Little Shasta River – a compendium of available information

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September 7, 2016

Executive Summary

The purpose of this document is to provide information regarding the historical and current conditions of the Little Shasta River, tributary to the Shasta River, in Siskiyou County, California. The Shasta River watershed provides spawning and rearing habitat for three salmonid species; Chinook salmon, coho salmon, and steelhead. At one time, the Little Shasta River provided high quality aquatic habitat. However, under current conditions it has elevated water temperatures and goes dry in the summer in the 11-mile-long valley reach. With the listing of coho salmon under both the California and federal endangered species acts it has become a high priority to identify restoration activities that will enhance coho recovery in the watershed and improve habitat conditions for other aquatic species as well. We thought it was important to gather all the historic information available to determine how this watershed once functioned. In addition, Department of Fish and Wildlife personnel collected water temperature data over a two-year period to assess the potential for the upper watershed to provide over summering habitat for salmonids. The various pieces of information presented here will inform the question: "what steps would be necessary to restore the Little Shasta River to functioning salmonid habitat?" We do not explicitly answer that question. It is our hope that this information will help land-owners and decision-makers come up with that answer.

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1. Introduction

The purpose of this document is to present available information on the Little Shasta River, including water temperature monitoring and instream flow data collected by Department of Fish and Wildlife (CDFW) in 2014 and 2015. In the past, the Little Shasta River maintained instream flows all year long (Watson 1919). However, since the early 1900's, the lower 11 miles of the Little Shasta River have been dewatered during base flows due to irrigation diversions. In the *Engineer's Report on the Water Supply and Use of Water from the Shasta River*, Smitherum (1925) wrote that: "Normally, neither the Little Shasta River [n]or Yreka Creek contribute any flow to the Shasta River during the low flow period." This occurred in spite of the fact that the watershed size is approximately 131 mi^2 and the Table Rock spring flows once provided year-round cold water inputs to the river at the base of the foothills. With the continued decline of the State and Federally listed coho salmon (*Oncorhynchus kisutch)* it is important to improve the aquatic habitat conditions within the Shasta River in general and the Little Shasta River specifically, for recovery purposes.

2. Study Area

The Little Shasta River is a tributary to the Shasta River located in central Siskiyou County in northern California. The Shasta River watershed (Figure 1) is bounded by Mount Shasta to the south, the Klamath Mountains to the west and the Cascade Range to the east. The Shasta River drainage area covers approximately 800 mi^2 ranging in elevation from just over 2,000 ft. (near the confluence with the Klamath River) to over 14,000 ft. (Mount Shasta).

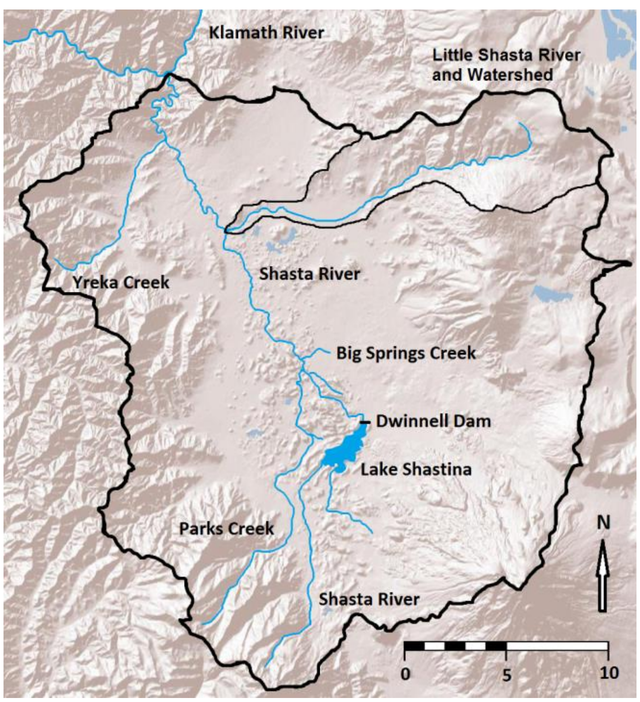

Figure 1. Shasta River Watershed

The Little Shasta River is approximately 27.5 miles long and enters the Shasta River from the east at river mile (RM) 16.3 (Figure 2). Elevations within the Little Shasta River watershed range from 8,241 ft. at Goosenest Mountain to 2,471 ft. at the confluence with the Shasta River (Figure 3). The watershed is comprised of Cascade volcanics in the headwaters transitioning through a steep constrained canyon reach, and then flowing through foothills with a diverse and mature riparian canopy, to the valley reach composed of dry flatlands. There are several intermittent tributaries that enter the Little Shasta River from the north. Land uses along the creek include cattle grazing in the high mountain wet meadows, timber harvest in the high to mid-elevations of the watershed, and various agricultural activities in the low gradient valley reach.

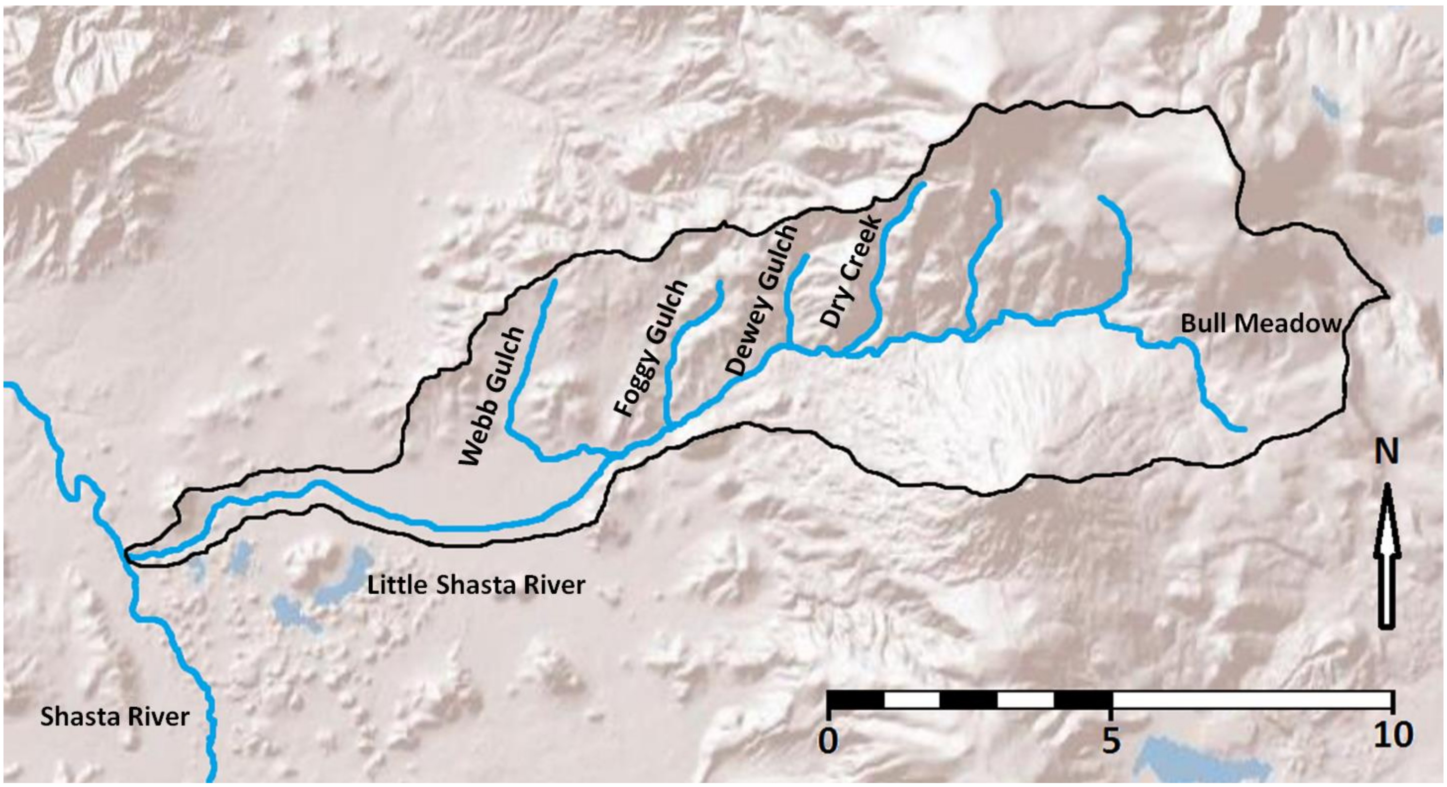

Figure 2. Little Shasta River Watershed

For the purposes of this report we have defined three stream reaches (Figure 3) of the Little Shasta River consistent with those described in McBain and Trush (2013): the Little Shasta River headwaters reach (Little Shasta Spring to Dry Gulch) is 10.1 miles long and runs from RM 27.5 to 17.4; the foothills reach (Dry Gulch to Ball Mountain Road) is 5.6 miles long and runs from RM 17.4 to 11.8; and the bottomlands reach (Ball Mountain Road to the confluence) runs from RM 11.8 to the confluence with the Shasta River.

Figure 3: Little Shasta River. (Scale in miles. Black bars delineate approximate reach boundaries.)

The headwaters of the Little Shasta River emerge from springs which are located in two discrete mountain meadows situated in the upper elevations of Ball Mountain (Figure 3). The main headwater spring, Little Shasta Spring, is situated on the north fork of the Little Shasta River at an elevation of 6,000 ft. (41°47'44.46"N, 122°12'43.75"W) and is located on property owned by Table Rock Ranch partnership near the US Forest Service (USFS) Martin Dairy campground.

The southern fork of the Little Shasta River originates from a spring located on USFS property in a meadow referred to as Bull Meadow (Figure 4). An old diversion structure is located adjacent to USFS property in the channel of the spring creek on property owned by the Table Rock Ranch Partnership (Figure 5). Riparian cover below the meadow is intact (Figure 6) except where logging operations have taken place (Figure 7). In most places from the headwaters downstream to RM 24 the gradient is fairly steep. There is a natural waterfall at the confluence of Dry Gulch and Little Shasta River which may function as a fish passage barrier (McBain and Trush 2013).

Figure 4. Bull Meadow.

Figure 5. Bull Meadow diversion structure

Figure 6. Riparian cover in the headwaters reach of the Little Shasta River

Figure 7. Upper Little Shasta River (headwaters reach) where logging has occurred.

In the foothills reach, between RM 17.4 and RM 11.8, riparian conditions are excellent with a dense and diverse riparian canopy, mature trees, and stable banks (Figures 8a and 8b). The gradient in this reach is low to medium and there are numerous riffles and pools. During a field reconnaissance conducted on June 15, 2015, trout were observed in the creek from a view point on Ball Mountain Road. The aquatic habitat condition in this reach appears to be very good.

Below ~ RM 11, riparian conditions tend to be unprotected and poor (Figure 9). The valley or bottomlands reach of the Little Shasta River is flow impaired by surface water diversion and groundwater pumping. As far as we know, all of the spring water from the Table Rock Springs Complex is diverted for agricultural use. During the summer months in 2014 no flow was observed in the channel at the Lower Little Shasta Road Crossing (41°42'41.29"N, 122°23'1.06"W) (RM 10.9).

The Little Shasta River deposits most of its coarse sediment load within the valley, prior to reaching the mainstem Shasta River. Reaches containing suitable spawning gravels occur primarily upstream of RM 10 (McBain and Trush 2010). The lower eight miles of the Little Shasta River traverse a low gradient valley, which likely has gaining stream flows (McBain and Trush 2013).   The water table in the valley reach intersects the land surface in various locations, creating ponds and wet meadows in the depressions (Mack 1960).

Figure 8a. Riparian canopy located on the foothills reach

Figure 8b. Riparian canopy located on the foothills reach

Figure 9. Little Shasta River bottomlands reach.

In the past, the Little Shasta River and other streams located along the east side of Shasta Valley derived most of their flow from springs and seeps issuing from the volcanic rocks of the Cascade Range (Mack 1960). At one time, the complex of springs located near the base of Table Rock (Figure 10) situated at the lower end of the foothills reach, flowed into the Little Shasta River (Figure 11).

Streamflow records for Little Shasta River are available for water years 1958 to 1978 (USGS 11516900). However, the gage was located at an elevation of 3,280 ft. and therefore did not measure the instream flow contribution of the Table Rock Springs Complex. The gage site captured drainage from an area approximately 48 mi^2 in size, including two peaks above 7,000 ft. (Goosenest and Ball Mountain). There are a few small diversions (0.17 cfs) located above the historic gage site, therefore the flows on record are almost "unimpaired."

Due to the gage location, winter and summer base flows, recorded in the range of 10 to 20 cfs, do not represent the additional spring input. For base flow computations, McBain and Trush (2013) assumed a 10 cfs accretion from Table Rock Spring Complex although they acknowledge that the actual accretion was likely higher. During the gaging period, typical annual snowmelt floods were between 50 to 100 cfs and peaked for a longer period of time than rainfall events. Mack (1960) calculated an average annual flow of the Little Shasta River of ~22,000 acre feet (~30 cfs).

McBain and Trush (2013) developed estimates of streamflow for the Little Shasta River under unimpaired conditions based on US Geological Survey (USGS) streamflow data and anecdotal evidence of spring discharges. They estimated that historically, summer base flows (July to October) were between 20 and 30 cfs, winter base flows (November to March) were between 20 and 30 cfs, winter floods (November to March) flowed from 50 to 200 cfs and snowmelt floods (April to June) flowed from 50 to 100 cfs.

Little is known about how the watershed was historically utilized by salmonids and specifically, coho salmon. Currently, the lack of flow during the summer months precludes juvenile coho summer rearing below RM 10. Fall-run Chinook salmon and steelhead have been documented in the river when early rains occurred and/or irrigators shut off their diversions creating conditions that allowed for upstream migration (Bob Smith, pers. comm.). CDFW first documented Chinook redds in the valley reach in 2000 and juvenile coho salmon at RM 9 in the spring of 2006 (Jim Whelan, pers. comm.).

3. Table Rock Spring Complex

A large complex of springs is located near Little Shasta River RM 14 (41°43'47.20"N, 122°20'21.18"W). This spring complex is referred to as the Table Rock Spring Complex (Figure 11). The Table Rock Springs Complex consists of large cold water springs and small thermal sodium bicarbonate springs (Mack 1960). These springs include but are not limited to Cold Spring, Evans Spring, and Jim's Spring (Table 1). Based on information obtained from, "Springs of California, U.S. Geological Survey Water Supply Paper" (Waring 1915) and the 1932 Shasta River Decree, these springs could have provided over 20 cfs of 13˚C (55˚F) water to the Little Shasta River.

Two clusters of highly saline carbonated springs occur in Shasta Valley and of the one near Table Rock, Mack (1960) writes, "The different outlets of Table Rock Springs yield water ranging in temperature from 57°F to 65°F (14˚C to 18˚C). The waters have a high content of calcium and sodium bicarbonate and sodium chloride. Water from one of the Table Rock springs, a few hundred yards north of Little Shasta River near the northern base of Table Rock, formerly was bottled as a carbonated mineral water."

Figure 10. Table Rock.

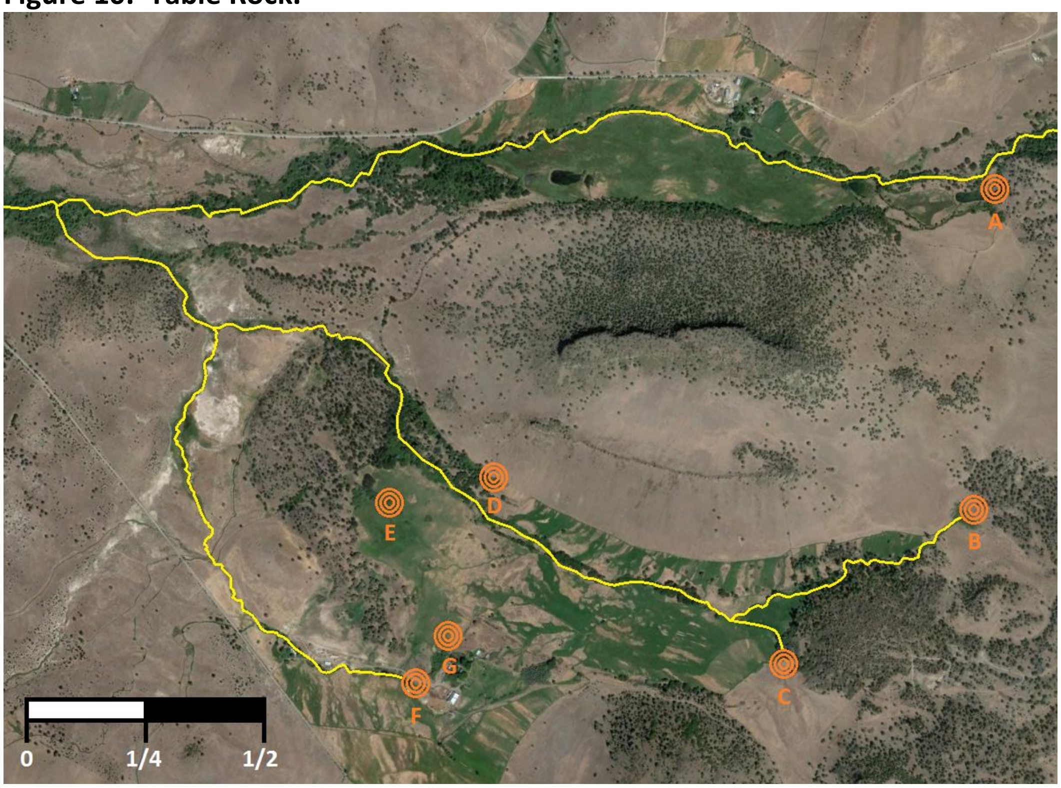

Figure 11. Aerial view of the Table Rock Springs Complex. Note: the main stem of the Little Shasta River flows north of Table Rock (scale in miles). See Table 1 for key to A – G spring identification.

Additional information in Mack (1960) includes the following: "Along the east side of Shasta Valley, at the spring near the base of Table Rock on the Terwilliger Ranch, an estimated flow of 2 to 3 gallons per minute (gpm) of carbonated water issues from the top of a low mound of calcareous tufa about 100 yards in diameter. Two miles downstream from that spring, strongly carbonated water rises from the lava-rock gravel at the south edge of the Little Shasta River (Figure 12). The spring there discharges about 1 gpm at a temperature of 57°F (14˚C). The rocks in the vicinity of the spring are strongly iron-stained and cemented by calcareous tufa. Cemented gravel is exposed in the stream bed several hundred feet upstream from the present spring, suggesting that carbonated water formerly issued from vents at that place. The third of the carbonated springs in the Table Rock area is near the southern base of Table Rock on the Martin Ranch. About 1 gpm issues from a vent some 75 yards west of a tufa mound, 10 feet high, which formerly was the principal outlet."

Figure 12. Soda spring located adjacent to the Little Shasta River 1891

Mack goes on to write, "Water from the springs near Table Rock is virtually a sodium bicarbonate water (percent sodium 85), the chloride making up about 26 percent of the total anions. In addition to high concentrations of sodium and chloride, these waters have an average of about 4,700 ppm of dissolved solids, and high concentrations of boron (14 ppm)."

Table 1. Springs of the Table Rock Springs Complex.

Spring Name	Map Point	Recorded Flow	Adjudicated Water Right	Reference in Adjudication
Cleland Spring (also known as Cold Spring)	A	10.8 – 14. cfs	9 cfs**	455 -Regulated by the watermaster
Jim Spring	B	2.33*	Combined within the Martin Spring water right**	458/459 Not regulated by watermaster
Martin Spring	C	3.13	2.63 cfs (includes Jim Spring water right)**	461,462,463 Not regulated by watermaster
Evans Spring	D	2.36*	2.36 cfs	467 Not regulated by watermaster
Kegg Spring	E	0.29*	0.5 cfs	468 Not regulated by watermaster
Bassey Spring	F	6 cfs	3.59 cfs	455 -Regulated by the watermaster
Unnamed Spring	G	N/A	1.4 cfs	No information

*Based on "Shasta River Adjudication Proceedings" 1925
**Pers. Comm. Tim Beck, Watermaster (December 2015)

Cold Spring, also known as Cleland Spring (Site A in Figure 11), is of particular interest due to historical information available. This spring is located at Little Shasta River RM 15 (41°44'26.56"N, 122°19'41.01"W). The historic channel appears to be about 0.4 miles in length. A flow measurement in 1915 reported that the spring was producing 14 cfs (Waring 1915). Flows recorded in 1954 are reported to be between 10.8 cfs and 13.8 cfs (Mack 1960) as shown in Table 2. A pH measurement on March 23, 1953 shows a pH of 7.4 (Mack 1960).

Mack (1960) writes, "Cold Spring (also called Cleland Spring), gushes from numerous vents for a distance of about 200 feet along the toe of a lava flow from Goosenest. At one place water jets from fractured basalt as though forced from a pipe. At the most southerly vent, water flows quietly from clinkers and talus blocks lying beneath massive black finely vesicular basalt. Water from the spring area is collected in a channel and is used for irrigation in Little Shasta Valley."

Table 2. Flow at Cleland Springs from January to May 1954 (Mack 1960)

Date	Flow Measured at Cleland Spring in cfs
January 22, 1954	12.7
Feb 11, 1954	13.5
March 25, 1954	13.8
April 14, 1954	10.8
May, 11, 1954	11.2

Bassey Spring Creek is located to the south of Little Shasta River (Site F in Figure 11). The confluence is located at Little Shasta River RM 12. Bassey Spring (41°43'6.39"N, 122°20'20.15"W) is located 1.5 miles up Bassey Spring Creek from the confluence with the Little Shasta River. A flow measurement taken in 1915 reports a flow of 6 cfs out of Bassey Spring (Waring 1915). According to the Shasta River Decree of 1932 another 1.4 cfs flows from a spring 150 yards due north of Bassey Spring ("Unnamed Spring" in Table 1). This 1.4 cfs is adjudicated for power use only and all the flow is supposed to be returned to Bassey Spring Creek. During field investigations conducted by the North Coast Regional Water Quality Control Board (NCRWQCB) during 2002 and 2003 they documented water temperature at Bassey Springs at 9° C (48˚F) (NCRWQCB 2004).

Also flowing into Bassey Spring Creek is Martin's Spring Creek. This creek carries the water from Evans Spring (Site D in Figure 11), Martin's Spring (Site C in Figure 11), and Jim's Spring (Site B in Figure 11). The length of Martin's Spring Creek is 2.0 miles. No historical flow measurements were found regarding this creek. According to the Shasta River Decree of 1932, 5.72 cfs is adjudicated out of this creek pursuant to the combined water rights for the three springs.

Jim, Martin, and Evans springs have not historically been regulated by the watermaster since there was no headgate with which to measure or control the water use. The Scott and Shasta Valley Watermaster District (Watermaster District) has notified the water users of these springs that, in the near future, they must install water measuring devices at these spring sources so that the water use can be regulated (Tim Beck, pers. comm.).

4. Water Rights

The Shasta River Adjudication Proceeding Judgement and Decree (No. 7035) was adopted in 1932. The purpose of the decree was to establish the volume of water allowable for diversion, the period of diversion, the points of diversion, and the area for authorized water application for landowners in the Shasta Valley. Currently, watermaster services are provided by a private contractor managed and paid for by the Watermaster District, a special district of Siskiyou County. Judge Laura Masunaga of the Siskiyou County Superior Court signed orders to transfer watermaster services from the Department of Water Resources (DWR) to the Watermaster District effective February 1, 2012. The main purpose of the Watermaster Program is to ensure that water is allocated according to established water rights as determined by the court adjudication by an unbiased, qualified person, thereby reducing water rights court litigation, civil lawsuits, and law enforcement workload. It also is supposed to prevent the waste or unreasonable use of water. Riparian water rights users along the Shasta River below Dwinnell Dam were not included in the adjudication and are not managed by the watermaster.

There are both winter and summer diversions on the Little Shasta River. In addition, there are storage water rights that are not identified in the decree. One of the storage diversions is operated by CDFW. CDFW operates a wildlife area, centered near RM 4, where three reservoirs, fed by a surface water diversion from the Little Shasta River, are filled to the extent possible and are used to irrigate uplands, as well as fill a series of diked seasonal wetlands to provide habitat for wildlife (see section 5 below).

The irrigation season on the Little Shasta River (as identified in the decree) begins March 1 and ends November 1, however, stock water rights allow diversion to continue throughout the winter months. As early as 1922, it was recognized that the diversions on the little Shasta River were problematic. In the Engineers Report dated January 24, 1922, G. Zander wrote," The development of irrigation from the natural flow of the Little Shasta River reached its limit some years ago, and since that time there has been considerable litigation among the various water users in the Little Shasta Valley."

Conceivably, this is when the design of the irrigation canal that runs from Montague Water Conservation District (MWCD) facilities at Dwinnell Dam to the Little Shasta Valley was initiated to bring additional flow to productive soils surrounding the town of Little Shasta. The 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.

Based on the adjudication, the summer maximum diversion quantity for irrigation in the Little Shasta River watershed is 92.3 cfs, although full diversion quantity is never available. The winter diversion quantity is 13.8 cfs for stock water. In addition, there are at least 5 winter storage rights that were authorized through the licensing procedure with the State Water Resources Control Board. These winter storage rights add up to about 45 cfs.

Water rights in the Little Shasta watershed are distributed based upon the priority of the water right and the volume of the water in the river. The list of priorities goes down to priority number 8; however, priorities 6 through 8 rarely receive water. For water years 2014 and 2015, only priorities 1 through 4 received water (a total of 14 cfs was allocated during those years) (Bob Smith, pers. comm.).

Table 3. Adjudicated Irrigation Season Water Rights (March 1 to November 1) on the Little Shasta River that are Regulated by the Watermaster.

Operator	Diversion Number	Total cfs (all priorities)
Hart, Phelps, Martin, Allen, Cowley Family Ranch	471, 474, 475	17.73
Musgrave Ditch (14 landowners)	472, 473	32.78
Cowley Family Ranch (Soule Ranch)	456	.12
Connick (used by Martin)	455 (Bassey and Cleland Springs)	12.59
Bacigalupi	451 (Cleland Springs)	1.12
Bacigalupi	448, 449, 450	1.6
TOTAL		67.57

5. Shasta Valley Wildlife Area

CDFW manages the Shasta Valley Wildlife Area (SVWA) which is located approximately 1.5 miles east of Montague along the Little Shasta River. The 4,657-acre property was originally a working cattle ranch and was acquired in fee title by the Wildlife Conservation Board in 1991. The following funds were used for the acquisition: Wildlife Restoration Fund, 1984 Fish and Wildlife Enhancement Fund (Proposition 19), California Wildlife Coastal and Park Land Conservation Fund (Proposition 70) and the Habitat Conservation Fund (Proposition 117).

The purposes of the acquisition are as follows:

1. To protect, enhance or restore riparian and wetland habitats (Prop's 19, 70, 117)
2. To provide habitat for waterfowl, threatened or endangered species and for species of special concern (Prop's 70, 117)
3. To provide habitat for deer and other wildlife species. (Prop 117)

4. To provide appropriate public uses including hunting, fishing, photography, wildlife viewing, nature study and other educational activities associated with fish and wildlife. (Wildlife Restoration Fund)

SVWA includes over 1,000 acres of managed permanent, semi-permanent and seasonal wetlands along with an additional 2,500 acres of managed uplands. The wetlands were created for migratory and resident water birds and other water dependent wildlife. The managed habitats are home to a diversity of plant and animal species. The wildlife area has recorded over 275 species of birds including nearly 70 species that are known to nest there. CDFW management activities have increased hunting, angling and public viewing opportunities to an average of 15,000 user-days/year on SVWA.

SVWA exercises the use of nine water rights licenses to divert water for both storage and immediate use. All nine licenses have been amended to include fish and wildlife enhancement as a beneficial use. Two licenses provide for year-round water use of up to 9 cfs, however, due to the priority of these two rights, they are not exercised outside of the winter diversion period. The remaining seven licenses allow for diverting water from the Little Shasta River for the purpose of storage in one of the three storage reservoirs located SVWA. These three storage reservoirs; Trout, Bass and Steamboat reservoirs are licensed to store up to 6,500 acre feet of water per year. SVWA water rights allow for the diversion of up to 35 cfs, however, due to fish screening and delivery ditch limitations, only 30 cfs can be diverted at any time. The diversion period for water storage starts on November 1st (for Bass Lake) and ends May 1st (Steamboat Reservoir). Intake flows are recorded every 15 minutes with a SonTek Argonaut - SW Doppler system.

Winter water right diversion at the SVWA typically starts in December and runs until the flows in the Little Shasta are no longer adequate (generally sometime in April), although some of SVWA's water rights within that period of time are authorized for a shorter duration. The first winter storage reservoir authorized in the Little Shasta River watershed was Bass Lake. The Bass Lake water right was issued in 1945 and the reservoir was first filled in 1947. Based on SVWA records, in normal rainfall years there is usually no water available in the Little Shasta River to divert past mid-April due to higher priority water rights upstream.

The most recent winter storage water right license that was issued in the Little Shasta River watershed is an impoundment on property currently owned by the Bacigalupi's. They have been diverting water for their reservoir since 2012. Prior to that time, Steamboat Lake, a large reservoir on SVWA, was the last storage right issued (1971). There are 3 other large (greater than 60 surface acres) reservoirs in the Little Shasta River watershed, two are on the Cowley property and one is on the Kuck property.

When CDFW began management of the SVWA property in 1991, there were no fish screens on any of the surface water diversions on the Little Shasta River. At the time, the Little Shasta River was considered a "dead stream" (Bob Smith, pers. comm.) due to over irrigation. Wildlife area staff first observed adult steelhead in the river in 1994 and that prompted installation of screens on private lands followed by the construction of a fish screen on SVWA.

Adult Chinook salmon were documented by CDFW in the Little Shasta River for the first time in 2000 when the Martin's and the Hart's stopped irrigating in early October. This coincided with a large run of Chinook salmon in the Shasta River. When the cold spring water was released into the Little Shasta River, ideal conditions were created for salmonid passage into the valley reach. Chinook spawning was documented up to RM 10 where the fish encountered a fish passage barrier at Hart's diversion. Thirteen (13) redds were recorded on SVWA property during that run.

Bob Smith, retired land manager for the SVWA, interviewed long-time Siskiyou County resident, Cline Soule, in in the year 2000 regarding his observations of salmon in the Little Shasta River. Mr. Soule stated that it was common to see Chinook in the fall when he was a child in the late 1920's to the early 1930's. Mr. Soule said that his father told stories of the Native American's coming out of the hills to harvest fish in the Little Shasta River. Cline recalled that when he was a child he rode horse-back with his father down to the Little Shasta River to look at the salmon.

CDFW's diversion ditch is located at RM 6 on the Little Shasta River. The diversion includes a bioengineered grade control structure consisting of interwoven woody debris and boulders. The fish screen is a 3/32" stainless steel instream cone which sits on a concrete apron and delivers water into the ditch through a 36" siphon (Figure 13). Based on the screen size and surface area, the structure has the capacity to convey up to 30 cfs.

Figure 13. Shasta Valley Wildlife Area Diversion.

The SVWA generally diverts water from the Little Shasta River during high flows in December, January, and February. In order to comply with Federal Endangered Species Act Section 7 requirements, SVWA staff measure the flow in the Little Shasta River each week during the diversion period approximately 2 miles downstream from the diversion ditch. They are required to maintain 10 cfs instream at the staff gage location (~RM 4). When flows exceed 10 cfs at RM 4, SVWA is allowed to take the amount of water that is in excess of 10 cfs (i.e., if the instream flow is 13 cfs at the staff gage they can only take 3 cfs).

Diverted water is pumped from the three storage reservoirs to flood and irrigate managed wetlands, pasture and grain fields. Active water management typically occurs during the summer and fall months. Water conservation measures are actively being applied including the installation of pipelines to replace open ditches and the installation of a pivot irrigation system. Two of the three reservoirs contain warm and cold water fisheries and receive up to 10,000 angler use days annually.

The SVWA property includes approximately 2.5 miles of the Little Shasta River (Figure 14). Starting in 1992, CDFW made riparian restoration on the Little Shasta River a high priority. From 1992 until 2009, over 20,000 trees were planted using various techniques and local cultivars. Most plantings were of red and sandbar willow but cottonwood, alder, and water birch were also included. Due to the severely altered hydrology of the Little Shasta River and potentially other reasons, the survival rate of the plantings has been less than 5%.

Figure 14. Little Shasta River on the Shasta Valley Wildlife Area

From 2001 to 2009 SVWA staff monitored Little Shasta River fish populations. A fyke trap was set up near the mouth of the Little Shasta River (RM 0.5) between February and April to sample outmigrants. Juvenile Chinook, adult and juvenile steelhead, lamprey and other nonnative fish species were documented in the Little Shasta River during the effort (Table 4).

SVWA is committed to the conservation of native fish and wildlife species, especially the conservation of threatened and endangered species, including coho salmon. In an effort to address the needs of anadromous fish, SVWA has voluntarily foregone the use of some water that would otherwise increase the extent of maintained wetlands. These measures were implemented with the clear intent of avoiding adverse effects on fisheries.

Table 4. Fish species encountered in the Little Shasta River during surveys conducted by SVWA staff

Year	Dates of fyke net operation	Fish species encountered
2001	March 1 – March 28	8 juvenile Chinook (40-50mm) (*Oncorhynchus tshawytscha*) 1 adult steelhead (410mm) (*Oncorhynchus mykiss*) 2 Klamath smallscale sucker (*Catostomus rimiculus)* 1 speckled dace (*Rhinichthys osculus*) 6 pond smelt (*Hypomesus olidus*) 6 brown bullhead (*Ameiurus nebulosus*) 8 prickly sculpins (*Cottus asper*) 9 green sunfish (*Lepomis cyanellus*) 61 bullfrog tadpoles (*Lithobates catesbeianus*)
2002	February 2 – April 12	75 juvenile Chinook (42-64mm) 3 speckled dace 2 prickly sculpin 12 green sunfish 3 bullfrog tadpoles
2003	February 19 – April 23	11 juvenile Chinook (42-53mm) 1 brown bullhead 1 prickly sculpin 1 bluegill sunfish (*Lepomis macrochirus*) 9 green sunfish 209 bullfrog tadpoles 2 mosquitofish (*Gambusia affinis*) 1 Pacific lamprey (*Lampetra tridentate)* (228mm)
2004	March 17 – April 8	21 juvenile Chinook 141 bullfrog tadpoles 4 green sunfish 1 speckled dace 1 brown bullhead
2005	March 11 – March 20	1 bullfrog tadpole
2006	March 24	1 green sunfish
2007	February 20 – April 23	2 juvenile Chinook (76, 77mm) 23 bullfrog tadpoles 2 speckled dace 7 mosquitofish
2008	March 10 – March 25	0 fish - The flow in the river was too high to trap effectively
2009	February 19 – April 30	0 fish - The flow in the river was too high to trap effectively

Notes: In 2001, the original trap set was on SVWA property just below the Little Shasta bridge. This site was abandoned due to low flow conditions. The second set was approximately 300 yards above the confluence of the Shasta River. During all other years the trap was set at this location. In most years the fyke trap was removed from the Little Shasta River due to large amounts of green algae compromising trapping efficiency.

6. Groundwater

The following is excerpted from Ward et al 2007:

> "The chemical characterization of groundwater within the Little Shasta Valley sub-area is based on groundwater samples from 11 wells. Nine wells were sampled in May, 1953 (three of the wells were re-sampled in October, 1953) (Mack 1960) and two wells were sampled by DWR in August, 1991 (DWR 2007).
>
> Groundwater chemistry data for the Little Shasta Valley sub-area show at least two different chemical characters. On the north side of the valley, south of Ball Mountain Little Shasta Road, the chemical character of groundwater is calcium-magnesium bicarbonate based on five samples taken in May, 1953 (Mack 1960) and one sample taken in August, 1991 (DWR 2007). TDS concentrations range from 224 to 543 mg/L. The well with the TDS concentration of 543 mg/L is located towards the center of the valley and also has higher concentrations of chloride, sulfate, and nitrate relative to wells sampled along Ball Mountain Little Shasta Road. Rock types influencing groundwater character on the north side of the valley are Tertiary volcanics and matrix deposits of the volcanic debris avalanche.
>
> On the south side of Little Shasta Valley, three groundwater samples show the character of groundwater to be sodium-magnesium bicarbonate. Two samples were taken in May, 1953 (Mack 1960) and one sample was taken in August, 1991 (DWR 2007). Higher concentrations of chloride are also observed. TDS concentrations range from 404 to 739 mg/L. Wells constructed in this area encounter matrix deposits and rocks of the Late Cretaceous Hornbrook Formation. High concentrations of chloride are likely the result of connate water within the marine-deposited Hornbrook Formation.
>
> Applied surface water conveyed from Lake Shastina and local diversions may also influence groundwater chemistry. Approximately 8,000 acres are irrigated with surface water within the sub-area. The three wells re-sampled in October, 1953 showed slightly reduced TDS concentrations relative to wells sampled in May, 1953, likely due to applied surface water.
>
> Portions of Shasta River below Dwinnell Dam, along with Parks Creek and Little Shasta River, are nearly completely dependent on the discharge of springs to sustain water quality and cold water flow during summer and fall months. Protection of coho salmon is contingent upon the continued availability of cold water. Recently approved TMDL targets identify increasing cold water flows as a key component to meeting water quality goals. Local government, along with the agricultural community, is faced with the task of determining how to accomplish this."

A total of 62 groundwater wells were documented in the Little Shasta Valley by DWR (Ward et. al 2007) through 2003 (Table 5) and the average well depth ranged from 157 feet for domestic wells to 182 feet for irrigation wells (Table 6). Average yield for domestic wells in Little Shasta Valley was 32 gallons per minute and average yield for irrigation wells was 165 gallons per minute.

Table 5. Well Counts in the Little Shasta Valley (through December 2003)

Hydrologic Sub-Area	Number of Groundwater Wells by Use			
	Domestic	Irrigation	Other*	Total
Little Shasta Valley	31	18	13	62

*Other uses types include livestock wells, test wells, or unknown well use.

Table 6. Well depth in the Little Shasta Valley

Hydrologic Sub-Area	Well Depth Data (feet)				
Little Shasta Valley	Average	Median	Minimum	Maximum	Well Count
Domestic	157	121	39	435	31
Irrigation	182	200	60	300	18

7. Gravel Inventory

Excerpted from McBain and Trush (2010):

> "Gravel distribution on the Little Shasta River was mapped in limited areas where access was permitted, then mapping results were extrapolated based on field observations and aerial photograph interpretation to estimate spawning gravel area for the entire reach. Reconnaissance surveys of the Little Shasta River were made at three locations: The Shasta Valley Wildlife Area at the Big Springs Road crossing, the Lower Little Shasta Road crossing just east of the Little Shasta Church, and at the Harry Cash Road crossing near the Hart – Cowley diversion (6.6, 10.6, and 11.8 miles upstream of the mainstem Shasta River, respectively). From upstream to downstream, we observed a particle size gradient that started as dominantly gravel and cobble with minor sand at the Harry Cash Road crossing, then became progressively finer to a dominantly sand-bedded channel with minor gravel at the Shasta Valley Wildlife Area. These observations are supported by the Little Shasta River longitudinal profile, which shows a major slope change as the channel crosses from higher elevations (1.24% slope) to the valley floor (0.02% slope). Because the Little Shasta River loses much of its gradient 9 miles upstream of the mainstem Shasta River confluence, much (if not all) of the coarse sediment supplied from the steeper upstream reaches deposits near the valley floor transition, resulting in only the finer sediments routing downstream. Based on this, coarse sediment storage is greatest near the gradient transition and coarse sediment contribution from the Little Shasta River to the mainstem Shasta River is little to none (therefore making Julien Creek the only tributary coarse sediment source in this part of the mainstem Shasta River).
>
> Despite its size as one of the largest tributaries to the mainstem Shasta River, the Little Shasta River likely supplies mostly finer sediment (i.e., < 2 mm) to the mainstem and does not represent a significant source of coarse sediment supply. This condition is compounded by a combination of both summer and winter flow diversions, which have reduced the channel's ability to transport any available coarse sediment downstream.

The Little Shasta River joins the mainstem Shasta River at RM 16.3. [If valley reach diversion barriers were removed] salmonid access on the Little Shasta River [could] extend upstream to approximately the Dry Gulch confluence at Little Shasta River RM 17.4, and possibly further if passage is possible past a series of cascades at the Dry Gulch confluence. Given the potentially extensive spawning and rearing habitat available along this 17.4 mi (or longer) stream, the Little Shasta River requires more field time and landowner access than was available for this spawning gravel assessment. Three reaches totaling 12,800 ft. were observed in the Little Shasta River between RM 5.6 and 12.3, during this project and a prior Instream Flow Methods Project (McBain & Trush 2009). The reaches include a 4,000 ft. sub-reach of the CDFG Shasta Valley Wildlife Area, a 5,800 ft. sub-reach on Jack Cowley's ranch, and a 3,000 ft. sub-reach on Blair Hart's ranch. Abundant spawning gravel was observed, primarily upstream of approximately RM 8.7. A quantitative estimate of spawning gravel was made only on the Cowley Ranch during this spawning gravel inventory; the other two reaches are described in qualitative terms.

Shasta Valley Wildlife Area (Station 130+00 to 350+00): The lower 5.9 miles of the Little Shasta River is a low-gradient, highly sinuous valley bottomlands reach with sediment dominated by sand and small gravel and occasional coarser riffles composed of spawning-sized substrates. Embeddedness is high, and water depths and velocities are lower due to the low gradient. Active (frequently mobilized) gravel bars are not visible in aerial photographs, indicating a lack of storage of spawning gravel sized sediment. A 4,000 ft. reach was observed at the Shasta Valley Wildlife Area during field visits in 2008 and 2009; a 1,800 ft. segment was mapped to demonstrate Direct Habitat Mapping methods (M&T 2009). Several riffles were observed in this reach. During the Instream Flow Methods project, two possible redds (species unknown) were observed within the habitat mapping reach and confirmed by CDFG biologists Mark Hampton and Bill Chesney.

Cowley Ranch (Station 502+00 to 560+00): A 5,800 ft. reach downstream of Lower Little Shasta Road was surveyed in May 2010. The reach has a 0.76% gradient. Channel morphology and salmonid habitat conditions are recovering in this reach following installation of cattle exclusion fencing in 2000. Vertical bank structure is developing and riparian vegetation recruitment is evident. A pool/riffle morphology is being maintained by winter and spring flood events: active gravel/cobble bars and floodplains are frequent, and abundant spawning gravel is available at typical pool-tail and riffle habitat units. This reach is downstream of most water diversion structures on the Little Shasta River and is dry during summer and fall of many irrigation seasons. Irrigation season ends November 1 on the Little Shasta River. [editor's note: The stockwater diversion season on the Little Shasta River runs from November 1 to March 1 and several landowners have storage rights that allow the diversion of winter flows.] Seventeen riffles totaling 968 ft. were mapped in this 5,800 ft. reach. With an estimated riffle width of 6 ft., a total of 5,800 ft^2 of spawning gravel were estimated. This gravel density (0.7 ft^2/ft.) was extrapolated to the entire 8.7 miles of the Little Shasta River assumed to contain spawning gravel, from the Rabbit Hill Ranch (station 460+00) to Dry Gulch (station 920+00). A series of steep, bedrock cascades present a potential anadromous salmonid migration barrier near the Dry Gulch confluence. The total estimated gravel area for the Little Shasta River was 30,700 ft^2. This area represents 7% of the basin-wide area estimate.

Hart Ranch (Station 630+00 to 660+00): A 3,000 ft. reach was surveyed on the Hart Ranch in March 2009. This reach is above nearly all of the large irrigation diversions on the Little Shasta River and is not de-watered during the irrigation season. The reach is also fenced and cattle grazing is excluded, consequently preserving good stream channel and habitat conditions in this reach. Several cold-water springs enter the Little Shasta River in this reach. Riparian vegetation consisted of mixed species and age-classes, and was contributing abundant large wood to the channel. The section surveyed had abundant coarse and fine sediment material that appeared frequently mobilized by winter and spring high flow events. Coarse sediment included small boulders, large and small cobble, and abundant gravel in the size range suitable for anadromous salmonid spawning. Spawning gravel quality appeared quite high in this reach. Equally significantly, progeny of salmonids spawning in this reach would have access to abundant, high quality year-round rearing habitat. Poor migratory access in and out of this reach, resulting from downstream irrigation diversions and diversion structures, and seasonal low flows, is presumed to be a key limiting factor to Little Shasta River life history tactics.

Two tributaries and the mainstem – upper Shasta River above Parks Creek, Parks Creek, and Little Shasta River – provided the majority (39%) of remaining spawning gravel supplies in the portion of the basin currently accessible to anadromous salmonids. While spawning gravel appears abundant in these reaches, migratory access resulting from low instream flows during the spawning season and migration barriers (the Hart-Crowley Diversion on the Little Shasta River, the Cardoza Diversion on Parks Creek) may limit their availability to contemporary life history tactics, especially for fall-run Chinook. The lower mainstem Shasta River downstream of the Little Shasta River may also contain abundant (and potentially highly used) spawning gravel supplies (12%), but the estimate from this reach was based only on extrapolating the spawning gravel density from other reaches, not on direct field observations. This estimate is thus unconfirmed.

The availability of abundant high quality spawning gravel in the upper reaches of the Little Shasta River provides an important opportunity to recover and sustain new coho salmon and steelhead life history tactics. Improved access and streamflow management are needed in the Little Shasta River to enable adult coho salmon and steelhead to migrate and spawn in gravel-bedded reaches below and above the Hart-Cowley Diversion Dam. Instream flows would also be needed to allow juveniles to emigrate in spring from these reaches."

8. Fish Passage Barriers

The Kuck diversion (RM 5) consists of a concrete sill with flashboards and weir fish ladder. At the head of the fish ladder is a self-cleaning 3/32-inch tube screen. This diversion structure replaced a tarp and boulder dam that was a fish barrier during much of the winter diversion season. The current structure has been problematic from a fish passage design standpoint as it requires constant maintenance by the landowner which is only done infrequently (Bob Smith pers. comm.). In recent years, the pool and weir structure has been inoperable (Bob Smith pers. comm.).

The Hart diversion (RM11) consists of a concrete sill spanning the Little Shasta River with flashboards that are installed during the diversion season to divert water for irrigation. Without the boards, the sill is a partial barrier for adult and juvenile salmonids. With the boards in place the dam is a complete barrier for all salmonids.

The Musgrave diversion is a short distance upstream of the Hart diversion. It consists of an approximately three-foot-high concrete structure spanning the river. Flashboards are installed during the diversion season. The flashboards are supported by steel supports spaced across the structure. An aluminum, pool and weir style ladder is located on the right bank of the diversion dam. The ladder does not meet current CDFW or National Marine Fisheries Service criteria for fish passage (Kevin Gale pers. comm.)

Bacigalupi's diversion in the foothills reach is constructed out of large boulders (Figure 15). During low flows this is likely a fish passage barrier as well.

Figure 15. Bacigalupi's diversion in the foothills reach of the Little Shasta River

9. Cultural History

It may seem unusual for a document such as this, which summarizes available information about natural resources of a given watershed, to include information about the cultural history of the area. This section provides several important insights into the historic condition of natural resources in the watershed.

Settlement patterns of the original occupants of the Shasta Valley indicate that key habitation sites occurred along river banks at the transition zone between the valley floor and the foothills (Hamusek et al. 1997). Up to six villages are known to have existed along the Little Shasta River prior to European settlement. One prehistoric site was occupied between about 3000 B.C. to A.D. 1200 (Hamusek et al. 1997). This highlights the fact that there were abundant resources in the area to support the needs of these villages. Salmon, one of the principal foods of the Shasta Tribe (Curtis 1924), were dried in the sun and stored. The average family would store about 100 salmon during the run (Curtis 1924). In addition to anadromous species, suckers, eels, crayfish, turtles, and mussels were also taken (Hamusek et al. 1997). However, with the arrival of Hudson's Bay Company fur-trappers (1828-1830) and the eventual discovery of gold at Yreka Flat (1851) came an influx of troubles for the Shasta Tribe. Members of the Shasta Tribe were either removed or greatly diminished in numbers by 1860 through the "Indian Wars." The term "Indian Wars" is really a misnomer. In 1855 the first militia company of Siskiyou County was formed, eventually calling themselves the Siskiyou Guard. The purpose of the group was to exterminate the Native Americans. After the 1856 campaign, Siskiyou County was considered “free of Indian troubles” until the Modoc War (California Military Department 2013).

As described below, the Little Shasta Valley was first settled by Europeans in 1851 or 1852. Hamusek et al. (1997) writes that a number of early settlers took up claims in Shasta and Little Shasta valleys in order to work as farmers and ranchers so they could provide food and other supplies to the miners. Some of the earliest Homestead Entry patents occurred along the foothill – valley margin in the Little Shasta valley. The area had good quality soil and abundant water, making it ideal for ranching and farming. Due to the richness of the soil and availability of water, Little Shasta quickly became a prosperous community. Old Ball Mountain Road has been in existence since prior to 1863 and served as a transportation route to Butte Valley (Hamusek et al 1997). It is not surprising that an area rich in natural resources for Native Americans would also be attractive to the settlers.

The below information and research was contributed by Dr. Joanne Mack, Faculty Emerita of the University of Notre Dame, Department of Anthropology, Curator of Native American Art and Culture, Snite Museum of Art.

John B. Rohrer first settled in Little Shasta Valley in either 1851 or 1852, and his first crop was raised in 1853. He erected the first house in 1857. When he initially settled the valley he had two partners, A. Dejalais and Frank Montre, neither of whom stayed. Two others raised crops in 1853, the Davis Brothers and John Kegg, but a fire destroyed their crops. Several others came into Little Shasta Valley between 1854 and 1860; in 1854 John Miller, David and Mrs. Deter; in 1855 George W. Asbaugh and his family, John Miller and his brother George, and Samuel Musgrave (Wells 1881). The Little Shasta School District was created in 1857. By 1860 several other ranches had begun in the valley. By 1870 the Table Rock School District was created for the upper portion of Little Shasta Valley. By the 1880's the town consisted of two stores, a post office, a flour mill, two school houses (Little Shasta and Table Rock), one church (Figure 16), and “scores of fertile and highly cultivated sections of the county.” (Wells 1881) (Figure 17). By 1881 (Wells), the Little Shasta valley was referred to as “one of the most fertile, productive and best cultivated sections of the county.” Several mills were present in the Little Shasta by 1881, including two lumber mills and one grist mill (Wells 1881). The lumber mills were owned by John Cleland (Table Rock area) and George Deter. The grist mill, located near Table Rock, was operated by Shepard, Terwilliger, and Walbridge (Wells 1881).

Figure 16. Historic Little Shasta church built in 1872

Figure 17. The Town of Little Shasta 1889

Normally the prehistory and proto-history of the Little Shasta River would not be separated from that of the Shasta Valley. There has not been a great deal of professional anthropological research done in the Shasta Valley in general and particularly not within any of the tributary watersheds. However, there are a few areas of the Little Shasta watershed from which some ethnographic and archaeological information has been obtained. The ethnographic information came from Shasta informants in the early 1900s and both Roland

Dixon (1907) and C. Hart Merriam (1919), who recorded the names and location of those Shasta Villages in Shasta Valley within the memories of their informants.

Dixon and Merriam recorded two different names for each of two villages along the Little Shasta River. One village was located at the junction of the Little Shasta with the Shasta River (Figure 18). Both Dixon and Merriam describe the location of the village as near the "little hill at the back" of Montague, which would place it just northeast of the confluence. Merriam calls the village *Chi-ri-wah,* and Dixon calls it *E-kah-heg (alternate spelling: Ikahig).* The second village as one goes up the Little Shasta was named *O-pe-goo-kwah,* which is also the Shasta name for Little Shasta River. It is located only a short distance upriver from *Chi-ri-wah*, so just a little above the confluence of the Little Shasta with the Shasta River. Merriam does not note on which side of the Little Shasta it was located, but it's likely it was on the north side given the topography in the area. The third named village is much further up the Little Shasta. It appears this is another instance where one village was given two different names. Merriam writes the name of the village is *Koo-roo-tah-tah-gak* and locates it by Table Rock near the hamlet of Little Shasta. He also notes it was known locally as "Little Shasta Rancheria" and "Table Rock Rancheria." Dixon writes the name of the village as *Irufatina*, but locates it as simply well up the Little Shasta River. Its location is shown on his map, but his map has such a large scale that it is difficult to pinpoint. Because of his general placement, *Irufatina* may be a fourth Shasta village, but it looks like it is in the vicinity of the Little Shasta hamlet. All these named villages together likely do not represent all the Shasta villages along the Little Shasta. They are merely the villages within the memory of Dixon's informant and Merriam's informant, neither of whom lived in Shasta Valley. We can conclude that these three or four villages were the most recently occupied, but they certainly would have not been the only villages occupied by Shasta people over the last 2000 years or more. Five additional cultural sites are known to exist on the SVWA.

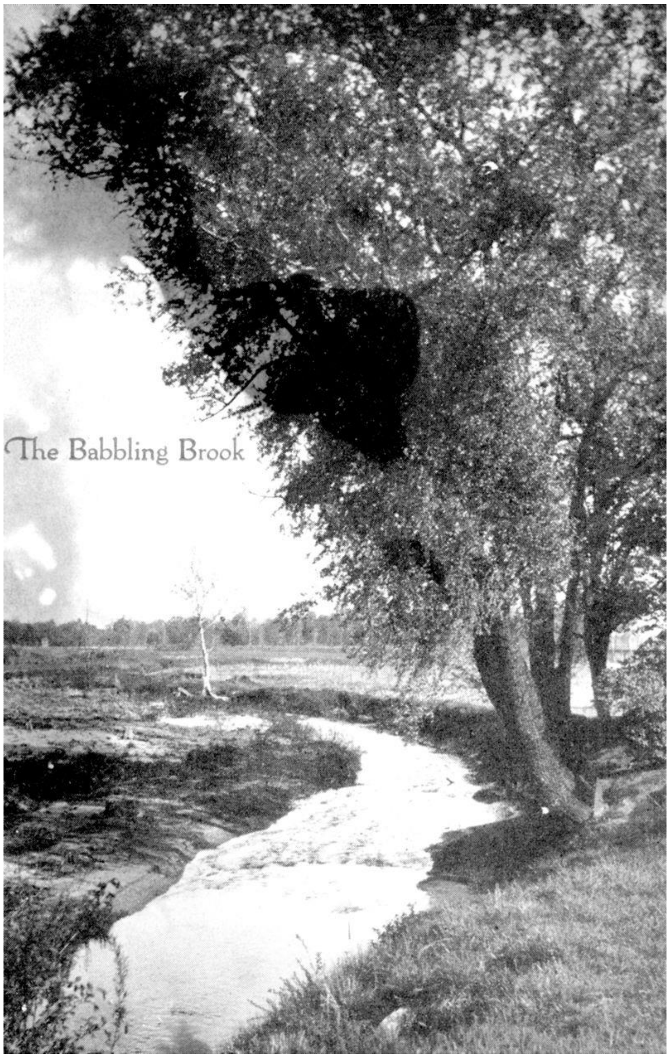

Figure 18. The Little Shasta River near the confluence with the Shasta River 1891 (notice the large riparian gallery located along the Shasta River on the horizon)

Nilsson (1985) excavated the Hunter Site (SIS-1088), located at the western edge of the Cascades on the Little Shasta River. The site report concluded that this large campsite was occupied between 5000 B.P. and 500 B.P. Further upstream in the headwaters area of the Little Shasta there are several recorded prehistoric sites. One is in the vicinity of Martin's Diary or more properly Martin's Spring House. The others are on the Klamath National Forest in the other basins, which make up the headwaters of the Little Shasta River. There have been nine sites recorded on the Klamath National Forest lands, and some have been test excavated by Klamath National Forest personnel. In addition, it should be noted there is evidence for older sites in the area just north of the Little Shasta Valley, dating between 7000 to 10000 years ago. In terms of more recent history, within the headwater's basins, in addition to Martin's Spring House, the remains of a California Conservation Corps spike camp and the remains of a Forest Service Ranger Station exist.

10. Water Temperature and Instream Flow Study

This study combined two different methodologies. First, a literature review was conducted to accumulate and summarize existing documentation regarding the environmental conditions of Little Shasta River over time, specifically water temperature and flow data. Second, field data was collected regarding water temperatures and flows in the Little Shasta River during 2014 and 2015.

A. Literature Review

Continuous water temperature monitoring was conducted at two locations on the Little Shasta River in late June through late October 2003 by the NCRWQCB in order to obtain information for the planning process to establish Total Maximum Daily Loads for the Shasta River watershed (NCRWQCB 2004). Weekly average water temperatures ranged between 15°C (59°F) and 20°C (68°F) at Ball Mountain Road (RM 11.3) during much of July and August, and water temperatures ranged between 20°C (68°F) and 25°C (77°F) at the mouth of the Little Shasta River during the same period (NCRWQCB 2004). The aerial thermal infra-red (TIR) investigation of the Shasta River watershed conducted in late July 2003 indicated an average median water temperature in the Little Shasta River of 28°C (82°F) between RM 11.3 and the confluence with the Shasta River (Watershed Sciences 2004).

Little Shasta River discharge was measured near Table Rock (41°43'58.75"N, 122°21'1.29"W) during water years 1952 – 1954 (Mack 1960) and stage measurements were taken by DWR in the same vicinity between 2010 and 2013. Measurement of pH was conducted on both March 24, 1953, and May 27, 1953 and showed a pH of 6.9 and 7.3, respectively.

Discharge measurements were also taken in 1922 and 1923 at a gage located one mile up the Little Shasta River from the confluence with the Shasta River (Zander 1925). These readings were taken prior to the water rights adjudication. The data for these years show spikes in flow in December and March, but by the later part of June 1922, and mid-May 1923, it appears all of the flow had been diverted for (Table 7).

The following is excerpted from McBain and Trush (2013):

> "For the Little Shasta River, we combined USGS 'Little Shasta River near Montague' gaging records (Station 11-516900) for the available period of record (1958-1978) with an assumed 12 cfs constant discharge from Evans Springs and Cold Springs. These hydrographs approximate unimpaired streamflow at the base of the foothills (Figure 19)."

Table 7. Daily discharge for Little Shasta River one mile above the confluence, 1922 – 1923 (from Zander 1925)

Day	May	June	July	August	September	October	November	December	January	February	March	April	May
1		9.5						47	167	32.5	47	18.5	5
2		3.5						45.9	143	32.5	47	18.5	1
3		3.5						44.7	119	32.5	47	18.5	1
4		3.5						43.6	95	32.5	47	18.5	2
5	47	3.5						42.4	71	32.5	47	17.7	2
6	47	5						41.3	47	32.5	39	17	5
7	43	5						40.1	47	32.5	39	16.3	3.5
8	39	11.5						39	47	33.8	39	15.7	2
9	47	54.5						39	47	35.1	39	15	1
10	47	32.5						39	47	36.4	39	14.3	1
11	26.5	32.5						39	44.1	37.7	28.8	13.6	1
12	26.5	26.5						39	41.2	39	18.5	12.7	1
13	26.5	22						39	38.3	40.3	18.5	12	1
14	26.5	18.5						39	35.4	41.6	18.5	11.3	1
15	26.5	12						39	32.5	42.9	18.5	10.6	1.5
16	26.5	12						51.6	32.5	44.2	18.5	9.9	1
17	18.5	9.5						64.2	32.5	45.6	18.5	9.2	1
18	18.5	9.5						76.8	32.5	47	26.5	8.5	1
19	18.5	7						89.4	32.5	47	26.5	12	
20	18.5	3.5						102	32.5	47	26.5	7	
21	18.5	3.5						114.6	32.5	47	26.5	5	
22	47	2.5						127.2	32.5	47	26.5	7	
23	47	2						139.8	32.5	47	26.5	5	
24	39	2						152.4	32.5	47	26.5	5	
25	37.5							165	32.5	47	26.5	1	
26	26.5							177.6	32.5	47	26.5	1	
27	26.5							190	32.5	47	26.5	1	
28	18.5							190	32.5	47	26.5	1	
29	15							190	32.5		26.5	7	
30	15							190	32.5		26.5	9.5	
31	15							190	32.5		26.5		

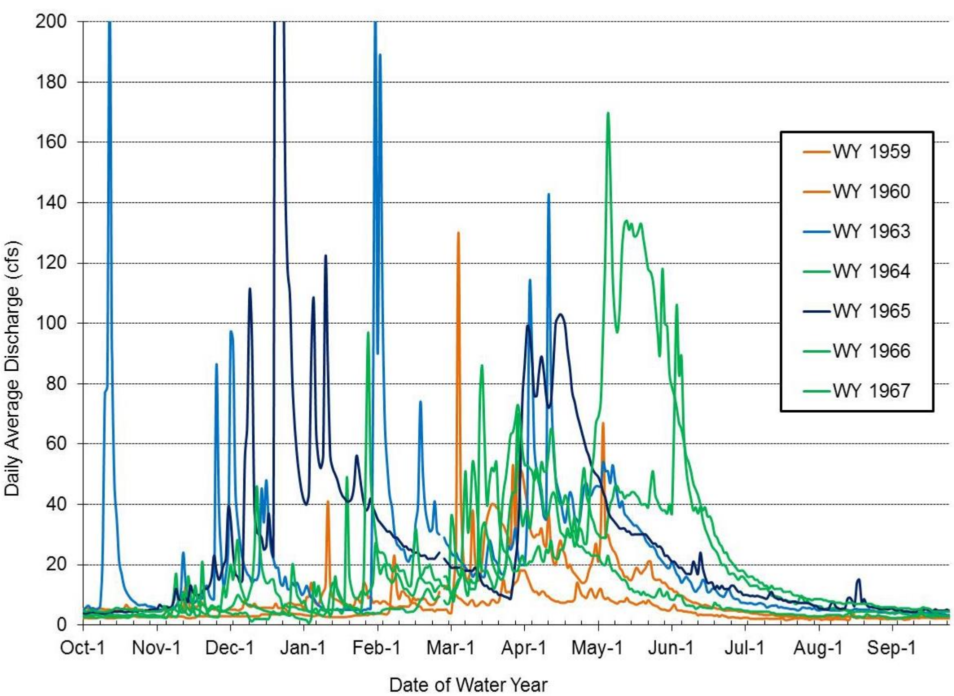

Figure 19. Published daily average streamflow data from USGS Little Shasta River gage (Station #11-516900) (McBain and Trush 2013).

In order to simplify mean daily flows representative of the Little Shasta River, we plotted USGS flow data from 1975 to 1977 representative of three hydrologic year types (wet, normal, and dry) as defined by Nichols et. al (2016) on a logarithmic scale (Figure 20).

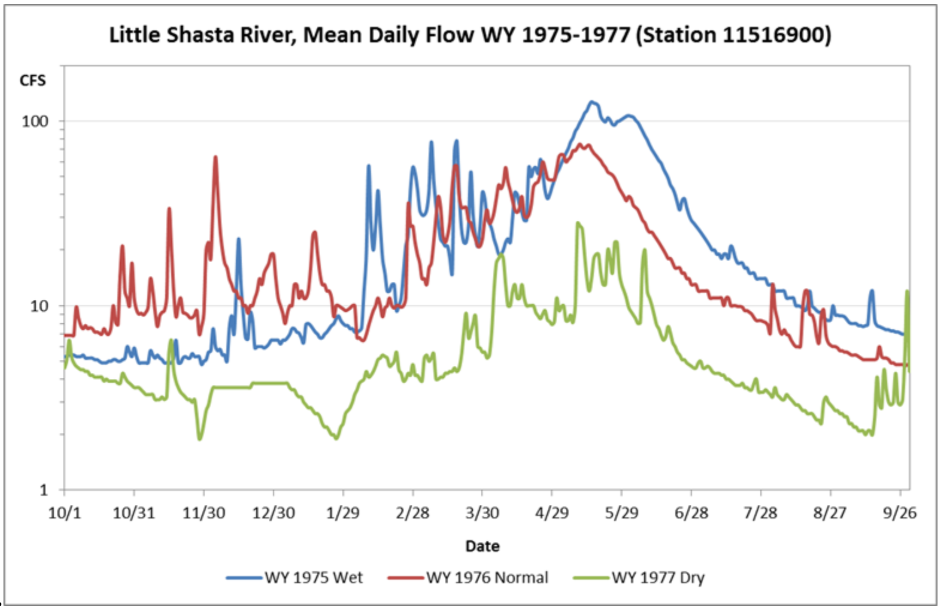

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Figure 20. Mean Daily Flow on the Little Shasta River during the years 1975 to 1977

B. Field Data Collection

Due to access limitations on private property, the water temperature monitoring conducted by CDFW staff was limited to public land located upstream of the Table Rock Spring Complex (Figure 21)**.** Five waterproof temperature loggers (U22-001, OnsetComp, Mass.) were placed opportunistically on public lands having access to points within the Little Shasta River watershed. All loggers were placed within the Little Shasta River except for LSR 3 (Bull Meadow Spring) which was located within a small spring-fed tributary. Temperature loggers were placed in PVC enclosures and secured to anchor points by stainless steel cable. Temperatures were logged hourly beginning on May 31, 2014. Loggers were downloaded in the field at regular intervals in order to minimize debris impaction of housings, although throughout sampling this was not a serious problem. However, high flow events early in 2015 relocated and dewatered the two lower loggers (LSR 1 and 2). Temperature data was uploaded using HoboWare Pro software vers. 3.7.2 (OnsetComp) and subsequently exported to Excel for further analyses.

Stream flow measurements were taken using a Model 2000 Flo-Mate, Marsh-McBirney, at three locations along the Little Shasta River on May 15, 2014. These locations correspond to logger locations at LSR 2, 4 and 5. Flow measurements were recorded immediately downstream of Little Shasta Spring (LSR 5) to determine the spring flow rate and at LSR 4 to determine if there was any flow accretion in that section of the headwaters reach.

The Little Shasta River was also periodically qualitatively evaluated for flow at the Lower Little Shasta Road Crossing located at RM 10.9. This was a visual assessment to see if there was any flow in the river channel downstream of diversions located near the Table Rock Springs Complex.

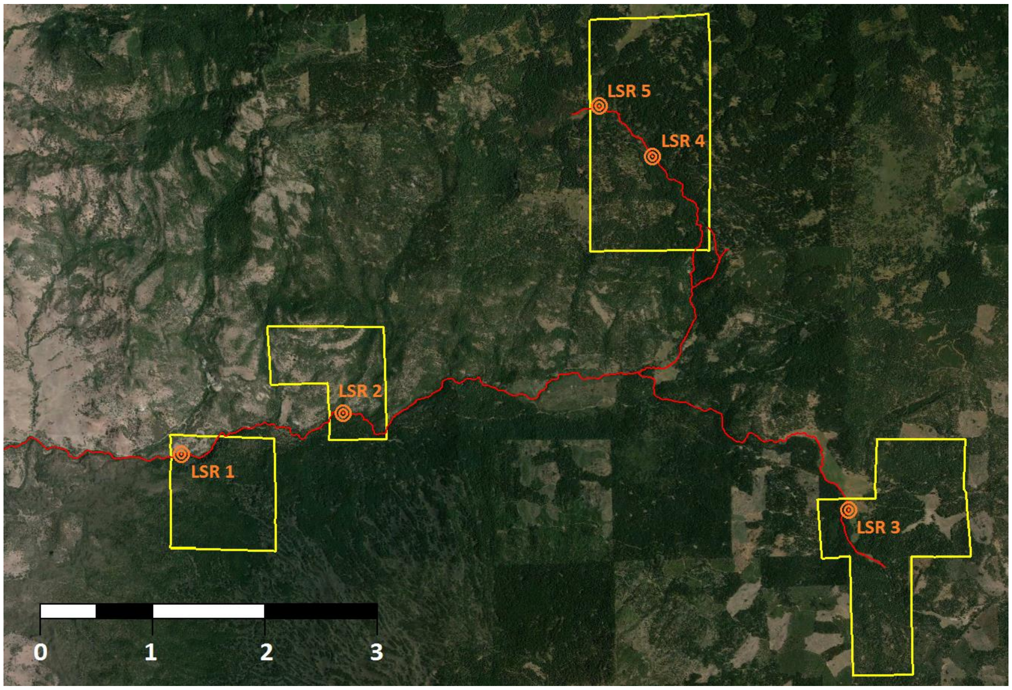

Figure 21. Temperature logger and flow data collection sites. Yellow polygons indicate USFS parcels with access to the Little Shasta River and headwaters (Scale in miles)

C. Study Sites and Results

Water temperature measurements

The Little Shasta Spring is one of the headwater springs of the Little Shasta River and is located 27 miles from the confluence with the Shasta River. The spring is at an elevation of 6,000 ft. and is located on private property upstream of the location of LSR 5 (41°47'44.67"N, 122°12'29.68"W). The LSR 5 temperature logger is located approximately 1600 ft. downstream from the spring source. The thermistor at this site is located in the middle of a meadow with little canopy cover (Figure T1).

For the period of May 31 to December 31, 2014, LSR 5 had a maximum weekly average temperature (MWAT) of 9.22˚C (48.59˚F) and a maximum weekly maximum temperature (MWMT) of 15.90˚C (60.62˚F). Both of these maximums occurred during the week ending July 18, 2014. From January 1 to September 30, 2015, temperatures were similar to the previous year although slightly cooler, with an MWAT of 8.58˚C (47.44˚F) for the week ending May 30, and an MWMT of 14.3 ˚C (57.74˚F) on the week ending July 6. The water at this location tends to range between 5˚C (41˚F) to 10˚C (50˚F) with the exception of winter times when it is generally cooler (Figure T2). As such, the water issuing forth from this spring tends to be colder than springs originating in the valley floor, which typically flow at temperatures between 12˚C to 14˚C (53˚F to 57˚F). Winter temperatures are more extreme at this location due to the higher altitude and increased snow cover.

Another interesting feature of this site is the amount of diurnal variation in water temperature, with summer temperatures fluctuating up to 10°C (18° F) daily. Although this amount of fluctuation is higher than temperature fluctuation observed in the valley, where the ambient temperature is generally higher, there is very little canopy cover between the spring source and the location of the logger (Figure T1). Figures T2 and T3 illustrate hourly temperature distributions at this location during the months of June through December 2014 and January through September 2015, respectively. In the summer months there are some excursions to higher temperatures, however, these are usually brief and seldom exceed 15˚C (59˚F).

Figure T1: Location of logger at LSR 5. Picture was taken looking downstream from the spring headwaters. The logger is attached to the small tree on river left indicated by the arrow. The logger is located in a meadow at the Martin's Dairy Campsite.

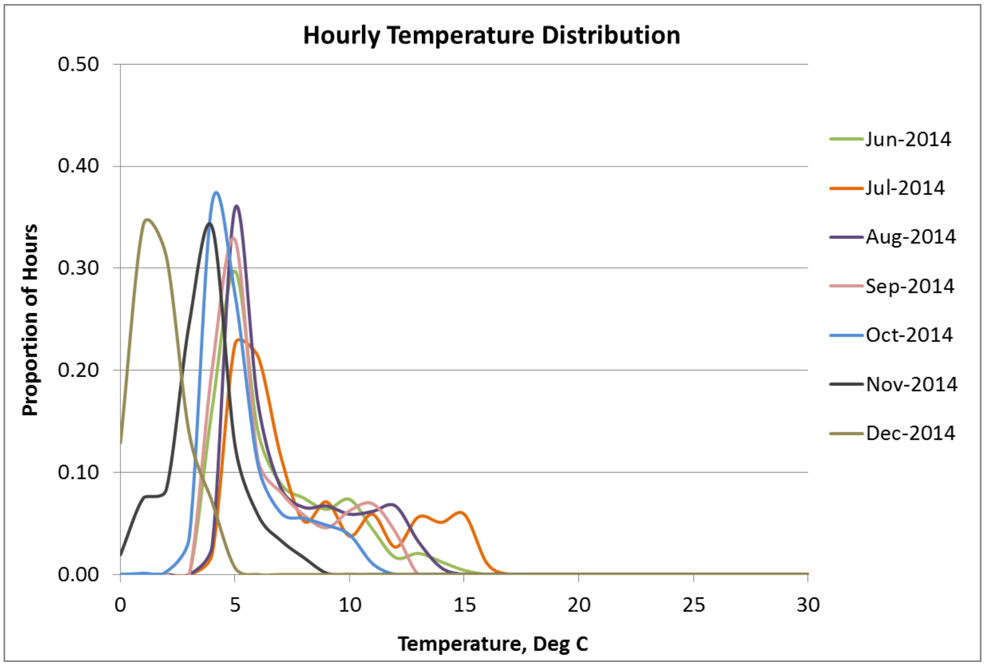

Figure T2: Hourly Temperature distribution at LSR 5 for temperatures recorded from June through December in 2014.

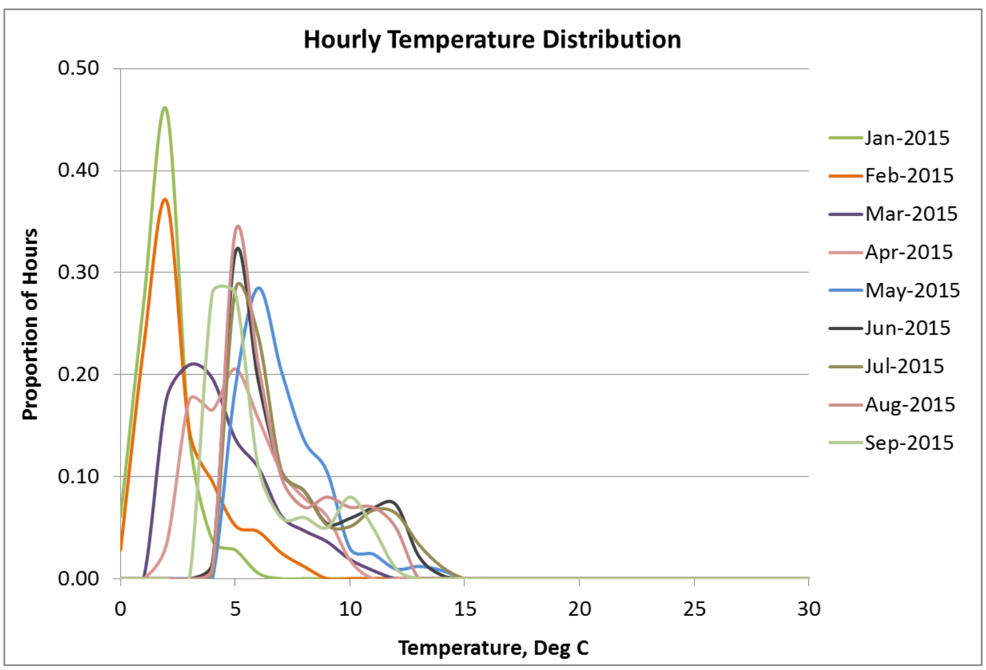

Figure T3: Hourly temperature distribution at LSR 5 for temperatures recorded from January through September 2015.

The temperature logger at LSR 4 (41°47'27.71"N, 122°11'56.57"W) is located approximately one half mile downstream from LSR 5 at RM 26 on the USFS Martin's Dairy Day Use Area. At this location there is more canopy cover and large woody debris than at LSR 5 (Figure T4). There is no cover directly overhead of the site where the LSR 4 thermistor is located. As a result, diurnal fluctuations during the summer can vacillate by as much as 15°C (27°F). The possibility that direct solar radiation was skewing temperature readings was considered, but due to consistency in the readings independent of the cloud cover we assume that this is not a problem. There is a lack of shading in this reach; however, the logger itself does not appear to be more exposed to solar radiation than similar locations where we monitor water temperature in the Shasta Valley, which function adequately without being skewed by direct solar radiation. It is likely the lack of shade and the relatively small volume of water allow for rapid water temperature warming during the summer. Figures T5 and T6 show hourly temperature distributions at this location for 2014 and 2015, respectively. Temperatures are higher at LSR 4 in 2014 than 2015 and they remain higher for longer periods of time. In 2014, LSR 4 had an MWAT of 12.92˚C (55.26˚F) and an MWMT of 21.46˚C (70.63˚F). Both of these maximums occurred on the week ending July 18. It is interesting to note that the difference between these two temperature metrics shows a nearly 10°C difference. In 2015, an MWMT of 20.05˚C (68.09˚F) occurred on July 5, whereas the MWAT of 11.98˚C (53.56˚F) was recorded the week ending July 2. As above, temperatures overall were cooler in 2015 compared with 2014. In late fall and wintertime, conditions frequently approached near freezing temperatures.

Figure T4: Looking upstream from the location of the logger at LSR 4. Note woody debris and canopy encroachment in contrast to LSR 5.

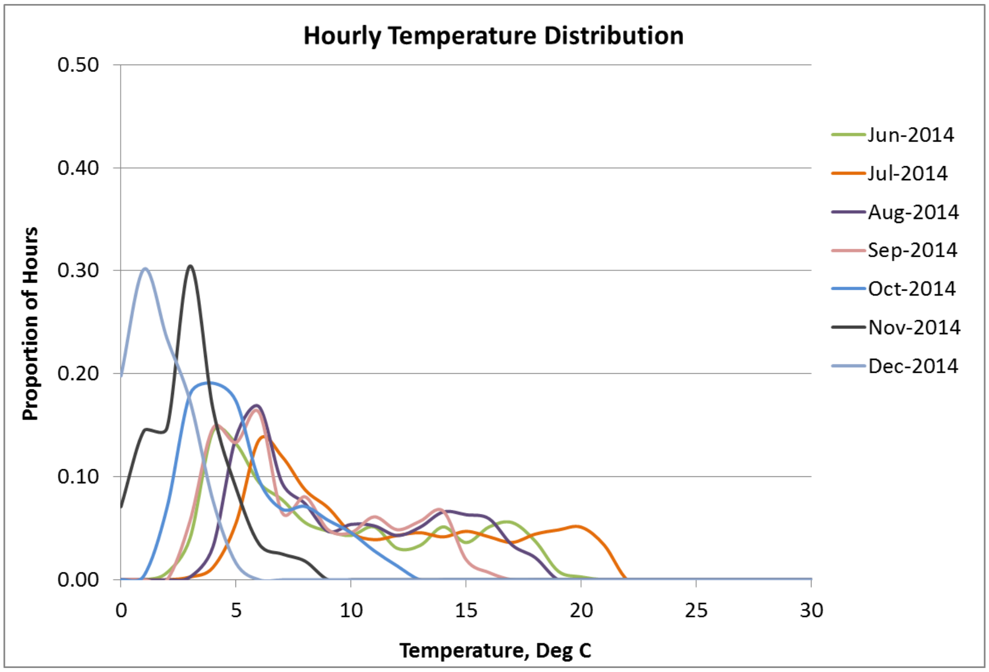

Figure T5: Hourly water temperature distributions at LSR 4 in 2014. Temperatures increase past 15°C and 20˚C (59-68˚F) over time.

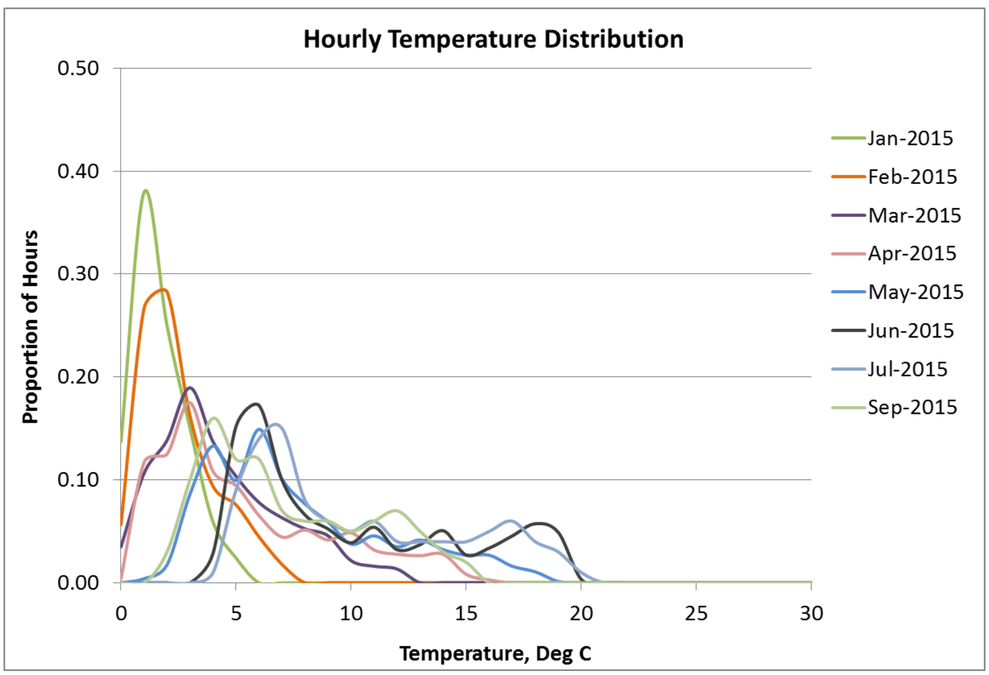

Figure T6: Hourly temperature distributions at LSR 4 in 2015. No data was collected in August due to a logger malfunction.

The temperature logger at LSR 2 (41°45'29.02"N, 122°15'6.91"W) is located approximately six miles downstream from LSR 4 at RM 20 (Figure T7). Between these two locations the river goes through pasture, mature timberland, and recently harvested timberland. In 2014, LSR 2 showed an MWAT of 20.33˚C (68.59˚F) and an MWMT of 22.54˚C (72.57˚F). Both of these maximums occurred the week ending July 19, 2014. Interestingly in 2015, the MWMT and MWAT values were nearly identical to those seen the previous year; however, they occurred the week ending July 6. As shown in Figures T8 and T9 showing water temperature distributions per month, LSR 2 heats up during the summer months with somewhat little diurnal change and little to no night time cooling. During this time, daily temperature fluctuations frequently range between 3-5°C (5.4-9° F). Hourly temperature distributions become more spread out in the summer months. The high proportion of temperatures near 5˚C (41˚F) recorded in December 2014 is due to the fact that there was an incomplete month of logging because the logger was recording temperatures below freezing. This highlights the need for increased checks and downloads during winter months. However, access at this location can become difficult during winter conditions. Furthermore, in 2015 four months of data were lost beginning in February after a high water event which dewatered the logger. The logger was not downloaded again for nearly three months.

Figure T7: Looking upstream at the logger at LSR 2 (arrow) located on river right.

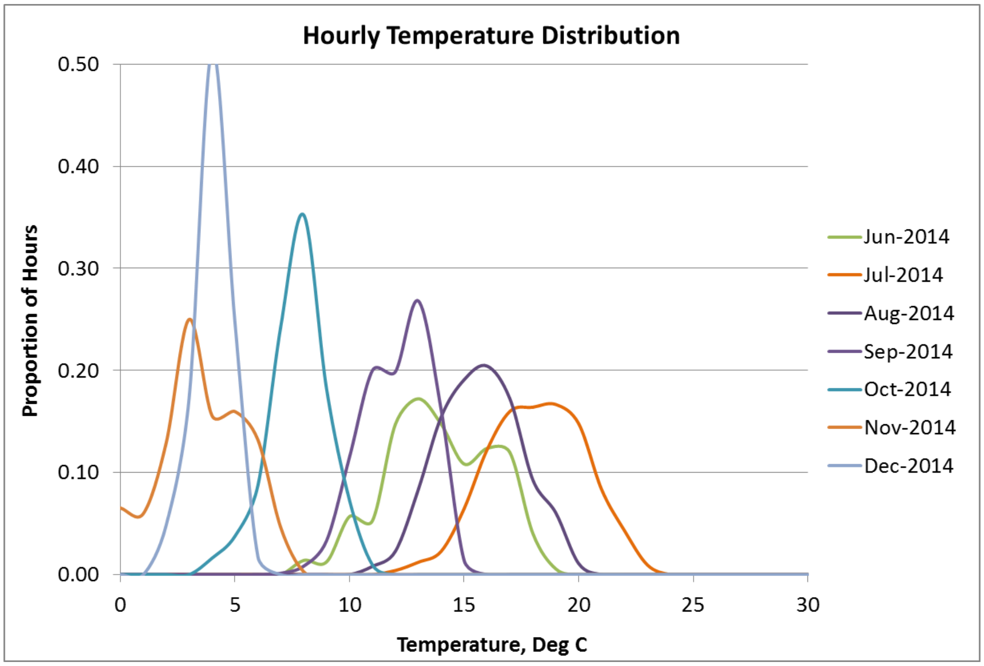

Figure T8: Hourly temperature distributions at LSR 2 for 2014.

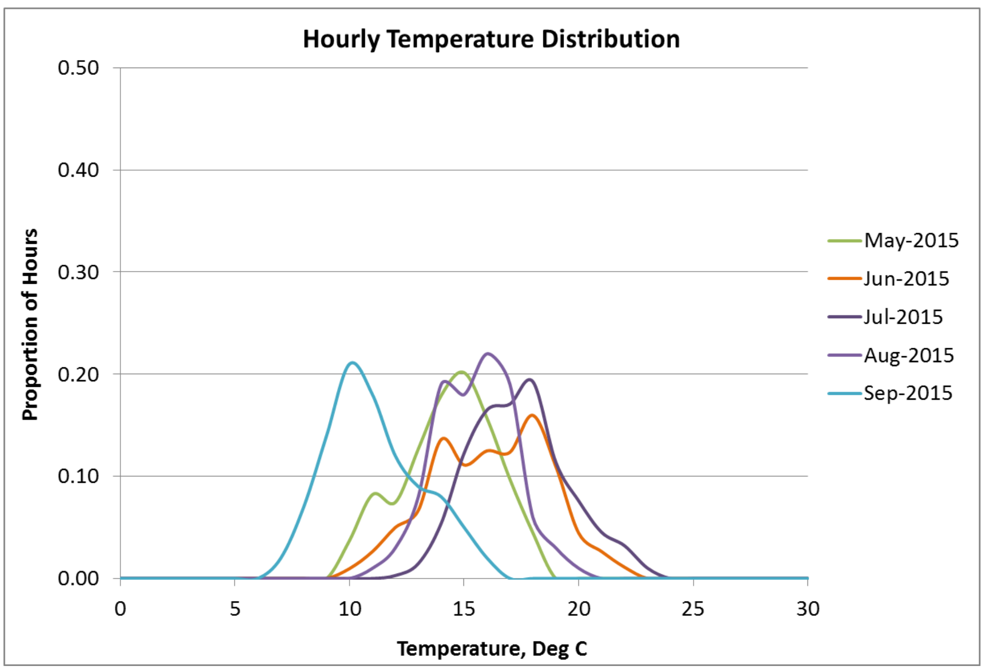

Figure T9: Hourly temperature distributions at LSR 2 for 2015. The data from January to April are missing due to the logger becoming dewatered and recording air temperatures.

The logger at LSR 1 (41°45'9.23"N, 122°16'44.21"W) is located two miles downstream from LSR 2 at RM 18. Here the Little Shasta River flows from timberland into oak woodland and the canopy cover is further increased (Figure T10). LSR 1 has an MWAT of 20.65˚C (69.17˚F) and an MWMT of 23.38˚C (74.08˚F). Both of these maximums occurred on the week ending July 19, 2014, similar to LSR 2. Also similar to LSR 2, the

MWMT and MWAT were nearly identical between 2014 and 2015, although occurring the week ending July 6. Again, at this location, the temperature increases in the summer months with little overnight cooling in contrast to those sites further upstream. Not surprisingly, this site also experiences the warmest water temperatures within the study, with a maximum of 24.27°C (75.67°F) recorded July 17, 2014. In 2015, the maximum temperature recorded was 23.93˚C (75.07˚F) on July 1. These high temperatures are illustrated in Figures T11 and T12 which document hourly temperature distributions at LSR 1. This location shows the greatest distribution and change of temperatures both monthly and seasonally.

Figure T10: Location of the logger at LSR 1. The arrow indicates the approximate position of the logger within the channel.

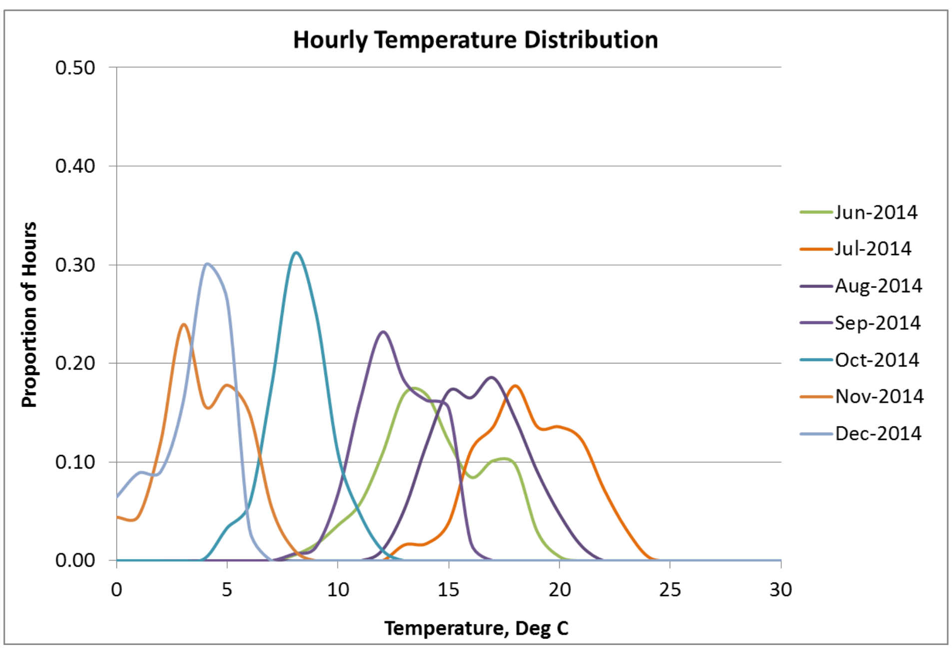

Figure T11: Hourly temperature distribution at LSR 1 in 2014. In December, temperatures often dropped below freezing. In addition, there may have also been dewatering events.

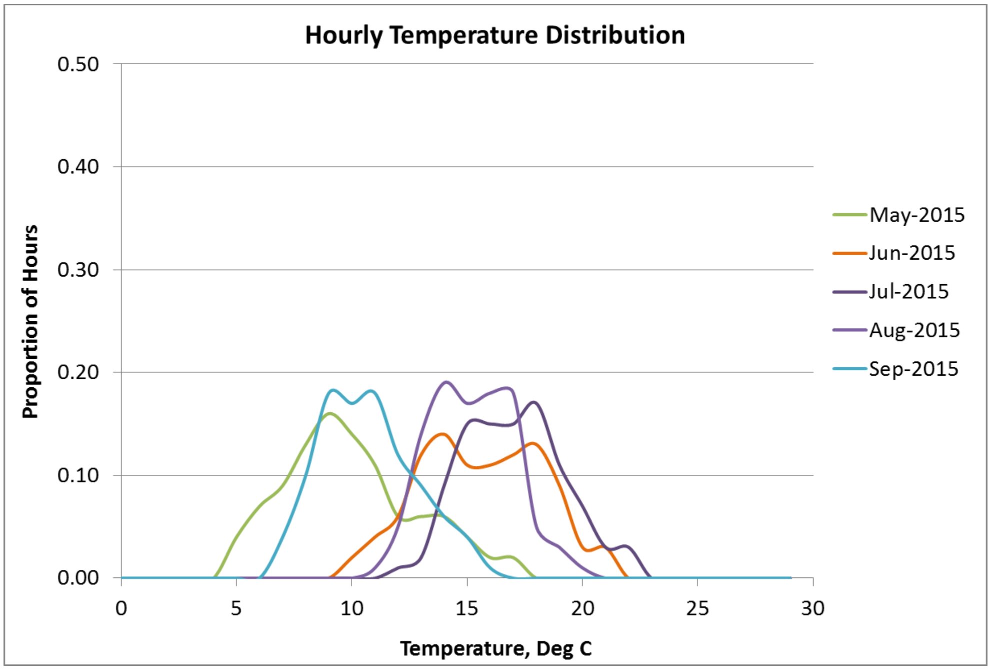

Figure T12: Hourly temperature distribution at LSR 1 in 2015. The logger appears to have been dewatered in December, but began recording water temperatures again during a high water event (data not shown) in February 2015 and then was subsequently dewatered. As such, only the data from May through September 2015 are shown here.

The temperature logger at LSR 3 (41°44'46.95"N, 122° 9'58.44"W) is located in a small spring channel in what is known as the Bull Meadow Branch of the Little Shasta River (Figure T13). The confluence of the Bull Meadow Branch and the mainstem is at RM 23.3. The Bull Meadow Branch meanders through a meadow, which is used as irrigated pasture for cattle. Its spring source is located approximately 3 miles from the confluence. The logger is located 0.3 miles downstream from the spring. This site has very consistent temperatures and is similar to environmental conditions at LSR 5 although the flow is of a smaller volume. The channel at this location is narrow, in most places it is no more than a foot in width and depth. Emergent grasses may provide some degree of shading, a feature present in LSR 4 and 5, but likely of lesser importance at those locations due to the greater channel widths.

During the summer of 2015, the channel width increased considerably in some portions due to the presence of cattle. LSR 3 had an MWAT of 11.04˚C (51.87˚F) and an MWMT of 17.08˚C (62.74˚F). Both of these maximums occurred on the week ending July 20, 2014. In 2015, an MWAT of 10.78˚C (51.40˚F) was recorded while the MWMT 17.52˚C (63.54˚F) both of which occurred on the week ending July 21. Figures T14 and T15 show hourly temperature distributions at this site per month.

Figure T13: This photograph was taken on Ball Mountain Road facing south towards Bull Meadow. The channel here is narrow and obscured by grasses. The arrow indicates the approximate position of the logger within the channel.

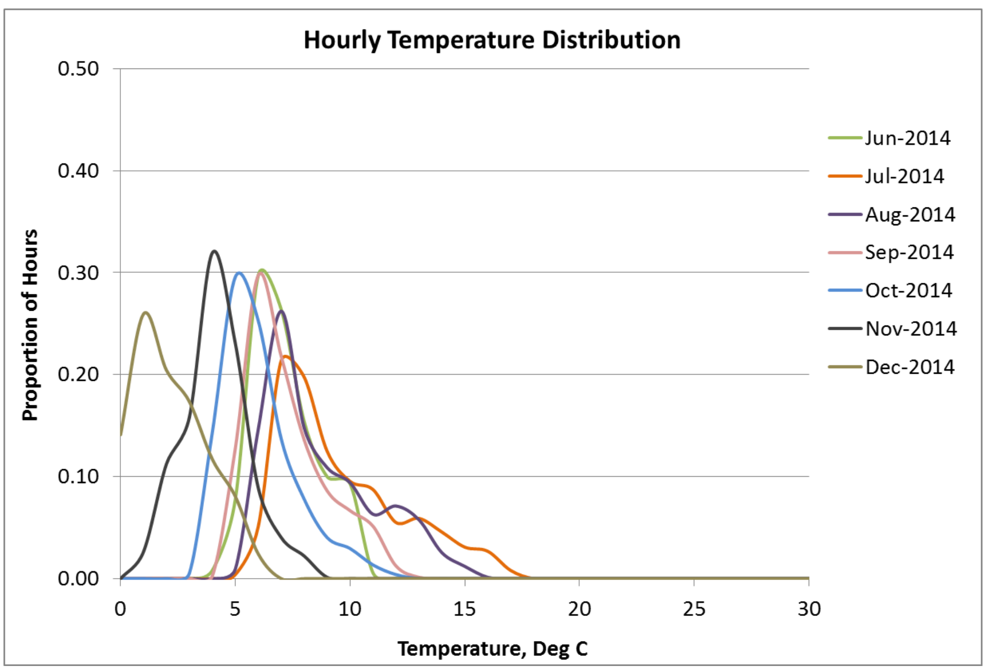

Figure T14: Water temperature distribution at LSR 3 during 2014. In December temperatures often approached freezing, but never dropped below that point.

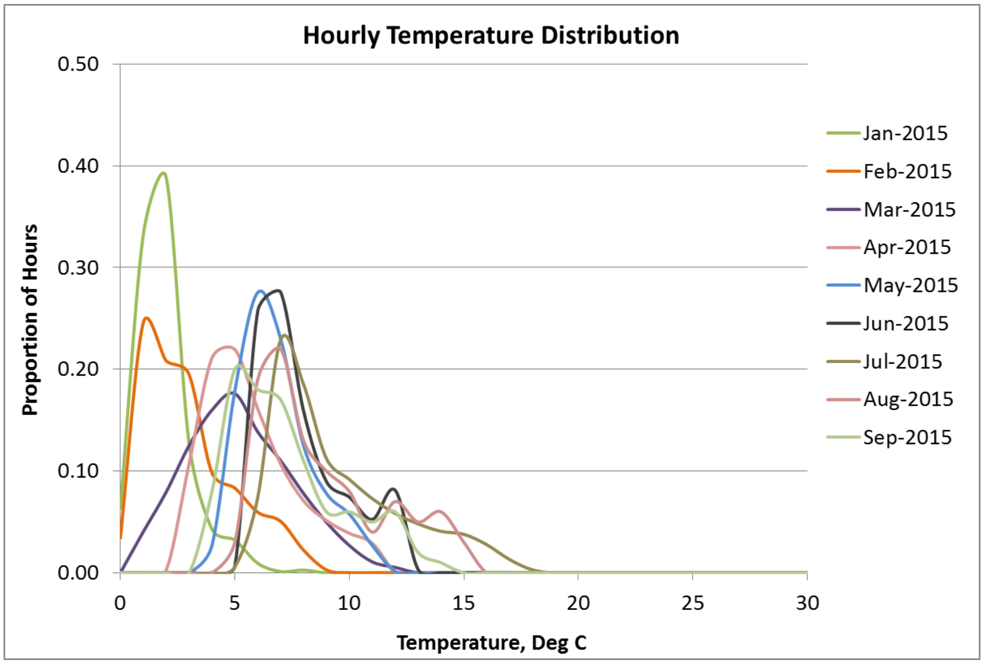

Figure T15: Water temperature distribution at LSR 3 during 2015.

Flow Measurements

Flow measurements were taken at two sites within the Little Shasta River watershed during this study. Flows were recorded on four occasions at LSR 5 and three occasions at LSR 2 seven miles downstream (Table T1). The variation in flow at LSR 5 may be due to the three diversions located at the spring source equaling a total of .17 cfs. This spring may also be subject to seasonal fluctuations depending on snowmelt.

Table T1: Flows measured in 2014 at LSR 5 and 2.

LSR 5		LSR 2	
Date	CFS	Date	CFS
5/15/2014	3.23	5/15/2014	4.34
6/19/2014	1.86	6/24/2014	2.33
7/18/2014	2.30	11/25/2014	4.67
11/25/2014	2.04		

The variation in flow at LSR 2 may also be due to surface water diversions located upstream. The total adjudicated flow allowed for diversion in this reach is 4.4 cfs, however it is not known if any of the diversions upstream were in use during the course of our study. Flow accretions of over 2 cfs occur between these two sites, one potential source is the Bull Meadow Branch and there may be additional springs located in this reach.

Throughout the 2014 monitoring period Little Shasta River was also visually checked at the Lower Little Shasta Road crossing located at RM 10.9. This visual assessment confirmed that the Little Shasta River was completely dewatered at this location. It was not until the December 1, 2014, that water was observed flowing in the river channel again.

D. Discussion

Among the study sites, a wide range of water temperatures were recorded; this was especially notable during the summer months. The temperature loggers are located in a variety of habitat types, ranging from spring-fed alpine meadow streams to higher gradient conditions transitioning to the valley floor. Figure T16 displays daily average temperatures from the end of May 2014 through September 2015. The loggers located in spring-fed reaches, LSR 3 and 5, show consistent lower temperatures in comparison to downstream sites. Unlike other spring-fed systems we have monitored; winter conditions contribute to overall lower water temperatures. Our experience with sites in the Shasta Valley is that spring-fed systems tend not to fluctuate as much during the winter. The trend toward near freezing conditions in LSR 3 and 5 is likely due to the effects of altitude and snow cover.

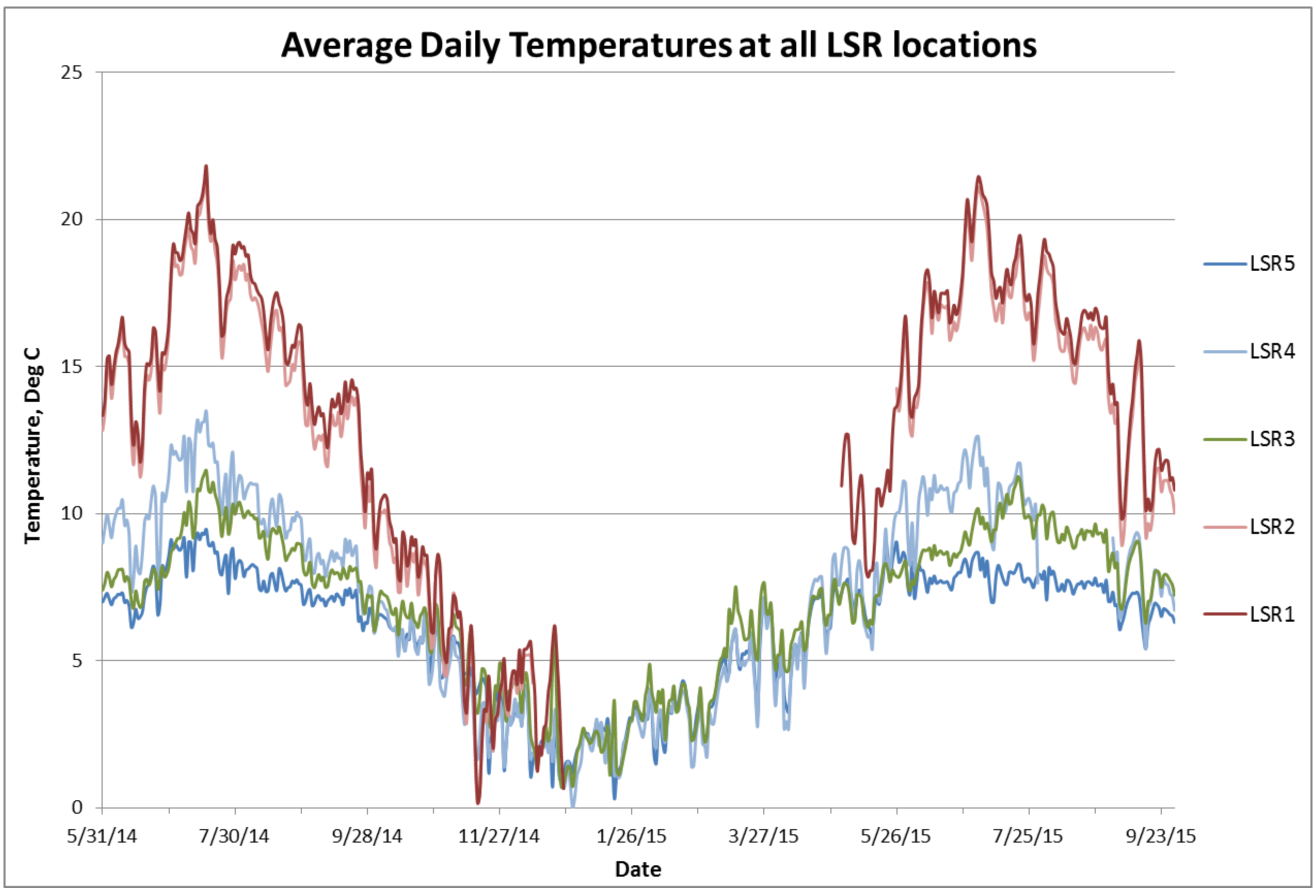

Figure T16: Average daily temperatures for all study locations from May 31, 2014 to September 23, 2015. LSR 1 is the furthest downstream and LSR 5 is closest to a spring source. LSR 3 is located in the Bull Meadow tributary to the Little Shasta River.

Although the upper Little Shasta River water temperatures may be beneficial for juvenile salmonids during some parts of the year, favorable temperature conditions degrade rapidly once the Little Shasta River emerges into the valley. This is reflected not only in our point measurements of valley reach temperatures, but also by an electrofishing trial and snorkel survey conducted in the spring of 2008 and 2015, respectively. During each of those surveys we observed a green sunfish dominated fish community which also included bass, shiner and mosquitofish in high numbers. Although rainbow trout were observed, the observation of a fish community consisting primarily of introduced, warm-water tolerant fish clearly indicates that while there may be aquatic habitat upstream that could be utilized by juvenile salmonids, suboptimal flow and temperature conditions occur in the valley reach.

E. Management Implications

According to McBain and Trush (2013), "The Little Shasta River unimpaired hydrograph was [historically] 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)." Based on our literature review, it is possible that the historic baseflow of the Little Shasta River was between 20 and 30 cfs with occasional snowmelt driven flows of up to 300 cfs and rare flood events of up to 800 cfs.

In the foothills reach, multiple cold water springs historically entered the Little Shasta River. These springs, if allowed to reconnect with the mainstem, could have a large impact on aquatic habitat quality throughout both the foothills reach and the bottomlands reach. The foothills reach has a moderate gradient, gravel bedded alluvial morphology, abundant deep pools, undercut banks, woody debris, and a dense riparian and mixed conifer canopy which may be suitable for salmonid rearing habitat (McBain and Trush 2013). However, current instream flows are inadequate to encourage upstream migration into the Little Shasta foothills reach (above the Musgrave/Hart Diversions) and passage through the foothills reach is uncertain. The Dry Gulch Falls may be impassable at low flows. Spawning habitat may be abundant in the foothills reach and above, but this has not been investigated. The presence of spring and summer rearing habitat has not been confirmed but may be available and suitable for salmonids.

Unfortunately, fish migration downstream during the spring may be hampered by flow diversions. During the irrigation season, the bottomlands reach has unsuitably high summer water temperatures or is dewatered (McBain and Trush 2013). If suitable late-summer and fall streamflows were available, it is possible that the foothills reach could once again provide spawning and/or rearing habitat. However, flow diversions for irrigation beginning in early spring appear to diminish habitat in the valley reach and water temperatures become unsuitable by mid-summer before the reach becomes completely dry (McBain and Trush 2013).

11. Optimum Flow Modeling

A. Methods

We predicted optimum instream flows for Chinook, steelhead, and salmonid species combined for spawning, rearing and occupancy in the Little Shasta River using equations and methods developed by Hatfield and Bruce (2000). Optimum flow (Qopt) is defined as the single flow that maximizes microhabitat availability for a given species (or several species pooled) during an identified life stage (Table X1.). The Hatfield and Bruce (2000) methodology estimates flow that maximizes weighted usable area of several western North American salmonids. Weighted usable area is an index of habitat suitability which is the wetted area of a stream weighted by its suitability for habitat use by an organism. Formula inputs were based on flow data obtained from USGS gage 11516900 (N 41.753056, W 122.299444) (Appendix 1). The gage operated from water years 1958 to 1978 and was located upstream of Table Rock Springs Complex on the Little Shasta River between Dewey Gulch and Dry Gulch. The mean annual discharge and the site coordinates for the USGS gage were used to develop the instream flow estimates identified below.

B. Results

The mean annual discharge for the period of record at the Little Shasta River gage site was 19.45 cfs (Appendix 1). Our results suggest that Chinook salmon would need 6 cfs of instream flow for rearing habitat and 30 cfs for spawning conditions at the site of the gage (Table X1). Since habitat in the river has the potential for utilization by other salmonid species, flows were also calculated for all salmonid species. Based on this analysis, an instream flow of 22 cfs is necessary for spawning habitat and 12 cfs is necessary for juvenile rearing habitat (Table X1). A hydrograph that illustrates our recommended interim instream flows in the Little Shasta River based on Hatfield and Bruce (2000) is provided in Figure X1. Based on our field observations, these seem like reasonable minimum flows for salmonid habitat in the Little Shasta River.

C. Discussion

Hatfield and Bruce (2000) write, “Our results are presented as a planning tool to (1) allow managers and project proponents to conduct a preliminary assessment of proposed water use development projects, (2) optimize research efforts for instream flow studies and experiments, and (3) set experimental boundaries for adaptive management of stream flow.” The flows presented here could provide the basis for instream flow discussion purposes. A minimum base flow of 12 cfs may be adequate to provide rearing habitat in the Little Shasta River for salmonids, however, it is unknown if temperature criteria for rearing coho salmon would be met in the valley reach due to the fact that there is very little riparian canopy. Based on our analysis, spawning flows of 20 to 30 cfs would need to be maintained from September through January.

However, there are several shortcomings in using this approach. The formulas provided by Hatfield and Bruce (2000) are simple to use in that they rely on latitude and longitude coordinates and mean annual discharge figures. This simplicity and ease of use comes at the cost of ignoring peculiar hydrologic processes that might be operating within the Little Shasta River watershed. The formulas are developed to calculate run-off conditions and do not account for spring inflows which are a salient feature of this watershed (albeit downstream of the gage location). If there were an opportunity to provide 13° C cold spring flow from the

Table Rock Springs complex to the Little Shasta River during base flow, it is likely that ~ 12 cfs would be adequate for achieving minimum habitat values for rearing salmonids. Field research would be required to determine if other aquatic and physical habitat features necessary for rearing salmonids are present.

Table X1. Results of Hatfield Bruce Analysis

Species	Lifestage	Use	Qm	Latitude	Longitude	Qopt	Period of Record
Chinook	Adult	Spawning	19.54	41.75294	122.3006	30	WY 1958 to 1978
Chinook	Juvenile	Rearing	19.54	41.75294	122.3006	6	WY 1958 to 1978
Steelhead	Adult	Occupancy	19.54	41.75294	122.3006	27	WY 1958 to 1978
Steelhead	Adult	Spawning	19.54	41.75294	122.3006	39	WY 1958 to 1978
Steelhead	Juvenile	Rearing	19.54	41.75294	122.3006	17	WY 1958 to 1978
All species	Adult	Occupancy	19.54	41.75294	122.3006	25	WY 1958 to 1978
All species	Adult	Spawning	19.54	41.75294	122.3006	22	WY 1958 to 1978
All species	Juvenile	Rearing	19.54	41.75294	122.3006	12	WY 1958 to 1978

Qm – mean annual discharge, Qopt – optimum flows

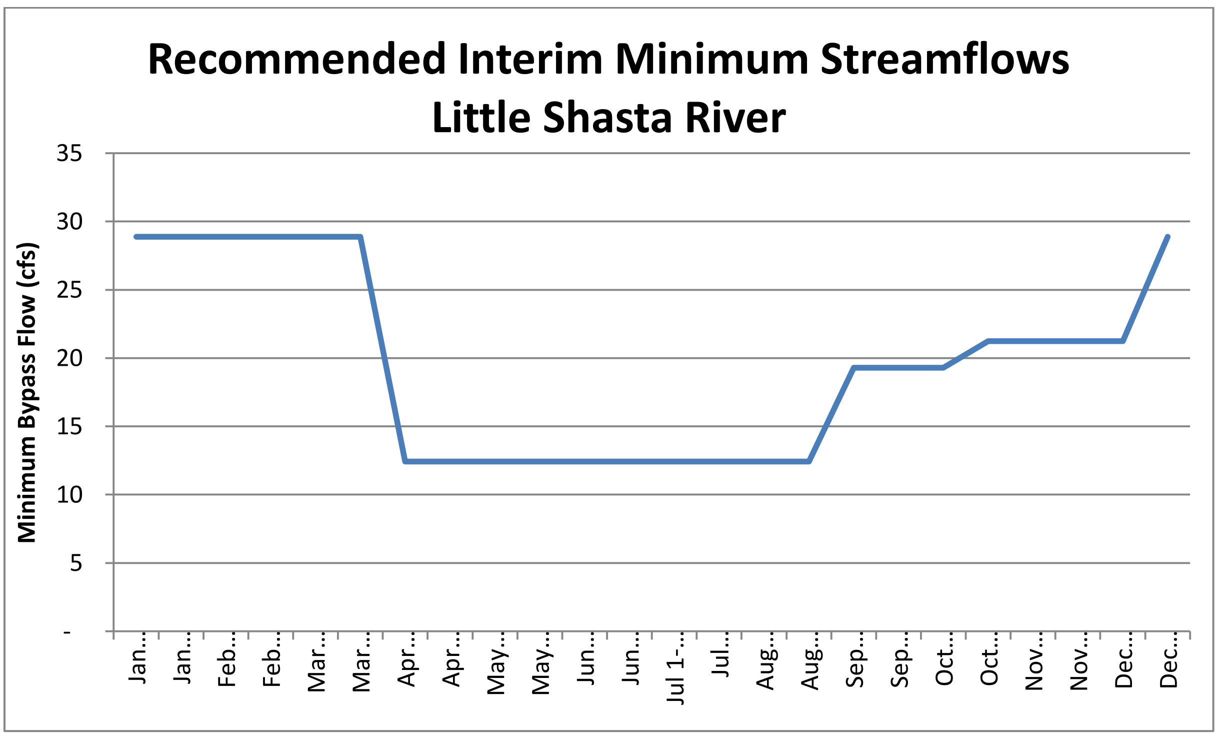

Figure X1. Recommended Interim Minimum Streamflows for the Little Shasta River

Another issue in regards to the optimum flows is observed in the seasonal flow percentiles found in Figure X2. The optimum flows for spawning were found to be 22 cfs for all species and 30 cfs for Chinook, specifically. A flow of 22 cfs during wintertime, when spawning is most likely to occur, is within the 75th percentile. If an instream flow goal of 30 cfs is selected, 84% of all winter flows for the period of record were less than the optimum predicted flow for Chinook spawning. Optimum flows for juveniles would also be difficult to maintain.

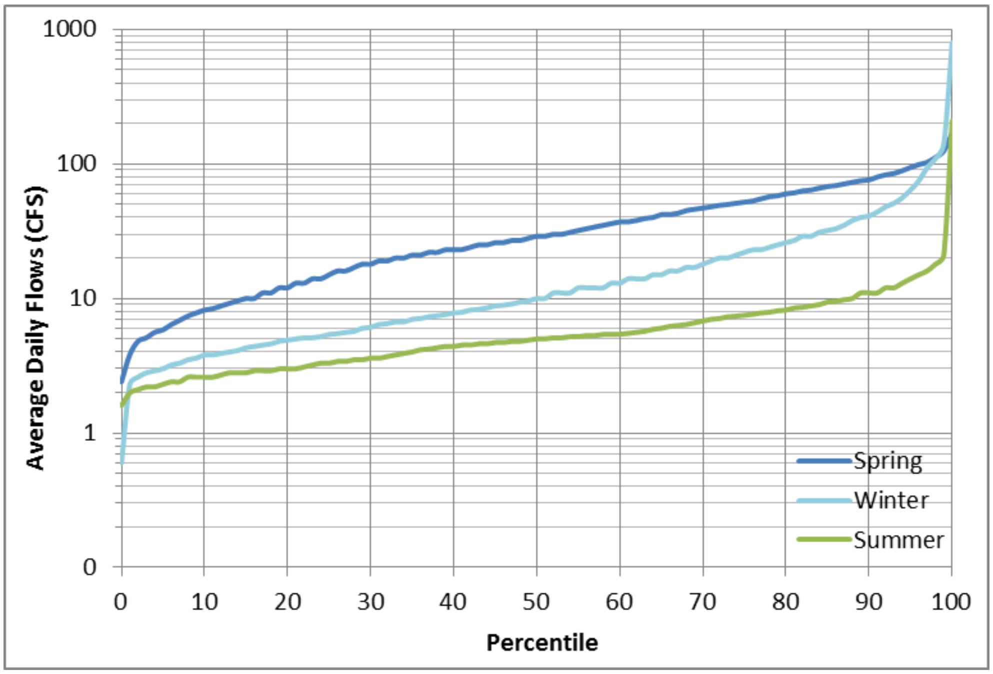

Figure X2: Seasonal flow percentiles as measured at USGS Gage 11516900 on the Little Shasta River from WY 1958 to WY 1978. Spring is April to June, summer is July to October, and winter is November to March.

Further work is necessary in order to develop instream flow targets specific to the Little Shasta River. The Hatfield Bruce methodology is recommended as a reconnaissance level tool and is not suitable for a detailed analysis of a watershed. However, it is clear that in its current state the Little Shasta River is not capable of supporting salmonids. To take the steps necessary to achieve the restoration of salmonid habitat would require input from the Table Rock Springs complex all year long (Figure X3). The formulas of Hatfield and Bruce (2000) allowed us to estimate a good starting point.

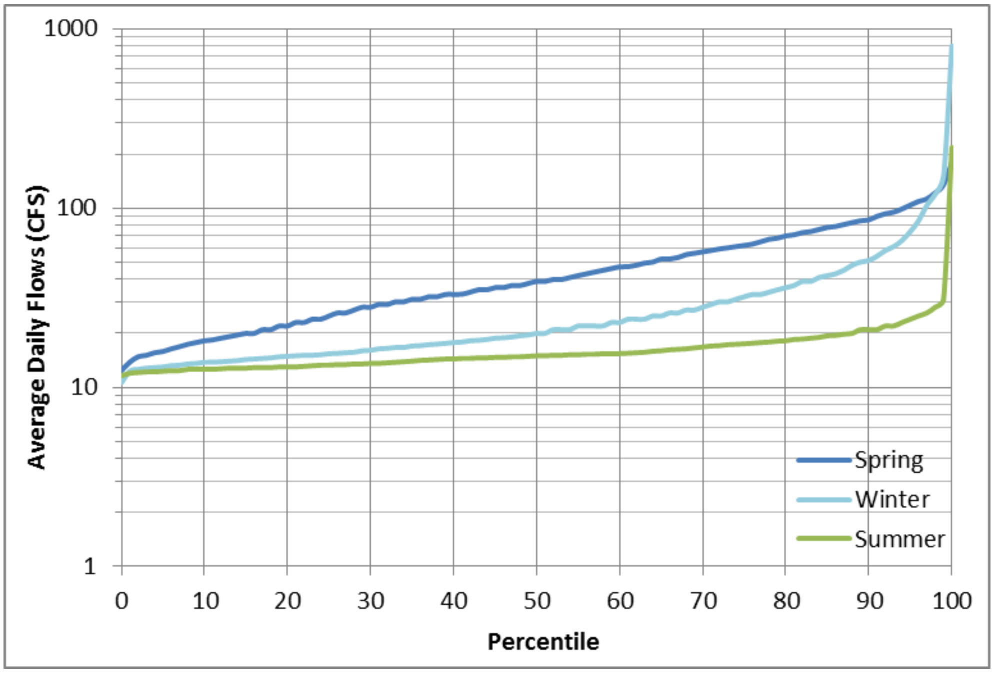

Figure X3: Seasonal flow percentiles with an additional 10 cfs from springs downstream of the USGS gage.

12. Additional Data Needs

Excerpted from McBain and Trush (2013):

- 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 streamflow threshold that provides unrestricted upstream salmon migration to the Little Shasta River Headwaters reach;

- reach-scale survey of 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 salmon fry and juvenile coho summer rearing habitat availability in the Little Shasta River and water temperature data for Little Shasta;

- 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;

- 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 to determine presence/absence and age class distribution of juvenile salmon.

13. Acknowledgements

This document could not have been produced without the initiation and fieldwork conducted by Seth Daniels and Steven Stenhouse. We are also indebted to Dr. Joanne Mack for her generous contribution and, in addition, Bob Smith who provided critical information. Historic photos are provided courtesy of the Siskiyou County Historical Society.

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Appendix 1. Hatfield Bruce Data and Analysis

WY	MAD	Lat	Long	QoO	QoS	QoR
58	29.10	41.75294	122.3006	31.99	28.36	16.10
59	6.07	41.75294	122.3006	12.49	10.08	5.55
60	9.52	41.75294	122.3006	16.36	13.57	7.54
61	11.16	41.75294	122.3006	17.99	15.06	8.40
62	12.52	41.75294	122.3006	19.28	16.25	9.08
63	21.61	41.75294	122.3006	26.75	23.30	13.15
64	17.03	41.75294	122.3006	23.20	19.92	11.19
65	30.75	41.75294	122.3006	33.06	29.41	16.71
66	10.90	41.75294	122.3006	17.74	14.83	8.26
67	24.57	41.75294	122.3006	28.89	25.36	14.35
68	8.02	41.75294	122.3006	14.76	12.11	6.71
69	24.22	41.75294	122.3006	28.65	25.13	14.21
70	20.60	41.75294	122.3006	26.00	22.58	12.73
71	34.54	41.75294	122.3006	35.45	31.76	18.08
72	38.04	41.75294	122.3006	37.56	33.85	19.31
73	10.38	41.75294	122.3006	17.23	14.36	7.99
74	28.42	41.75294	122.3006	31.54	27.92	15.84
75	25.79	41.75294	122.3006	29.75	26.19	14.83
76	19.62	41.75294	122.3006	25.25	21.86	12.32
77	5.65	41.75294	122.3006	11.96	9.61	5.29
78	21.80	41.75294	122.3006	26.90	23.44	13.23

WY – water year
MAD – mean annual discharge
Lat – latitude
Long – Longitude
QoO –Occupancy flow
QoS – Spawning flow
QoR – Rearing flow