate of coho salmon fry and juvenile rearing habitat area in the Canyon reach, and streamflow threshold for providing access to those rearing sites;
- relationship between size and timing at Klamath or ocean entry, and survival-to-recruitment;
- evaluation of the fate of early emergent fry entering the mainstem Klamath in late winter and early spring;
- estimate of the size class distribution of Canyon Tactic 0+ coho salmon emigrating from the canyon in May-June relative to the overall size class distribution of 0+, particularly comparing to sizes of 0+ emigrating from Big Springs Complex;
- the role of Shasta Canyon as winter rearing area for out-of-basin coho salmon;
- the role of Shasta Canyon in genetic mixing (both coho salmon and Chinook salmon) and re-colonization due to poorly imprinted early outmigrants from canyon rearing elsewhere. (maybe this goes elsewhere);
- evaluation of impacts of Higgs hydro, Smith hydro and Smith O&C dams on fish passage, bypass flows, screening, etc.

7.4.12. Tactic 12: Coho Salmon Little Shasta River Foothills Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Little Shasta Foothills	→	→	Little Shasta Bottomlands/ Mainstem/ Canyon

Tactic 12: Coho Salmon Little Shasta River Foothills Tactic

Description of life history tactic:

The Little Shasta River unimpaired hydrograph was nearly as ideal a hydrograph as could be provided for salmonids – consistent year-round baseflows augmented by local cold-water springs, and a modest snowmelt that annually inundated highly productive rearing areas (floodplains, side channels, beaver ponds). Additionally, the Little Shasta has a relatively benign winter high flow regime (as depicted in the historical gaging records) and the potential for high winter survival. For coho salmon, the 5.6 mile long Little Shasta River Foothills reach from Dry Gulch to the Blair Hart Diversion provided high quality spawning and rearing habitat. The reach had a moderate gradient, gravel-bedded alluvial morphology, abundant deep pools for juvenile coho salmon rearing, undercut banks and accumulations of woody material, and a dense riparian and mixed conifer canopy. The elevation, channel morphology, riparian canopy, and cold mountain runoff combined to sustain high quality coho salmon rearing habitat throughout the year, for most or all water year types, even dry years. Additional production for this tactic may have occurred farther upstream in the Headwaters reach above a natural waterfall at the confluence of Dry Gulch that may have been passable by adult coho salmon. As with other tributary tactics, juveniles could overwinter in the Foothills reach, or disperse in the fall to seek over-wintering habitat elsewhere, presumably in the lower-gradient Little Shasta River Bottomlands. In spring, pre-smolts and smolts depended on adequate streamflows through at least late-April or mid-May to emigrate through the Bottomlands reach where good rearing habitat conditions were strongly streamflow dependent. Longer sustained rearing would increase smolt output.

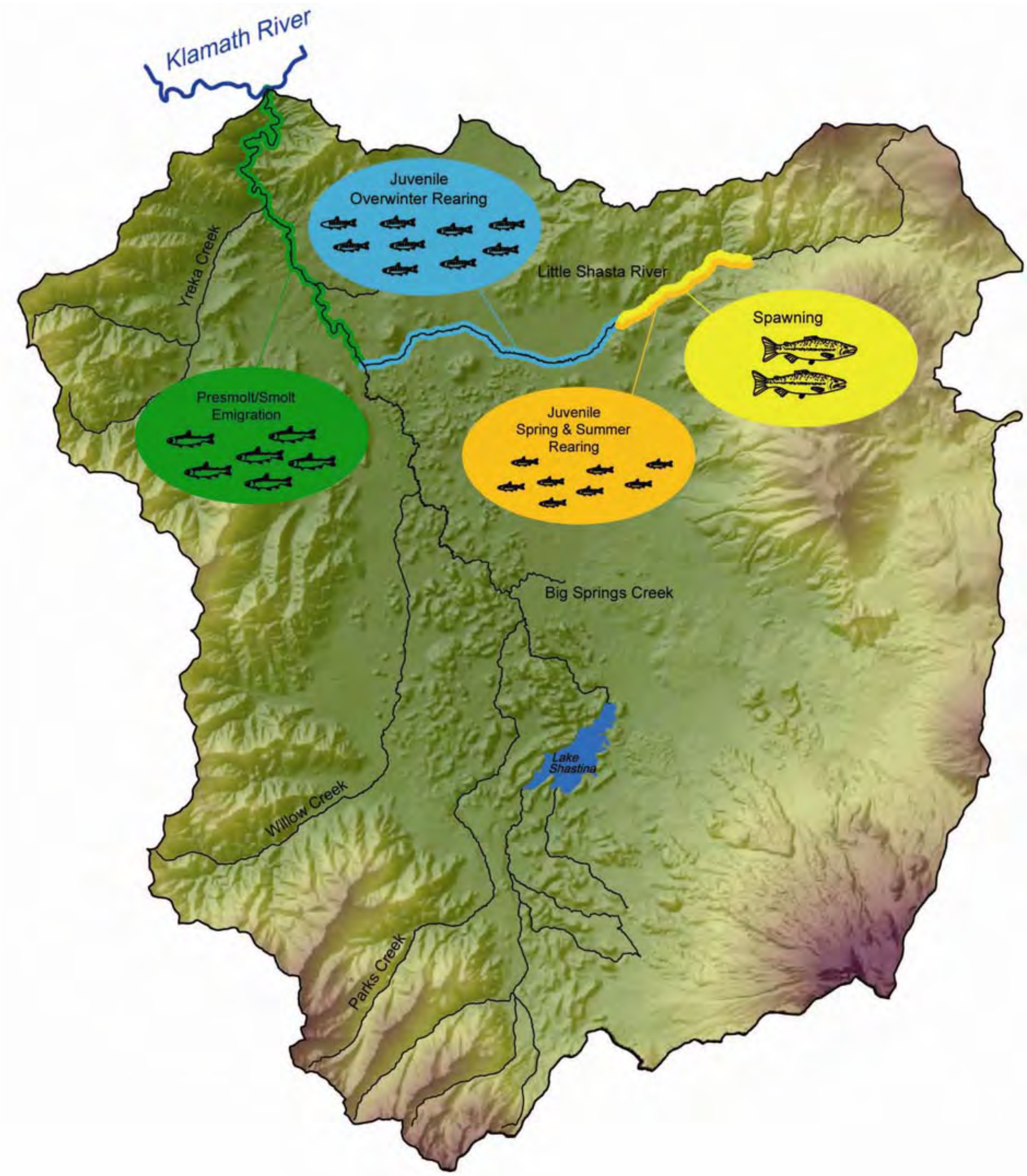
Current status of tactic and habitat conditions

The Little Shasta River presents the ideal opportunity to augment life history diversity for Chinook salmon, coho salmon, and steelhead populations as a way to hedge against unforeseen constraints in other reaches or tributaries. The Little Shasta River is relatively isolated from the rest of the basin, habitat is available for all life stages of all three salmonid species, and only moderate streamflows would be required to sustain high quality year-round rearing habitat. The Little Shasta Foothills reach (above the Musgrave/Hart Diversions) is presently not easily accessible to agency or private researchers. Currently, streamflows are inadequate to encourage upstream migration, particularly early in the fall for Chinook salmon. Passage through the Foothills reach is uncertain. The Dry Gulch Falls may be impassable at low flows, or at least discourages migration. Spawning habitat may be abundant in the Foothills reach and above, but has not been investigated. Spring and summer rearing habitat is also not confirmed but is presumed suitable to at least moderate rearing densities and growth rates. Spring downstream migration may be hampered by flow diversions. During the irrigation season, the Bottomlands reach has unsuitably high summer water temperatures or is dewatered.

High priority data and information needs

- estimate of streamflow threshold that provides unrestricted upstream coho salmon migration to the Little Shasta River Headwaters reach;
- reach-scale survey of coho salmon habitat availability from the mainstem Shasta River confluence to the Little Shasta River Headwaters reach (approximately Dry Gulch), to determine (1) extent of spawning habitat, (2) extent of rearing habitat, and (3) location of natural and anthropogenic migratory barriers;
- relationship between streamflow and coho salmon fry and juvenile summer rearing habitat availability in the Little Shasta River Headwaters reach flow and water temperature data for Little Shasta Headwaters and Foothills reaches;
- analysis of existing and potential riparian vegetation coverage in the Foothills;
- assessment of current impaired streamflow conditions and their effect on riparian vegetation recruitment, seed release timing (phenology) of primary woody riparian species, and assessment of streamflow magnitude and timing that may promote natural regeneration of riparian vegetation;
- estimate of streamflow threshold that provides unrestricted upstream migration into the Headwaters reach;
- relationship between streamflow and ephemeral coho salmon rearing habitat in side channels and on floodplains in the Little Shasta River Bottomlands reach, or minimum flow threshold providing rearing habitat in these features;
- estimate of streamflow threshold that provides coho salmon rearing habitat in side channels and on floodplains in the Little Shasta River Bottomlands reach;
- direct observation or electrofishing surveys in the Headwaters reach to determine presence/absence and age class distribution of juvenile coho salmon.

7.4.13. Tactic 13: Coho Salmon Little Shasta River Foothill – Bottomlands Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Little Shasta River Foothills	→	Little Shasta River Bottomlands	Mainstem/Canyon

Tactic 13: Coho Salmon Little Shasta River Foothills– Bottomlands Tactic

Description of life history tactic:

The near-term recovery of coho salmon in the Shasta Basin will require utilizing any available cold-water habitat for summer rearing. Several Little Shasta River tactics propose to take advantage of potentially the best remaining year-around habitat in the Little Shasta River, in the Foothills reach above the Musgrave Diversion. This reach provides at least five miles of spawning habitat and summer cold-water rearing habitat. The primary instream flow need is to restore baseflows in the fall to allow adult migration upstream to the Foothills reach. Spawning habitat is presumed to be abundant enough to fully seed this reach with emergent fry. The reach has a riparian canopy, a gravel-cobble bed, and likely has abundant large wood providing good rearing habitat conditions during summer. Fry that remain to rear in the Foothills reach would then be available to migrate into winter rearing habitat in the Bottomland reach below the Hart Diversion downstream to the confluence with the mainstem Shasta River. High quality winter rearing in this reach could be provided through winter and into spring. Spring streamflows through May would also be required in the Bottomlands reach, with a well-timed pulse flow to provide snowmelt runoff. These streamflow components would stimulate benthic macroinvertebrate productivity and to allow fry to grow and redistribute to the mainstem and canyon, continue juvenile rearing and growth until large enough to smolt. Because irrigation season begins March 1 on the Little Shasta River, March and April would be important months for providing juvenile rearing habitat in the Bottomlands reach. Springtime streamflows should enable fry and juvenile migration both upstream (fry dispersal to upstream reaches if spawned below diversions) and downstream (juvenile and pre-smolt emigration to high quality rearing habitat in the Bottomlands reach and in the Shasta River mainstem and canyon reaches.

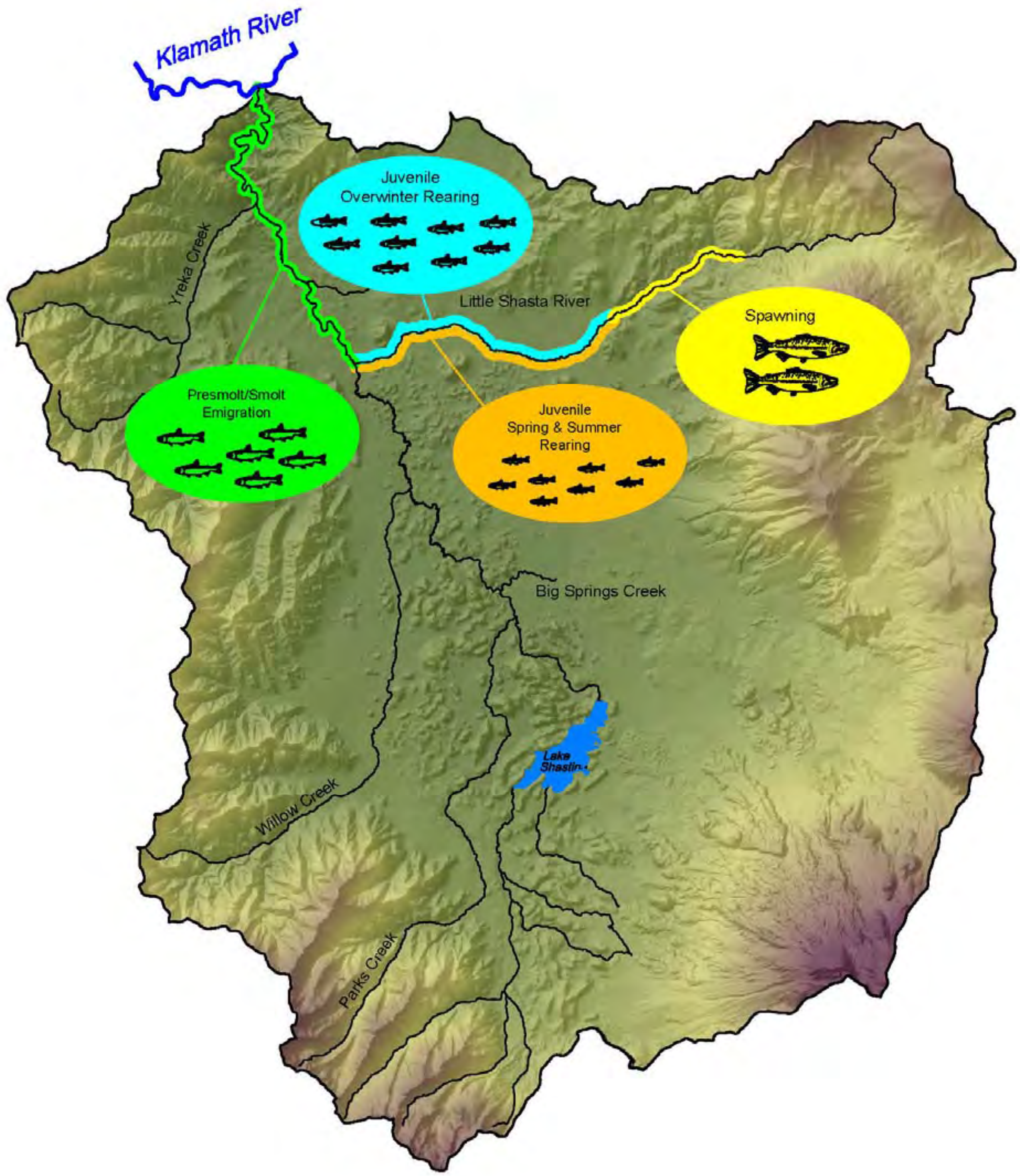
Current status of tactic and habitat conditions

Currently, streamflows are inadequate to encourage upstream migration into the Little Shasta Foothills reach (above the Musgrave/Hart Diversions), particularly early in the fall for Chinook salmon. Passage through the Foothills reach is uncertain. The Dry Gulch Falls may be impassable at low flows, or at least discourages migration. Spawning habitat may be abundant in the Foothills reach and above, but has not been investigated. Spring and summer rearing habitat is also not confirmed but is presumed suitable to at least moderate rearing densities and growth rates. Spring downstream migration may be hampered by flow diversions. During the irrigation season, the Bottomlands reach has unsuitably high summer water temperatures or is dewatered.

High priority data and information needs

[same data and information needs as Tactic #12]

7.4.14. Tactic 14: Coho Salmon Little Shasta River Bottomlands Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Little Shasta Foothills	Little Shasta Bottomlands	→	Mainstem/Canyon

Tactic 14: Coho Salmon Little Shasta River Bottomlands Tactic

Description of life history tactic:

With the exception of a reach mimicking the canyon, the Little Shasta River is appropriately named, having good habitat conditions analogous to the mainstem but on a smaller scale. The winter flood and spring snowmelt hydrographs were present but much smaller compared to the mainstem. The year-round baseflows from local springs resembled the mainstem. Productivity of the Little Shasta Foothills reach, and especially of the Bottomlands reach, was likely extremely high. The Bottomlands tactic would have accessed the Little Shasta River Headwaters reach for spawning and rearing life stages, but was different from the Headwaters tactic because fry and juveniles migrated to the Bottomlands reach throughout the spring and summer and found abundant, high quality habitat in the 11.8 miles of this low-gradient reach. This tactic probably far outperformed the Headwaters tactic of smolt production because of the habitat quality in the Bottomlands reach. As in the mainstem Shasta River, the Little Shasta River probably historically maintained suitable water temperatures throughout the summer, abundant food from aquatic macrophytes and emergent vegetation (cattail and bulrush), and extensive rearing capacity in spring and summer from snowmelt-flooded floodplains, side channels, beaver ponds, and high quality habitat in the Little Shasta mainstem. Growth rates and fish densities would have been high through spring, summer, and into fall. With such optimal habitat conditions, juvenile coho salmon would have remained in this reach through the winter, where habitat capacity and overwinter survival would have continued to be high. Upstream dispersal of fry and juveniles may also have allowed access to cold-water habitat in the Headwaters reach. This tactic historically benefited from a snowmelt runoff of ~50 to 100 cfs sustained flows in April and May in most years. By May, coho salmon smolts of the Bottomlands tactic would have been large enough to emigrate to the mainstem and Klamath River, and the Pacific Ocean.

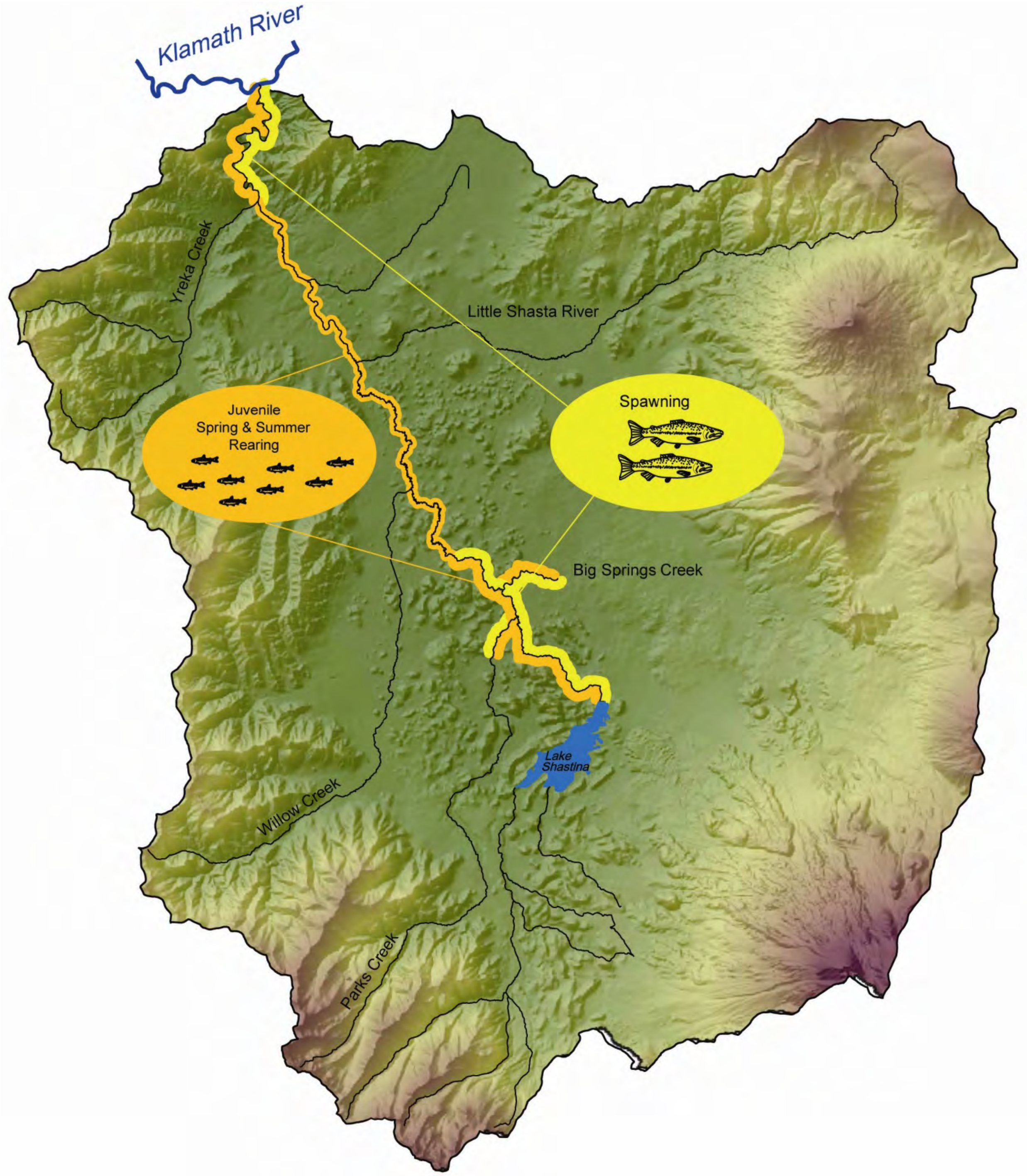
Current status of tactic and habitat conditions

Although juvenile coho salmon have been captured in the Little Shasta River sporadically in recent years (M. Farmer, personal communication), habitat in the Foothills and Bottomlands reaches is not available consistently to sustain a coho salmon tactic. Streamflows appear inadequate (frequently no flows) in the fall and winter of most/all years to promote upstream migration. Adult passage through the Bottomlands reach is also uncertain. If suitable late-summer and fall streamflows were available, adequate streamflows and spawning habitat in the Foothills reach could provide abundant spawning. However, flow diversions for irrigation beginning in early spring appear to diminish habitat in the Bottomlands, and water temperatures become unsuitable by mid-summer before the reach becomes completely dry.

High priority data and information needs

- reach-scale survey of coho salmon habitat availability from the mainstem Shasta River confluence to the Little Shasta River Headwaters reach (approximately to Dry Gulch), to determine (1) extent of spawning habitat, (2) extent of rearing habitat, and (3) location of natural and anthropogenic migratory barriers;
- relationship between streamflow and coho salmon fry and juvenile summer rearing habitat availability in the Little Shasta River Foothills and Bottomlands reaches flow and water temperature data for Little Shasta Foothills and Bottomlands reaches;
- water temperature data for Little Shasta Foothills and Bottomlands reaches;
- estimate of water temperature threshold or other environmental cues that encourage emigration of coho salmon juveniles from the Big Springs Complex in spring;
- analysis of existing and potential riparian vegetation coverage in the Bottomlands;
- relationship between streamflow and ephemeral coho salmon rearing habitat in side channels and on floodplains in the Little Shasta River Bottomlands reach, or minimum flow threshold providing rearing habitat in these features;
- direct observation or e-fishing surveys in the Foothills and Bottomlands reach, and/or downstream migrant trapping data at the mouth of the Little Shasta River, to determine presence/absence and age class distribution of juvenile coho salmon.

7.4.15. Tactic 15: Fall-run Chinook Salmon Yearling Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Canyon	→	0+ ENTER KLAMATH	

Tactic 15: Fall-run Chinook Salmon Yearling Tactic

Description of life history tactic:

A large proportion of the fall-run Chinook salmon run utilizes the 7.8 mile Shasta Canyon reach for their entire Shasta River life history, spawning in the fall, emerging in late winter and spring, then emigrating to the Klamath beginning in February and continuing through June (CDWR 1986). The unimpaired snowmelt runoff likely ranged as high as 400 to 800 cfs in the Canyon during April, May, and June (in wetter years) which may have greatly improved fry rearing habitat suitability in the Canyon by inundating floodplains and side-channels. CDFG estimates the average 2001-2005 Chinook salmon production from the Shasta River was 2.34 million fry (Chesney et al. 2007), and that over 89% of the total 0+ Chinook salmon emigrated as emergent fry between mid-February and early April. Peak Chinook salmon emigration timing (March through April) may therefore correspond to reduced flows in the spring (from irrigation diversions) and increased water temperatures, which prompts most Chinook salmon produced from redds in the Canyon (the Chinook salmon Canyon tactic) to emigrate as emergent fry (Chesney et al. 2007). However, given the uncertainty of survival in the Klamath River as a small Chinook salmon fry, an important life history variation for Chinook salmon was to remain in the benevolent mainstem Shasta River at least through the summer for additional growth. Snyder (1931) noted abundant Chinook salmon fry in seine hauls in the lower Klamath River in late September 1920 and explained that "It would appear from what has been discovered at or near the mouth of the river that a pronounced emigration of young salmon occurs in the late summer and early fall." The fall-run Chinook salmon Yearling tactic in the Shasta River was probably sustained by cold summer baseflows that allowed a portion of the cohort to rear through the summer throughout the Shasta River mainstem, gain additional size/weight, then emigrate when Klamath mainstem temperatures cooled in fall. Smolt-to-adult survival of fall-run Chinook salmon may be enhanced by growth rate and size at ocean entry. Progeny of most fall-run Chinook salmon spawners would benefit from higher spring flows and improved rearing habitat conditions (the Chinook salmon Canyon tactic), and progeny of late-fall spawned Chinook salmon and smaller individuals of the cohort may benefit from extended rearing by remaining through the summer (the Chinook salmon Yearling Tactic). Late-fall emigration would also reduce risk of mortality from disease in the Klamath River.

Current status of tactic and habitat conditions

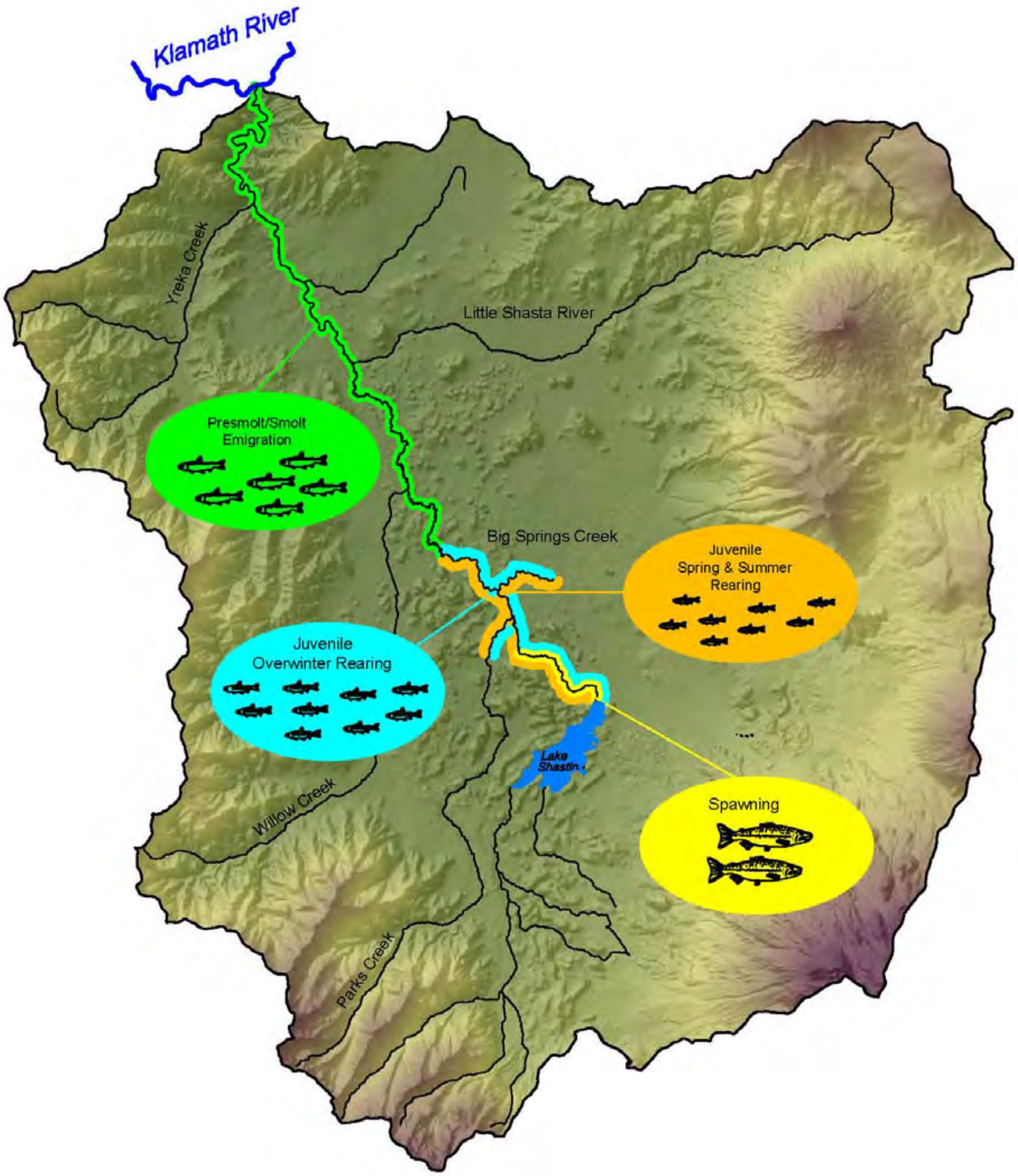
The spawning distribution for fall-run Chinook salmon includes the Shasta Canyon as well as the Big Springs Complex (the Nelson Ranch and Below Dwinnell reaches, Big Springs Creek, lower Parks Creek, and Hole in the Ground. CDFG studies have documented a substantial loss of suitable rearing habitat in these reaches of the Shasta River as a result of water management operations. Elevated water temperatures in early spring may force most or all Chinook salmon fry to emigrate before the low summer flow period. Given suitable summer baseflow and water temperature conditions, fry and juvenile Chinook salmon rearing habitat would be abundant throughout the Shasta Canyon and upper mainstem Big Springs Complex reaches. Currently, survival of emergent fry Chinook salmon entering the Klamath River is unknown, but elevated water temperatures, low summer flows, and high infection of juvenile Chinook salmon by myxozoan parasites (Nichols and Foott 2005, from Chesney et al. 2007) indicate survival may be low. The risk of infection from parasites appears to increase later in the season, after most Chinook salmon outmigrants leave the Shasta. The predominance of salmon following this tactic in the Shasta River may indicate that early outmigration is beneficial, when late outmigration has a high risk of mortality. The yearling tactic may not be beneficial under contemporary Klamath River summer conditions.

High priority data and information needs

[same data and information needs as Tactic #1]

- relationship between size at Klamath or ocean entry, timing of entry to Klamath, and survival to recruitment;
- distribution and abundance of juvenile Chinook salmon summer rearing habitat in the Big Springs Complex (and possibly in a restored Dwinnell reach);
- water temperature threshold that encourages extended residency in the Shasta River mainstem, and location/prevalence of cold water refugia along the mainstem.

7.4.16. Tactic 16: Coho Salmon Below Dwinnell Dam Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Below Dwinell	Below Dwinnell, Big Springs Complex	→	Mainstem/Canyon

Tactic 16: Coho Salmon Below Dwinnell Dam Tactic

Description of life history tactic:

This tactic is similar to the Big Springs Complex coho salmon 1+ tactic, but incorporates the 6.9 mile long section of mainstem Shasta River below Dwinnell Dam downstream to the Big Springs confluence. This reach may have been one of the few reaches capable of providing habitat for all the freshwater life stages: spawning, incubation and early emergent fry rearing, summer rearing, winter rearing, and even pre-smolt rearing before the cohort began migrating to the Klamath River and the Pacific Ocean. Given the increase in stream gradient through the Nelson reach and the Below Dwinnell reach, spawning gravels may have been (and still may be) abundant in this reach. However, since construction of Dwinnell Dam in 1928, spawning habitat is degraded by the blockage of sediment supplied to this reach from above Dwinnell Dam, and from the loss of winter floods that historically maintained the channel morphology and habitat characteristics. As with other tactics that utilized spawning reaches for fry rearing, some fry remained within these same reaches, while some fry were forced to emigrate to find suitable habitat in other areas because of high fry rearing densities within the spawning grounds. Fry that remained could have reared throughout this reach an entire year under historical conditions. Upon emigrating in the spring, this tactic, like many others, would have benefited from the excellent rearing conditions afforded in the mainstem Shasta River, the Klamath River mainstem, and estuary.

Current status of tactic and habitat conditions

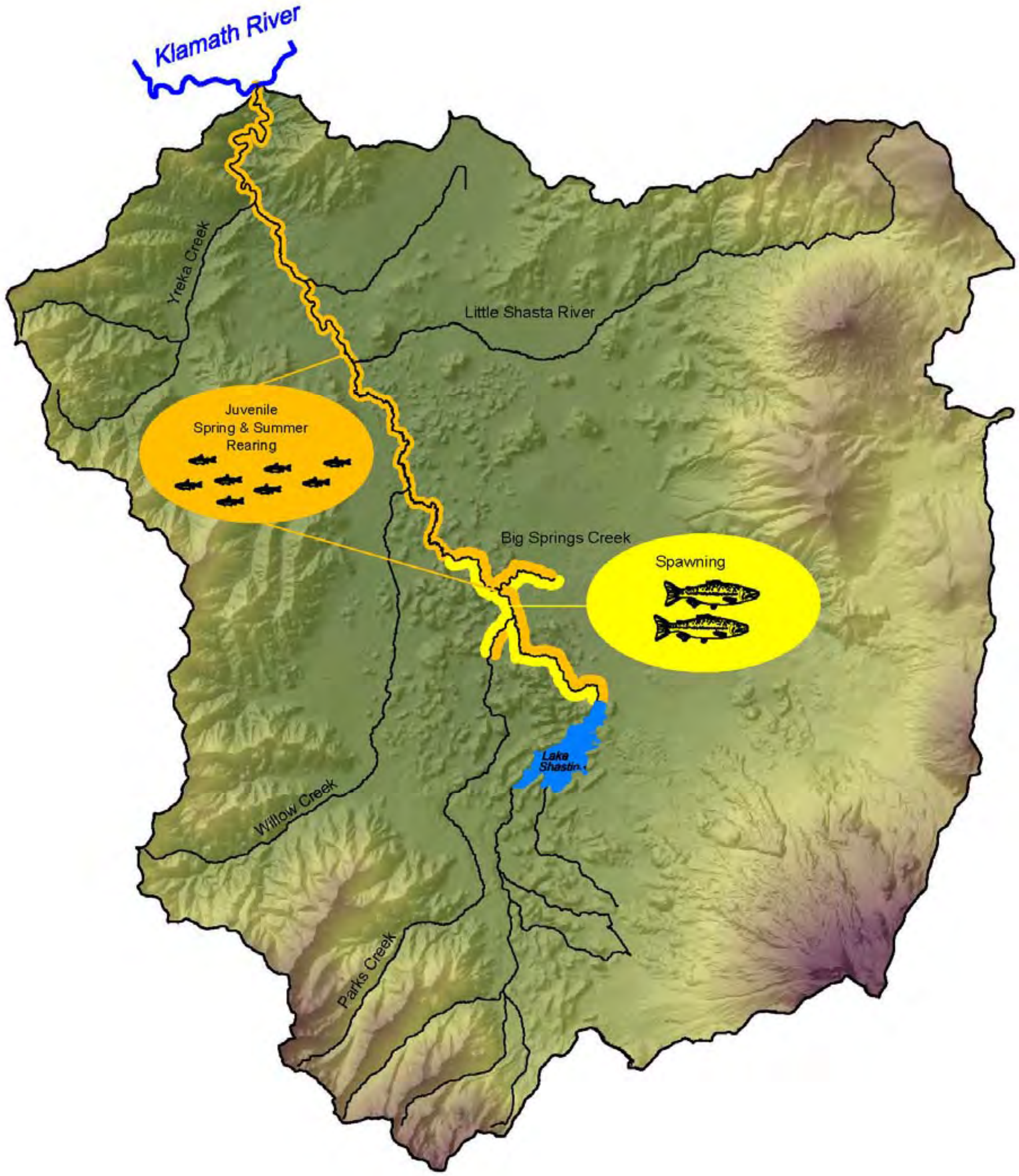
During the irrigation season, the reach below Dwinnell Dam has unsuitably high water temperatures and low baseflows that cannot sustain spawning or rearing habitats. Conditions of early emergence rearing habitat, juvenile spring/summer rearing habitat, and juvenile overwintering rearing habitat have not been well-documented. Based on what is known, spawning and rearing could occur if streamflows were available below the dam. However, high quality cold water releases from Dwinnell Dam may be problematic, given potential water quality issues in Lake Shastina (Vignola and Deas 2005). Providing cold baseflows during irrigation season (April 1-October 1) in the Below Dwinnell reach would require that local springs near the dam be allowed to feed the mainstem, perhaps augmenting small releases of Lake Shastina water when water quality conditions are not severe. Water diversion rights could be offset by water delivery from Dwinnell Dam. The quantity of flow of these springs is unknown. This type of water transfer would not only benefit the Below Dwinnell reach, but would also improve temperature and flow conditions in the Nelson Ranch reach and conditions farther downstream.

High priority data and information needs

[same data and information needs as Tactic #3]

- relationship between streamflow and coho salmon spawning habitat abundance in the Below Dwinnell
- estimate of the distribution and abundance of spawning gravels, and assessment of spawning gravel quality in the Below Dwinnell reach; preparation of gravel maintenance plans in the Below Dwinnell reach;
- location of springs, groundwater seepage, and other sources of cold water summer rearing habitat refugia in the Below Dwinnell reach;
- mapping to determine extent of existing riparian vegetation, identification of plant stand types, evaluation of age-class structure, and location of geomorphic surfaces capable of supporting riparian vegetation recovery;
- feasible riparian vegetation recovery options, including experimentation with snowmelt flood releases to promote riparian plant seedling germination, initiation, and survival to recruitment; and riparian planting experimentation.

7.4.17. Tactic 17: Spring-run Chinook Salmon Mainstem Tactic



Spawning - Incubation - Early Fry Rearing	Juvenile Spring - Summer Rearing	Juvenile Over-Winter Rearing	Presmolt - Smolt Emigration
Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun-Jul-Aug-Sept	Oct-Nov-Dec-Jan-Feb-Mar	Apr-May-Jun
Below Dwinnell, Big Springs Complex	——→ 0+ ENTER KLAMATH		

Tactic 17: Spring-run Chinook Salmon Mainstem Tactic

Description of life history tactic:

The spring-run Chinook salmon was more accurately an entire life history strategy rather than a tactic, and they likely occupied the entire watershed that was historically available to anadromous salmonids. But it is described in this context to highlight the breadth of life history diversity sustained by historic flow and habitat conditions in the Shasta River. The Spring-run Chinook salmon were likely the dominant historical life history strategy. Snyder (1931) documented the spring-run Chinook salmon from anecdotal evidence and from records of the commercial catch in the estuary in 1918-20, and is quoted to say "They [spring-run Chinook salmon] formerly came to the Shasta River in great numbers, an old resident referring to it as the best spawning tributary of the Klamath River." Snyder also quoted R.D. Hume's description of the Klamath River: "In 1850 in this river during the running season, salmon were so plentiful, according to the reports of the early settlers, that in fording the stream it was with difficulty that they could induce their horses to make the attempt, on account of the river being alive with the finny tribe. At the present time the main run, which were the spring salmon, is practically extinct…" Wales (1951) concluded his analysis of the Shasta River Chinook salmon with the assertion that "… it is my belief that a very large part of the former king salmon run in the Shasta River was spring run fish. Actually I believe that only about 8% of the run was fall run". The spring-run Chinook salmon began entering the Klamath in late March, peaked in April and May "during its flood height of very cold water, and pass up stream under the same conditions" (Snyder 1931), and waned by mid-June. Adults were smaller in size than fall-run Chinook salmon, were sexually immature, and lacked spawning colors. Snyder (1931) put their arrival in the Shasta River in June and early July where they held until becoming sexually mature to spawn at about the same time as the fall-run Chinook salmon. Spring-run Chinook salmon likely shared life history characteristics of the fall-run Chinook salmon in terms of spawning location and habitat preferences, incubation and emergence timing, fry and juvenile rearing, and emigration timing. There is no specific documentation of their habitat utilization within the Shasta Basin differentiated from the fall-run Chinook salmon. Wales (1951) stated "we have no records to show what part of the spawning run of kings used the river and tributaries above the dam but it is known that this area was important." Snyder attributed the depletion of the spring-run Chinook salmon to "construction of dams on the mainstem Klamath River…mining operations, overfishing both in the river and at sea, irrigation and other causes…".

Current status of tactic and habitat conditions

Spring-run Chinook salmon were extirpated from the Shasta River at least by the early 1900's, but still persist in the Trinity and Salmon rivers. Assuming they historically concentrated in the Shasta mainstem reaches where cold water temperatures persisted throughout the summer (the Foothills, Below Dwinnell, Nelson Ranch, and Middle Shasta River reaches), their recovery to the Shasta basin is imminently feasible. Summer water temperatures in the Shasta River currently are not suitable to sustain oversummering adult Chinook salmon. But given favorable water temperatures in summer and fall in the Shasta mainstem, habitat in the reaches below Dwinnell Dam appears to be suitable for the remainder of their life stages.

High priority data and information needs

- Restoring the spring-run Chinook salmon tactic to the Shasta River should be a high priority for salmonid recovery in the basin, but the data and information needs are beyond the scope of this plan.

7.5. Appendix E. WY2010-2011 Shasta River Coho Salmon Voluntary Emergency Action Plan (12-03-10)

2010 Shasta River Coho

Voluntary Emergency Action Plan 12/03/2010

This Emergency Action Plan represents the efforts of the Shasta Work Group to develop potential solutions which will serve to advise interested stakeholders on issues relating to protecting and enhancing coho salmon populations in the anadromous portions of the Shasta River Watershed. The Shasta Work Group is an ad-hoc and autonomous committee representing a variety of interests, whose members possess knowledge of issues regarding sustainable agriculture and needs of coho salmon. The Shasta Work Group is an advisory group and has no regulatory authority.

1= HIGH, 2= HIGH-MEDIUM, 3= MEDIUM, 4= LOW-MEDIUM, 5= LOW

Completed	Item #	Prioritization (1-5)		Suggested Date Actions Should be Completed	Key Entity	Implementation Status, (to be updated)	Reason	Comments/Next Steps	Potential Funding Sources
	1	1	Conduct investigations at barriers based on their priority (below) to determine how to provide temporary access for fish around these diversions while a permanent solution is being worked on. Barrier should be assessed in the following order: Bridgefield Springs Complex, Kettle Springs, Cardoza, GID/Huseman, waterwheel at Big Springs Creek and Novy-Rice.	7/15/2010	CDFG, NOAA, Landowners	Investigation completed on the waterwheel @ Big Springs Creek. Access to Bridgefield Springs Complex has not been provided and limited access has been provided to Kettle Sp.	Investigations should occur strategically and begin on those barriers listed as higher priority.	Temporary access is needed to accomplish this recommendation	In-kind contributions from agencies with in-house engineering staff.
X	2	1	Confirm the water rights at diversions in the Bridgefield Springs Complex.	7/15/2010	CDWR, CDFG, NOAA, RWQ	Completed by CDWR.	Foundation info for fish screens, headgates, water lease etc…	This information is needed to do any water leasing/dedications. CDWR will undertake this.	In-kind contribution from CDWR.
X	3	1	Confirm the water rights at diversions on Kettle Springs	7/15/2010	CDWR, CDFG, NOAA, RWQ	Completed by CDWR.	Foundation info for fish screens, headgates, water lease etc…	This information is needed to do any water leasing/dedications. CDWR will undertake this.	In-kind contribution from CDWR.
	4	1	Assess category 10 and 11 unfenced areas to determine what fence categories these reaches should be in.	7/15/2010	SVRCD, CDFG, NOAA, RWQ	No progress	Need to determine if any of these areas need fencing that will impact fall spawning.	Categories 10 and 11 are reaches that haven't yet been assessed, and/or are not likely to have priority recovery importance in the near term. Approx 8 landowners would be involved.	Could be conducted during ITP/1600 site visits by CDFG and SVRCD.
	5	1	Install all category one and two fences shown on fencing maps.	8/1/2010	Landowners, all funding partners	In progress			Some funding is available by FWS. TNC has electric fencing available in the interim while funding is acquired.
	6	1	Create an irrigation operations manual (i.e., the core component of a ranch mgmt plan) for all diversions on Emmerson Investment owned land that will integrate irrigation needs and practices with biological needs of fish. Test the management plan this 2010 irrigation season to insure appropriate results.	8/15/2010	Landowners, all funding partners	In progress		The group agreed that there needs to be close coordination among the Emerson ranches staff and partners to achieve this.	Emmerson Investments LLC., SVRCD/CRMP watershed coordinator funding. SVRCD- TMDL ranch planning funding?

	7	1	Conduct any necessary experiments, trial runs, modeling or data collection to test hypothesis and/or support or negate actions identified below. This action requires gaining access to critical areas of the watershed including Parks Creek, Kettle Springs, Bridgefield Springs Complex, and the Upper Shasta River. Actions include confirming natural flows from springs and the Upper Shasta River, evaluating temperature and tailwater returns, assessing barriers, determining minimum instream flow needs etc...	9/1/2010	CDFG, AquaTerra, Grant Davids Engineering, McBain and Trush	In progress	Sun angles dropping and its cooling off. Need to test during the irrigation season.		Many different studies are currently funded and are ongoing. The additional data needs could be folded into ongoing studies. Such as: McBain and Trush flow and gravel studies, SVRCD/AquaTerra tailwater monitoring, Davids Engineering Water Efficiency Study, etc.
	8	1	Acquire written permission to access properties on Parks Creek, Kettle Springs, Bridgefield Springs, and the Upper Shasta River for monitoring of fish presence by CDFG during 2010-2012 to help direct and inform actions listed below.	9/1/2010	CDFG, NOAA	Limited access aquired to date.			No cost.
	9	1	Trap and haul adults from the Shasta Canyon area up into the Big Springs complex area.	10/1/2010	CDFG, NOAA, SVRCD, TNC, other Partners	Evaluated and denied.	These may be an important strategy to mitigate for any natural caused events which may wipe out redds or rearing habitat. Such events could be winter floods that scour redds, or a hot spring. The decision to do this needs to happen ASAP so it can be installed prior to adult migration.	The group agreed that conditions in Parks Creek are problematic, often leading to loss of Coho redds, eggs, or juveniles…while this is not the case in Big Springs Creek. Physical or electrical barrier(s) could be installed. It was felt that this form of intervention has good potential.	CDFG fisheries budget, other??
	10	1	Build a temporary, partial barrier across the Shasta River upstream from Big Springs in fall 2010, to direct adult Coho salmon spawners into Big Springs complex area.	10/1/2010	CDFG, NOAA, Landowners	Evaluated and denied.			CDFG fisheries budget, other??
	11	1	Trap and haul juveniles from the Shasta Canyon area into the Big Springs complex area.	10/1/2010	CDFG, NOAA, Landowners	Evaluated and still being considered.			CDFG fisheries budget, other??
	12	1	Agreements in place to implement measures to insure instream flows are achieved in Parks Creek for all life stages of Coho, if present, through a variety of methods: 1600/ITP permit requirements, purchase and/or lease of water or possibility for pasture swaps. Details: Continue to support efforts by McBain and Trush to determine interim minimum instream flows. The following landowners should be contacted: MWCD, Emmerson Investments LLC., Edson Folke, Mole-Richardson, Cardoza, Jacobson.	10/1/2010	SVRCD, CDFG, NOAA, CDWR, RWQ	CDFG and McBain & Trush to meet a formulate flow requirement.		There are fish passage issues that need to be addressed during both the spring and fall, to ensure successful movement of anadromous fish to and within Parks Creek.	SVRCD has acquired some water trust $'s for high priority transactions. More funding may be needed.
	12A	1	Monitor Big Springs Creek for sediment, e.g., improved tailwater management, and ensure that sediment sources are treated.	10/15/2010	RWQCB, Landowner	In progress			
	13	1	Determine whether fish screens are needed at the diversions in the Bridgefield Springs Complex and insure that all construction work is completed.	10/15/2010	CDFG, Landowner	Fish screens needed if barriers are remediated.	1600 permits may require this to be installed by October 15, 2010		In-kind assessment by CDFG

	14	1	Determine whether fish screens are needed at the diversions on Kettle Springs and insure that all construction work is completed.	10/15/2010	CDFG, Landowner	Fish screens are needed CDFG is including screening in ITP and expects screens to be installed by March 2011.	1600 permit may restrict construction timing.		In-kind assessment by CDFG
	15	1	Agreements in place to implement measures to insure instream flows are achieved in Kettle Springs to support all life stages of fish (if present) through a variety of methods including: 1600/ITP permit requirements, purchase and/or lease of water or possibility for pasture swaps. Details: Continue to support efforts by McBain and Trush to determine interim minimum instream flows for Kettle Springs. This includes collecting data the summer of 2010 to determine quantity of flow needed to achieve temperature goals and provide for suitable habitat. Landowners to contact regarding implementing this measure is Emmerson Investments.	1/1/2011	SVRCD, CDFG, NOAA, CDWR, RWQ				SVRCD has acquired some water trust $'s for high priority transactions. More funding may be needed.
	16	1	Agreements in place to implement measures to insure instream flows are achieved in the Bridgefield Springs Complex area to support adult spawners, emergence fry, or oversummer rearing juveniles (if determined to be present) through a variety of methods including: 1600/ITP permit requirements, purchase and/or lease of water or possibility for pasture swaps. Details: Continue to support efforts by McBain and Trush to determine interim minimum instream flows for Kettle Springs. This includes collecting data the summer of 2010 to determine quantity of flow needed to achieve temperature goals and provide for suitable habitat. Landowners to contact regarding implementing this measure is Emmerson Investments.	1/1/2011	SVRCD, CDFG, NOAA, CDWR				SVRCD has acquired some water trust $'s for high priority transactions. More funding may be needed.
	17	1	Identify, design, permit and install tailwater reduction projects in the Bridgefield Springs Complex Area that could readily be installed by February 2011.	2/15/2011	SVRCD, AquaTerra, Funding Partners, Landowners	No progress			SVRCD-Tailwater Grant
	18	1	Put in place a monitoring program that shows real-time temperature and flows in critical reaches of the watershed so landowners and resource managers can respond to changing conditions. Provide resources that will inform landowners and resource managers of changing conditions and forecast future conditions.	2/15/2011	CDFG, CDWR, NOAA, RWQ				In-kind contribution from agencies, organizations and landowners. Time contribution only.
	19	1	Obtaining necessary permissions from Emmerson Investments so the SVRCD can have access to the lands adjacent to Kettle Springs so to begin monitoring tailwater returns and identifying tailwater reduction measures.	3/1/2011	Emmerson Investment, AquaTerra, SVRCD, RWQ	No access to date.			No cost to provide access, monitoring paid for out of SVRCD tailwater grant.
	20	1	Identify, design, permit and construct projects adjacent to Kettle Springs that will reduce tailwater input without putting more land into production and that will not increase diversions from springs that would otherwise return to the river.	3/1/2011	AquaTerra, SVRCD, Landowner, RWQ				SVRCD tailwater grant, may need other funding depending on scope of projects.
	21	1	Identify, design, permit and construct projects in the Upper Shasta River that will reduce tailwater input without putting more land into production and that will not increase diversions from springs that would otherwise return to the river.	3/1/2011	AquaTerra, SVRCD, Landowners, RWQ				SVRCD tailwater grant, may need other funding depending on scope of projects.
	22	1	Insure that any barriers in Kettle Springs are remediated so to provide safe passage for Coho year-round.	3/1/2011	CDFG, NOAA, Landowner		Barrier committee ranked high		Little to no cost assuming cooperation from landowner.

	23	1	Insure that any barriers in the Bridgefield Springs Complex area are remediated so to provide safe passage for Coho year-round.	3/1/2011	CDFG, NOAA, Landowner		Barrier committee ranked high		Little to no cost assuming cooperation from landowner.
	24	1	Insure that passage past the Cardoza diversion is provided for fish whether it be through infrastructure upgrades or dam management techniques.	3/1/2011	CDFG, NOAA, Landowner	No progress	Barrier committee ranked high		Little to no cost assuming cooperation from landowner.
	25	1	Work with agencies to identify and implement a strategy at Big Springs Lake Dam so to allow a minimum of 3 cfs of water below the dam all year-round. This measure may be achieved through 1600, Fish and Game Code 5937, or water leases or exchanges. A accurate measuring devices are needed at the outlet of Big Springs Lake and at all diversions in the lake.	4/1/2011	CDFG, NOAA, RWQ, Landowners			This could involve wells within the Big Springs interconnected groundwater zone. It was reported that blasting associated with county Big Springs Road work in the 1980s may have affected groundwater conditions adversely, and that removal of the Big Springs Lake dam could accentuate spring water yield. There may also be new landowners who have diverted cold water into impoundments (e.g., Taylor Springs by Sunshine Lane), thereby reducing cold water delivery to the Shasta River.	Time needed to coordinate with landowners. In-kind contributions from agencies and landowners.
	26	1	Insure that temporary fish passage is provided for 0+ juveniles and 1+ out-migrant fish at GID/Huseman diversion.	4/1/2011	CDFG, NOAA, Landowner	No progress	Ranked high by barrier committee. One potential solution is an Archimedes screw method?		Unknown costs. Potentially significant?
	27	1	Insure the protection of a minimum 40 cfs cold water springs from Big Springs Creek at the waterwheel.	4/1/11-10/1/11					No cost.
	28	2	Develop a strategy and implement trial runs during the 2010 irrigation season to see how delivery of water discharged from Dwinnell Dam for prior water right users downstream can be changed to minimize the negative effects the water may have on springs down river, especially Clear Springs. These trial runs will inform a solution to this issue for next 2011 season.	9/1/2010	CDWR, CDFG, RWQ, SVRCD, MWCD, Landowners	No progress		Explore current diversion practices with Ira, to see if any improved water mgmt can be achieved. Temperature of water coming out of Clear Springs seems to fluctuate. Mike Deas is taking water quality and temperature samples above, at, and below Dwinnell Dam.	No costs, in-kind contributions in time from agencies and landowners.
	29	2	Install all fences listed as category three on the fencing maps or provide interim measures to prevent livestock access to reaches between October-December and March-June.	9/15/2010	Landowner, partners				Need funding.
	30	2	Install headgates and measuring weirs at any points of diversion in the Bridgefield Complex area and regularly monitor diversion rates to insure that rates meet water rights.	3/1/2011	CDWR, CDFG, Landowner		1600 permit conditions may require this task to be completed by October 15, 2010		Need funding.
	31	2	Install headgates and measuring weirs at any points of diversion in Kettle Springs and regularly monitor diversion rates to insure that rates meet water rights.	3/1/2011	CDWR, CDFG, Landowner				Need funding.

	32	2	Confirm that all diversions in Parks Creek are equipped with measuring devices and are diverting within their legal water right. Other riparian and appropriate rights should also be evaluated to make sure they are consistent with Riparian Statements of Water Use.	4/1/2011	CDWR, CDFG, Landowner				No cost, in-kind CDWR.
	33	2	Confirm that all diversions in the Upper Shasta River are equipped with measuring devices and are diverting within their legal water right. Details: The following water diversions should be visited and confirmed: #156-166. Other riparian and appropriate rights should also be evaluated to make sure they are consistent with Riparian Statements of Water Use including diversion at Clear Springs.	4/1/2011	CDWR, CDFG, Landowner				No cost, in-kind CDWR.
	34	3	Install all fences listed as category four on the fencing maps.	9/15/2010	Landowner, partners		If successful on acquiring flows in Parks Creek this may become important spawning habitat.		Need funding.
	35	3	Agreements in place to implement measures to ensure instream flows are achieved in the Upper Shasta River to support all life stages of Coho, if present, through a variety of methods: 1600/ITP permit requirements, purchase and/or lease of water or possibility for pasture swaps. Details: Continue to support efforts by McBain and Trush to determine interim minimum instream flows. The following landowners should be contacted: MWCD, Emmerson Investments LLC., Hidden Valley Ranch, Taylor Ranch.	1/1/2011	CDFG, NOAA, SVRCD, CDWR, Landowner			Need sufficient lead time to accomplish this, so need to act on this immediately.	SVRCD has acquired some water trust $'s for high priority transactions. More funding may be needed.
	36	3	Work with watermasters, Montague Water Conservation District and water users in the Upper Shasta River to design and implement an irrigation schedule that will coordinate irrigation water needs so that cold water effects of Clear Spring are maximized while allowing water users to continue to divert their legal water right using existing infrastructure. *Details:* Collectively agree upon an irrigation strategy which will coordinate water delivery so that cold water benefits are maximized downstream. Meet with water users and Montague Water Conservation District to seek buy-in for implementing an approach and perhaps do a trial run this 2010 irrigation season to see if there are temperature benefits.	4/1/2011	CDWR, MWCD, CDFG, Landowner, SVRCD			Need to accomplish task 26 first to be able to accomplish task 34.	No cost, in-kind contributions from CDWR, MWCD and landowners.
	37	4	Increase flows in the Upper Shasta River by discharging ~ 5-7cfs? of water from Dwinnell (if water temperatures <18 degrees C) to Shasta River from October through December, 2010 and if flows are deemed to be suitable for fish passage. Details: Decide whether it is good to entice fish up into the far upper reaches of the Shasta River due to these flows which will mean their populations will have to be maintained throughout their life stage. This may or may not be doable. Obtain historical temperature data, if available, to see what temperature outflows from Dwinnell would be during Oct through Dec. Determine a strategy to compensate MWCD for released water if determined to be a benefit to the system.	10/1/2010	CDFG, NOAA, CDWR, RWQ, MWCD, Landowner			It was re-emphasized that management would need to be sustained to ensure successful Coho salmon rearing, if they were enticed to spawn in the upper Shasta River. This may not be addressed in 2010, and must be reconciled with task 9 (barrier location that directs adult Coho spawners into Big Springs Creek). It was also mentioned that groundwater well mgmt in the Shastina area (e.g., Rancho Hills) could be used to supplement surface flows in the Shasta River.	SVRCD has acquired some water trust $'s for high priority transactions. More funding may be needed.

		38	4	Insure that temporary fish passage is provided at the waterwheel on Big Springs Creek from March through July.	2/1/2011	CDFG, NOAA, CDWR, Landowners		Ranked medium/low by barrier committee		Unknown costs. Solution may be available in-should by CDFG screen shop?
		39	5	Install category six fences shown on fencing maps.	2/1/2011	Landowner, partners				No funding.
		40	4	Implement a pilot study which will release pulse flows (of ~ 45 cfs) from Dwinnell downstream to the Upper Shasta River during March through May to assist with emigration of smolts, will remove any natural barriers (beaver dams) and may improve hydrological integrity. Details: Work closely with MWCD on developing a strategy to acquire released water.	3/1/2012	CDFG, NOAA, CDWR, RWQ, MWCD				Unknown cost.
		41	4	Insure that temporary passage for juvenile 0+ and out-migrant 1+ Coho is provided at the Novy-Rice diversion.	4/1/2011	CDFG, NOAA, Landowners		Ranked high by barrier committee		Unknown costs. There may be no cost.