ANNUAL SHASTA RIVER TMDL MONITORING REPORT 2021

PPREPARED AND SUBMITTED BY

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RCD
SHASTA VALLEY
RESOURCE CONSERVATION DISTRICT

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INTRODUCTION

The Shasta River is listed in the Shasta TMDL for high temperature and low dissolved oxygen (DO). Agricultural activities (livestock impacts, impoundments, and diversions) have been identified as the main source of these impairments (NCRWQCB 2007). Sizable diversions of water from the Shasta River and excessive irrigation return flows, or tailwater, returns to the river system degrade water quality and impact the *beneficial uses*, which include: 1) cold freshwater habitat (COLD) that supports migration, spawning and rearing (MIGR, SPWN) of salmonids including Chinook, steelhead and state and federally ESA-listed coho (RARE), 2) drinking water (MUN), 3) recreation (REC-1 & 2), 4) agricultural supply (AGR) and 5) groundwater recharge (GWR) (NCRWQCB 2007).

Under the protocols established in the Monitoring Plan, QAPP and PAEP approved by the SWRCB, the SVRCD is monitoring water quality on the Shasta River and its tributaries. The goals of this monitoring effort are to assess progress in meeting TMDLs (temperature and DO) by monitoring Shasta River water quality and to identify locations where the restoration or alteration of riparian habitat, land management actions, and land management practices would likely improve water quality in the Shasta River and its tributaries.

This report summarizes and discusses meteorological data and the impact on the Shasta River watershed, as well as temperature and DO monitoring data at 25 sites (ten sites measured DO) on the Shasta River and tributaries Parks Creek and Yreka Creek. Access to monitoring locations was acquired from private landowners through landowner agreements.

MONITORING LOCATIONS

Temperature and DO were measured from April 1st through October 1st, 2021 at 25 locations on the Shasta River and its tributaries (Table 1). The study area spans approximately 40 river miles from Dwinnell Reservoir to the mouth of the Shasta River at its confluence with the Klamath River (Figure 1).

TABLE 1. REACH, SITE ID, RIVER MILE, EQUIPMENT DEPLOYED AND MEASURED METRICS DURING THE 2021 IRRIGATION SEASON. SITES ARE LISTED IN ORDER FROM UPSTREAM AT THE OUTLET OF DWINNELL RESERVOIR TO DOWNSTREAM AT THE MOUTH OF THE SHASTA RIVER.

Reach	Reach Description	Site ID	River Mile	Equipment	Measurement
6	Dwinnell Reservoir Outlet to Parks Creek	105SRHVRPOD	39.1	TidbiTs®	Temperature
		105SRHVSPL	38.1	TidbiTs®	Temperature
		105SRHVRALC	37.9	TidbiTs®	Temperature
		105SRU1DO	37.9	D-Opto	DO/Temperature
		105SRHVDSSPG	37.8	TidbiTs®	Temperature
		105SRU0IT	37.7	TidbiTs®	Temperature
		105SR7163DS	36.9	TidbiTs®	Temperature
		105SRHIGF	36.6	TidbiTs®	Temperature
5	Parks Creek to Big Springs Creek	105SRP1DO*	SR 33.9; PC 0.04**	D-Opto	DO/Temperature
		105PCFPDO*	SR 33.9; PC 7.3**	D-Opto	DO/Temperature
		105PCAFPT*	SR 33.9; PC 9.3**	TidbiTs®	Temperature
		105PCBMDT*	SR 33.9; PC 10.9**	TidbiTs®	Temperature
		105PCB1DO*	SR 33.9; PC 11.7**	D-Opto	DO/Temperature
4	Big Springs Creek to Willow Creek	105SRV1DO	26.0	D-Opto	DO/Temperature
		105SRV4AT	25.2	TidbiTs®	Temperature
		105SRV4BT	24.3	TidbiTs®	Temperature
3	Willow Creek to Little Shasta River	105SRT1DO	23.0	D-Opto	DO/Temperature
		105SRS1DO	16.7	D-Opto	DO/Temperature
		105SRM1DO	14.6	D-Opto	DO/Temperature
		105SR400T	12.3	TidbiTs®	Temperature
		105SRA1DO	11.8	D-Opto	DO/Temperature
		105SRA01T	10.2	TidbiTs®	Temperature
1	Yreka Creek to Shasta River Mouth	105YCA01T*	SR 7.3; YC 0.6**	TidbiTs®	Temperature
		105SRTM01	5.3	TidbiTs®	Temperature
		105SRL1DO	0.6	D-Opto	DO/Temperature

* Site was located on tributary to Shasta River

** River miles are provided both for where the tributary meets the mainstem as well as tributary river mile for the monitoring site.

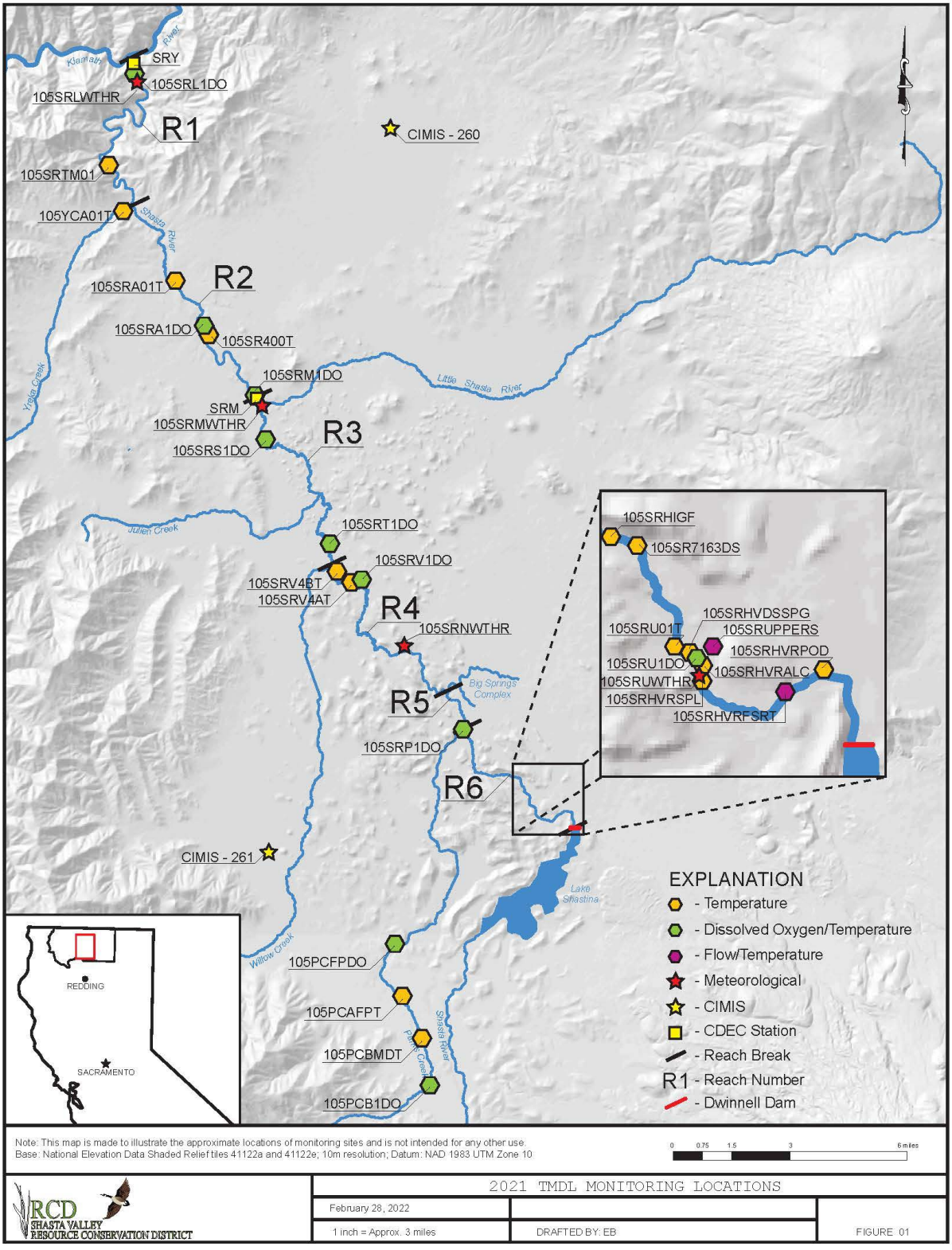

FIGURE 1. MAP OF 2021 TEMPERATURE, DO, FLOW, METEOROLOGICAL AND CDEC MONITORING LOCATIONS.

METHODS

Dissolved oxygen Sampling

Dissolved Oxygen (DO) and temperature were measured at ten sites (Table 1; Figure 1) with ZebraTech D-Opto Loggers, which use optical fluorescence sensing elements to measure DO in liquids. These DO loggers were housed in custom made canisters designed to suspend the logger above sediment in the benthic zone, and to maintain a stationary position in the river in high flow.

Where possible, DO loggers were placed in runs or pool tail-outs and within the thalweg or deepest part of the cross-section. D-opto loggers were downloaded, cleaned of bio-fouling and re-calibrated per manufacturer specifications every three weeks. Intervals of more than three weeks may have increased the risk of optical lens bio-fouling that may have caused the logger to record inaccurate measurements.

Temperature Sampling

Temperature loggers were deployed at 15 sites (Table 1; Figure 1) in sets of two (paired for quality control) and housed in custom made canisters to protect them from direct sunlight. Where possible, temperature loggers were placed in runs or pool tail-outs and within the thalweg or deepest part of the cross-section.

In 2021, temperatures were recorded at 15-minute intervals (D-Opto loggers and Onset® Tidbits®) at temperature monitoring locations as identified in Table 1 and on Figure 1. The 7-day average daily maximums (7-DAD Max) were calculated as the 7-day running average of daily maximum temperatures. Dates reported correspond with the middle date of this running average.

In addition to the 7-DAD Maximum temperature graphs are an analysis of the Maximum Weekly Average Temperatures (MWAT) and Maximum Weekly Maximum Temperatures (MWMT) for each site. The use of MWAT values was first proposed by the National Academy of Sciences (NAS) in 1972 as a long-term standard for preventing chronic sub-lethal effects for a variety of fish species. However, the MWAT is not calculated consistently by all researchers and agencies. The MWAT, as reported by Carter (2005), is the highest single value of the seven-day moving average temperature. Likewise, the MWMT is the highest seasonal or yearly value of the daily maximum temperatures over a running seven-day consecutive period. This methodology for calculating MWAT and MWMT was followed in this report and calculated for the entire irrigation season. Additionally, the absolute maximum is calculated as the highest daily maximum temperature for the entire irrigation season.

The objective of the MWAT index is to provide an upper temperature standard that is protective of juvenile salmonids during the summer rearing period. The MWAT is a common measure of chronic (i.e. sub-lethal) exposure, the absolute maximum is a measure of acute (i.e. lethal) exposure, and the MWMT is a common measure of both chronic and acute effects (Carter 2005). The MWMT describes the maximum temperatures in a stream, but the value is not overly influenced by the maximum temperature of a single day. Table 2 describes the MWMT for the Shasta River during various life stages of coho salmon (Carter 2005). Refer to Carter (2005) for additional information regarding temperature effects on various life stages of Chinook and steelhead salmonids.

TABLE 2. MWMT FOR DIFFERENT LIFE STAGES OF COHO SALMON (REPRODUCED FROM CARTER 2005).

Coho Life Cycle						
	Adult Migration	**Spawning**	**Egg Incubation**	**Fry Emergence**	**Juvenile Rearing**	**Juvenile Out-migration**
Coho Periodicity	Sept 15 – Jan 31	Nov 1 – Jan 31	Nov 1 – Mar 31	Feb 1 – Apr 15	Jan 1 – Dec 31	Feb 15 – July 15
MWMT Criterion (°C)	20	13	13	13	18	18

In addition to water temperature and dissolved oxygen sampling, meteorological and discharge data were collected and used to inform and evaluate water temperature and dissolved oxygen sampling. ambient air temperature, precipitation, and solar radiation data were retrieved from four field meteorological stations, located along the Shasta River between Dwinnell Reservoir and the Klamath River, to inform water temperature and DO results in this study.

RESULTS AND DISCUSSION

METEOROLOGICAL CONDITIONS

Meteorological data is measured at several locations throughout the Shasta River watershed. Regional snowpack and snow water content are measured annually as part of the Department of Water Resources Statewide Monitoring Network, which partners with more than 50 state, federal, and private agencies. The cooperating agencies take snow and water content measurements in January, February, and March. The USFS continues to collect monthly data for April and May. Results from each monthly survey at a given site are tabulated and form an average of a regions annual snowpack and water content, which gives forecasters and resource managers the ability to make important management decisions. These data are also compared against a running historical average for the site for the given month. Regional data are summarized annually by the US Forest Service Shasta-Trinity National Forest, and presented in Table 3. For the last several years, the region has received significantly less water in the upper watershed.

TABLE 3. REGIONAL SNOW DEPTH AND WATER CONTENT FOR THE MONTH OF APRIL OF 2021 AND 2020.

Course	Elevation (ft. asl)	2021 Snow (in)	2021 Water (in)	2020 Snow (in)	2020 Water (in)	Historic Avg Snow (in)	Historic Avg Water (in)
Horse Camp	7900	68.5	26.5	69.0	22.5	117.44	52.5
Sand Flat	6800	63.5	26.5	57.0	24.0	97.84	40.72
North Fork	6900	42.5	22.0	26.0	7.0	59.26	24.06
Grey Rocks	6200	73.0	52.5	57.0	21.5	104.33	45.71
Sweetwater	5850	44.5	10.5	13.5	5.0	37.11	13.53
Parks Creek	6700	66.5	25.5	37.0	14.0	86.57	34.49
Deadfall Lakes	7200	55.0	22.0	45.0	15.5	73.87	31.57
Average of Courses Sampled (in)		**59.1**	**26.5**	**43.5**	**15.6**	**82.3**	**34.7**
Percent of Historic Average		**72%**	**76%**	**53%**	**45%**		

Note: Sites within Shasta River watershed are highlighted in light blue

In 2019, the SVRCD utilized Prop 1 funds through the DWR Sustainable Groundwater Planning (SGWP) grant program to implement two Hydrologic Data Acquisition System (HyDAS) stations in the upper Shasta River watershed. The stations are located on the north flank of Mt. Shasta, and the Goosenest. These stations provide snow depth and snow water content in real time. However, as of yet these stations do not have established snow courses and their small sample size prevents a comparison to an historical site average.

The SVRCD also utilized SGWP funds in 2019 to implement two California Irrigation Management Information System (CIMIS) stations. CIMIS stations collect and utilize meteorological data to provide accurate estimates of Evapotranspiration (ET) for a reference crop like alfalfa or grass. Through 2021, the SVRCD staff maintained the CIMIS station on a monthly basis. In addition to cooperating the CIMIS stations, the SVRCD cooperated and maintained four meteorological stations donated by the North Coast Regional Water Quality Control Board (NCRWQCB). These stations are located within the riparian corridor of the Shasta River between Dwinnell Reservoir and the confluence with the Klamath River. These four stations are not used to estimate ET, and are primarily used to record accurate air temperature and precipitation measurements adjacent to the Shasta River. Where available, annual precipitation and ET totals from the CIMIS stations, and precipitation totals from the NCRWQCB meteorological stations are presented for 2021 and the 2021 irrigation season in Table 4.

TABLE 4 . METEOROLOGICAL TOTALS FOR SVRCD COOPERATED CIMIS AND WEATHER STATIONS.

Station ID	Station Name or Reach	Elevation (ft. asl)*	2021 Total Precip (in)	2021 Total ET (in)	4/1/21 - 9/30/21 Total Precip (in)	4/1/21 - 9/30/21 Total ET (in)
105SRLWTHR	Reach 1	2050	n/a	n/a	1.88	n/a
260	Montague	2265	8.45	54.64	1.59	43.60
105SRMWTHR	Reach 2	2465	8.08	n/a	1.51	n/a
105SRNWTHR	Reach 4	2555	n/a	n/a	1.77	n/a
105SRUWTHR	Reach 6	2665	n/a	n/a	1.15	n/a
261	Gazelle	2745	7.40	51.91	1.33	40.38

*WGS-84 Datum

Note: CIMIS Stations are highlighted in light blue

Ambient air temperatures recorded at the CIMIS and NCRWQCB meteorological stations were examined to assist with analysis of seasonal and inter-annual river temperature and dissolved oxygen trends. As air temperatures increase into the summer, water temperatures in the Shasta River generally increase while dissolved oxygen levels decrease. An exception to this trend is in the upper Shasta River and Big Springs Creek where extensive macrophyte growth during mid and late summer minimizes increases in water temperature (Jeffres et al. 2009), although it is not clear if this exception is dependent on a normal water year. Additionally, tailwater returns to the river via overland flows are greatly affected by air and ground surface temperatures, and can subsequently have an impact on instream temperature and dissolved oxygen demands.

Temperature, rainfall, and solar radiation data from site 105SRMWTHR is shown in Figure 2. Site 105SRMWTHR is centrally located within the Shasta River watershed (see Figure 1). Meteorological data display warm-dry weather during the summer season and cooler temperatures and increased precipitation during the winter months, typical of a Mediterranean climate. Incursions in the maximum daily solar radiation occur during the winter months when cloud cover is heavy and prevalent. During the summer months the peaks in the maximum daily solar radiation are coincident with decreases in daily maximum air temperatures. Precipitation data values for each day have been summed and multiplied by 100 for graphical purposes. Precipitation events at this site coincide with reductions in maximum daily air temperature and relative peaks in daily solar radiation values. The Lava Fire started as a result of a lightning strike on June 24, 2021 and ultimately burned 26,409 acres within the Shasta River watershed. For approximately six consecutive weeks beginning July 18, 2021, maximum daily air temperatures at the site approached 40°C. Maximum daily air temperature and solar radiation data decreased dramatically on July 27, 2021, despite very little precipitation registering at site 105SRMWTHR. However, on that same day in the southern extent of the watershed an intense precipitation event occurred on Mt. Shasta. The intense rain, in conjunction with weeks of high temperatures and the recently burned vegetation on the north side of Mt. Shasta, led to a flash flood event in Whitney Creek that delayed traffic, caused evacuation warnings over the course of the following week, and left large deposits of sediment in and around the channel.

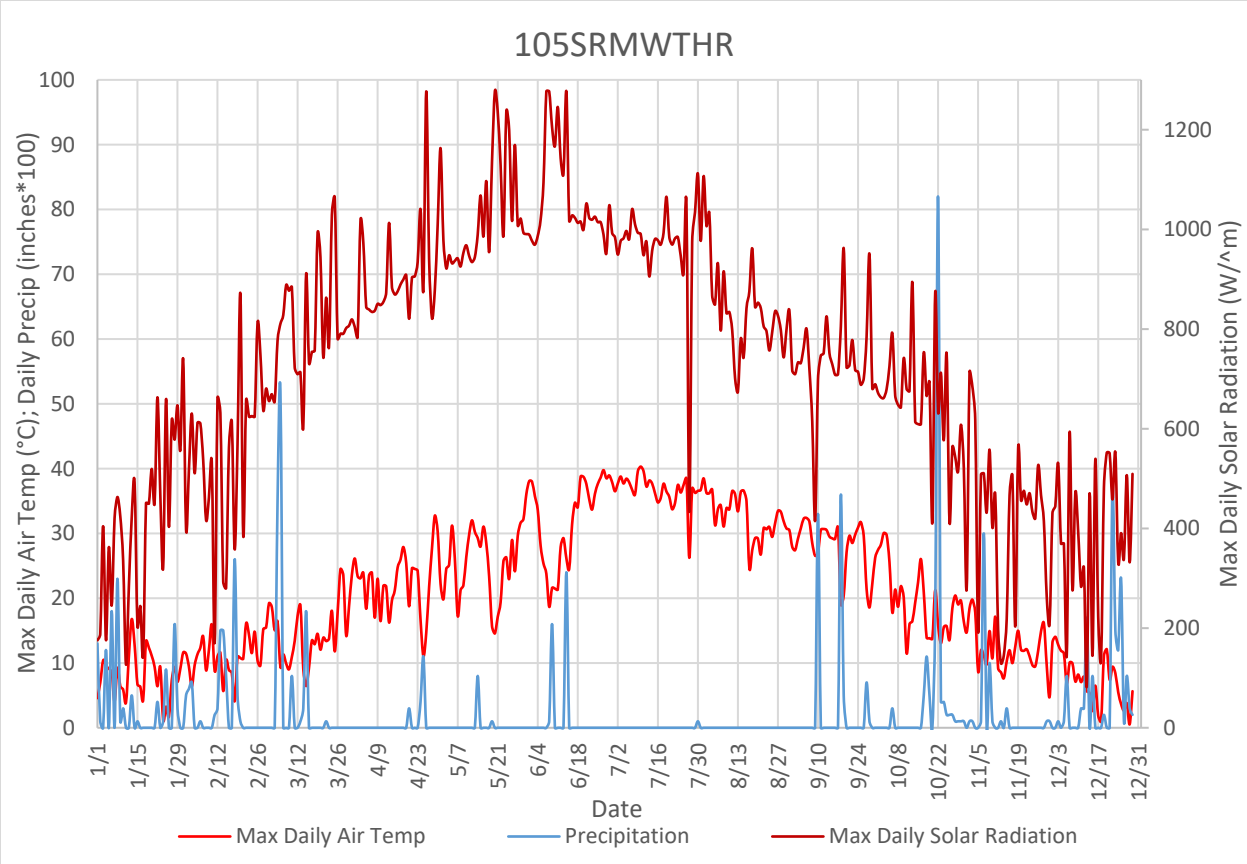

FIGURE 2. MAX DAILY AIR TEMPERATURE, DAILY TOTAL PRECIPITATION * 100, MAX DAILY SOLAR RADIATION FROM SITE 105SRMWTHR, 2021.

SHASTA RIVER FLOW

Publicly available flow data recorded at fifteen-minute intervals at US Geologic Survey rated stream gauge sites near the cities of Montague and Yreka (see Figure 1) is shown in Figure 3 and displays discharge of the Shasta River in cubic feet per second. Due to persistent drought conditions within the region, on May 10, 2021 California Governor Gavin Newsome declared a drought emergency for 41 counties, including Siskiyou County. Despite voluntary reductions in water use by stakeholders within the Shasta Valley, on August 17, 2021 the State Water Board adopted an emergency regulation which became effective on August 30, 2021. This emergency legislation establishes emergency drought minimum flows in the Shasta River watershed as measured at the Shasta River gauge near Yreka. The corresponding monthly emergency flow volume is shown in Figure 3 as a red line, and given in Table 5. In order to meet the emergency drought minimum flow volumes set forth in the legislation, certain water rights are being curtailed by the State Water Board.

TABLE 5. SHASTA RIVER EMERGENCY DROUGHT MINIMUM MONTHLY FLOW REQUIREMENTS.

Shasta River Emergency Drought Minimum Flow Requirements											
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
135	135	135	70	50	50	50	50	50	125	150	150

Note: Values are in cubic feet per second and measured at the Shasta River Gauge near Yreka.

Between the months of October through March, the SRY gauge consistently records greater discharge than the SRM gauge. Between the months of April through September, the SRM gauge consistently reports higher flows than the SRY gauge. Though summers are warm and dry, significant reductions in flow volumes at both SRM and SRY gauges occurs on April 1 coinciding with the onset irrigation season and surface water diversion. Flow volumes increase significantly on October 1, coinciding with the end of irrigation season and the return of cooler days and increased precipitation. In a coordinated effort between water users in late-May, flows reached nearly 50 cfs for between twenty-four and forty-eight hours. Flow volumes both in and outside of irrigation season are markedly lower than in previous years. According to USGS data, flows at SRY reached an annual low of 4.51 cfs on July 6, 2021, and an annual high of 210 cfs on December 23, 2021. Total discharge measured at the Shasta River gauges near Montague and Yreka is presented in Table 6.

TABLE 6. 2021 SHASTA RIVER ANNUAL DISCHARGE AND IRRIGATION SEASON DISCHARGE TOTALS.

Gauge Location	Total Discharge 1/1/21 – 12/31/21	Total Discharge 4/1/21 – 9/30/21	Total Emergency Minimum Discharge 1/1/21 – 12/31/21	Total Emergency Minimum Discharge 4/1/21 – 9/30/21
Montague	60,368 af	11,544 af	n/a	10,910 af*
Yreka	63,917 af	10,864 af	68,282 af	19,342 af

*Total discharge at Montague if 20 cfs is achieved all irrigation season.

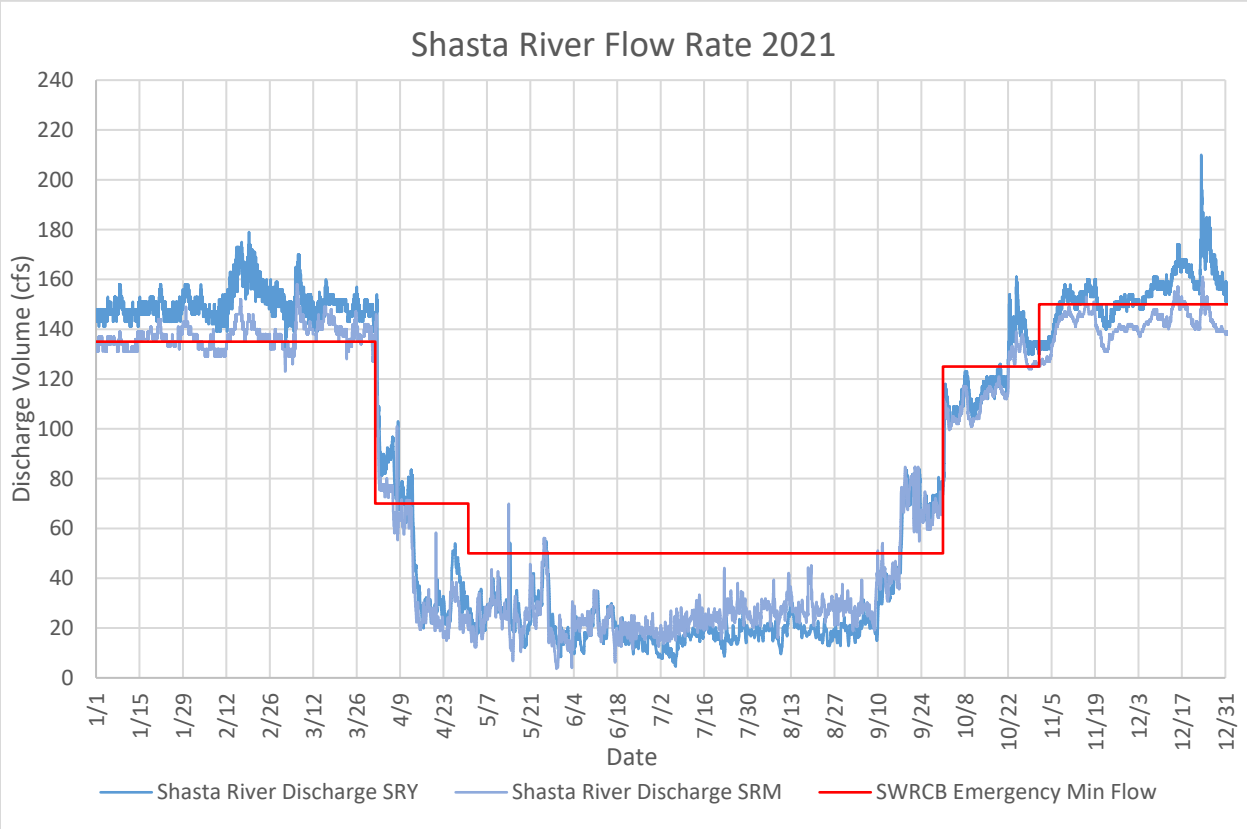

FIGURE 3. CONTINUOUS SHASTA RIVER DISCHARGE FOR 2021 MEASURED AT SRM AND SRY GAUGES WITH STATE WATER RESOURCES CONTROL BOARD MINIMUM INSTREAM FLOW CRITERIA.

TEMPERATURE RESULTS

Temperature was measured at 25 sites on the Shasta River and its tributaries in 2021. Temperatures in the Shasta River and its tributaries fluctuate daily and are moderate in comparison to air temperatures due to the high specific heat capacity of water.

Table 7 summarizes 2021 MWMT, MWAT, Absolute Maximum temperatures recorded over the course of the period monitored at each site in the Shasta River, Parks Creek, and Yreka Creek. A percentage has been calculated for each site corresponding to the number of days where the site exceeded the TMDL threshold of 18°C. The general trend of 7-DAD Max temperatures among all sites measured is a continuous rise that appears to correlate with seasonal warming, and late season decreases that correlate with cooling temperatures and decreased solar radiation from regional wild fires and/or increased instream vegetation. All sites saw a peak in 7-DAD Max temperatures during the month of July, before the onset of the smoke.

TABLE 7. 2021 SHASTA RIVER MWMT, MWAT, ABSOLUTE MAX TEMPERATURE, AND PERCENTAGE OF DAYS WHERE THEY DAILY MAXIMUM TEMPERATURE EXCEEDED THE TMDL LIMIT OF 18°C. ALL REACH 5 SITES ARE LOCATED PARKS CREEK. SITE ID 105YCA01T IN REACH 1 IS LOCATED ON YREKA CREEK.

Site ID	Reach	MWMT (°C)	MWAT (°C)	Abs. Max Temp (°C)	% Days Exceeded TMDL
105SRHVRPOD*	6	21.83	20.10	22.82	48
105SRHVRSPL*	6	24.63	20.87	25.02	85
105SRHVRALC*	6	17.07	14.84	18.46	0
105SRU1DO	6	24.62	20.73	25.06	79
105SRDSSPG*	6	24.82	20.98	25.33	88
105SRU0IT*	6	24.53	21.13	25.38	82
105SR7163DS*	6	25.22	22.08	26.38	91
105SRHIGF*	6	25.21	22.25	26.33	89
105PCB1DO	5	23.44	21.41	23.72	68
105PCBMDT*	5	23.46	18.66	23.91	58
105PCAFPT*	5	29.90	23.48	30.95	74
105PCFPDO	5	29.48	23.63	30.65	81
105SRP1DO	5	29.48	23.63	30.65	84
105SRV1DO	4	21.25	20.52	21.72	45
105SRV4AT*	4	22.12	20.88	22.51	56
105SRV4BT*	4	22.87	21.17	23.21	58
105SRT1DO	3	24.26	21.57	24.89	59
105SRS1DO	3	25.00	23.26	25.24	69
105SRM1DO	2	27.25	24.29	27.68	70
105SR400T*	2	27.91	25.34	28.17	86
105SRA1DO	2	27.51	25.43	28.08	79
105SRA01T*	2	29.94	25.82	31.36	87
105YCA01T*	1	22.46	20.86	22.68	52
105SRTM01*	1	29.00	25.85	29.41	83
105SRL1DO	1	30.22	26.53	30.52	75

* Due to an equipment malfunction temperature only sites stopped recording data from September 7, 2021 until equipment was removed.

REACH 1

Figure 4 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Max water temperatures at a site within the tributary Yreka Creek (105YCA01T) and sites downstream of the confluence of Yreka Creek within Shasta River Reach 1. 7-DAD Maximum temperatures at Yreka Creek are consistently cooler than all other sites within Reach 1 throughout the monitored period. The temperature gap between Yreka Creek and the Shasta River in Reach 1 widens substantially from mid-June through mid-August when Reach 1 7-DAD Maximum temperatures reach their maximums. Despite the cool water input from Yreka Creek, its flows are minimal, ranging from 1-4 cfs during the summer. 7-DAD Maximum temperatures throughout Reach 1 are generally consistent with each other, increasing only slightly in the downstream direction.

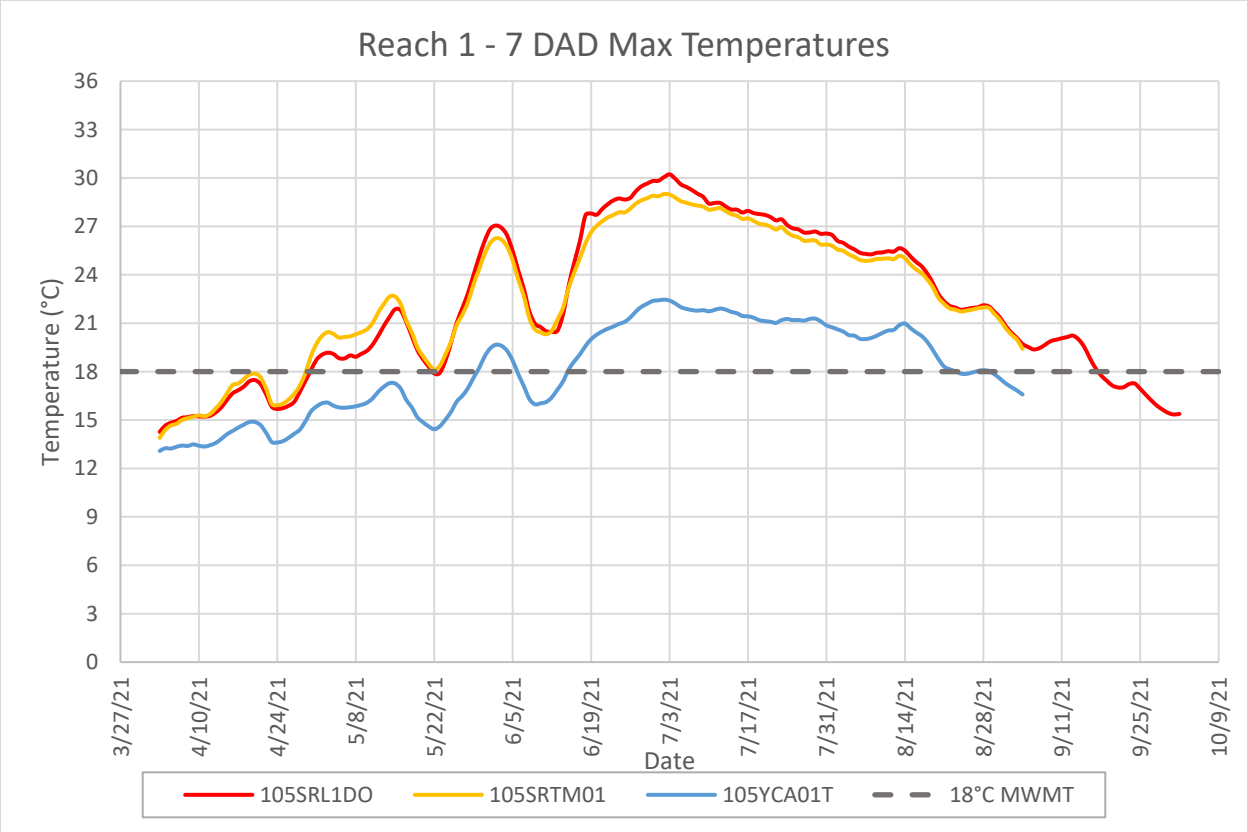

FIGURE 4. 2021 7-DAD MAXIMUM TEMPERATURES AT REACH 1 (SHASTA RIVER AND YREKA CREEK SITES).

REACH 2

Figure 5 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 2. These sites are located downstream of the USGS operated weir near Montague. 7-DAD Maximum temperatures at all sites within Reach 2 are generally consistent with one another with 7-DAD Maximum temperatures increasing in the downstream direction. Due to an instream construction project near 105SRM1DO, the corresponding 7-DAD Maximum temperature data were removed. Data indicate a cooling trend in July and August that can be partially attributed to the presence of heavy smoke from regional wildfires that led to reduced solar radiation.

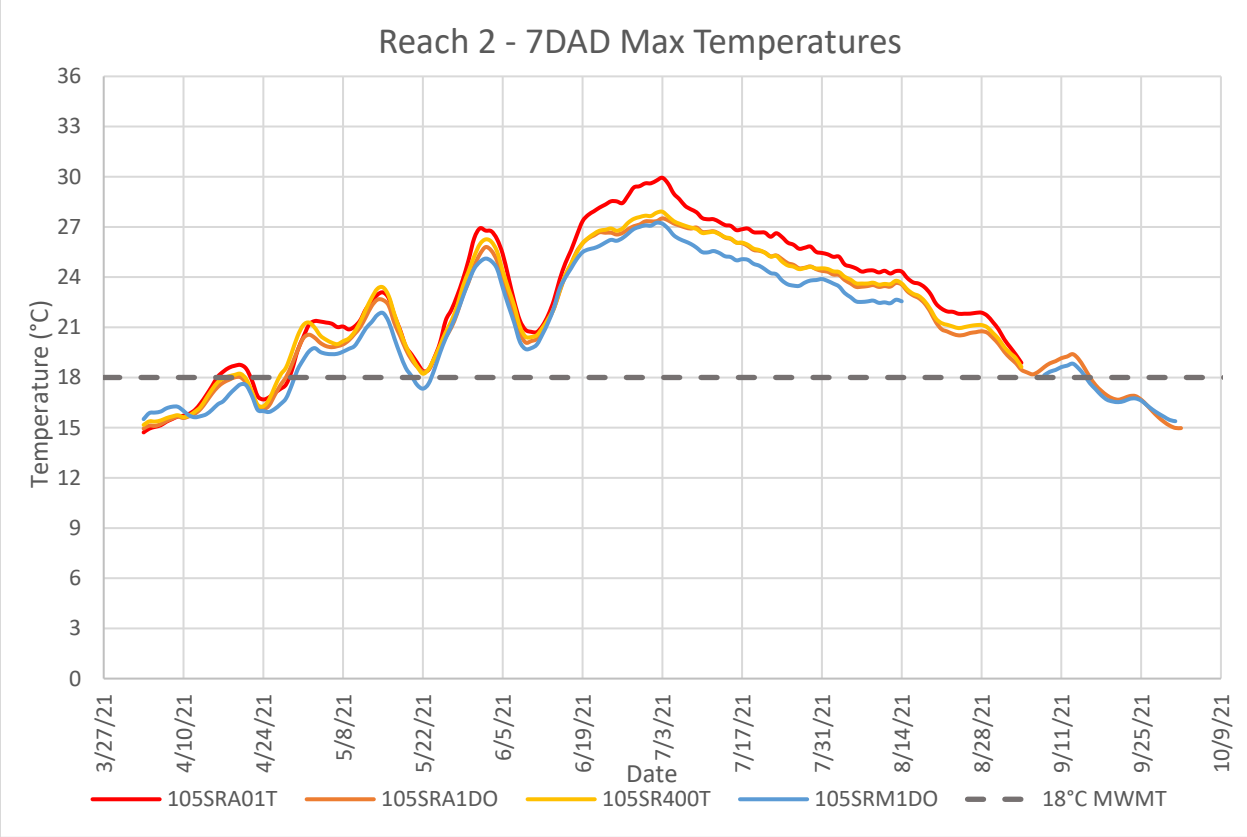

FIGURE 5. 2021 7-DAD MAXIMUM TEMPERATURES FOR REACH 2, SHASTA RIVER.

REACH 3

Figure 6 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 3. Equipment at 105SRT1DO was vandalized at the beginning of the season and the corresponding 7-DAD Maximum temperature data was removed. 7-DAD Maximum temperatures increased in the downstream direction slightly through all sites in this reach.

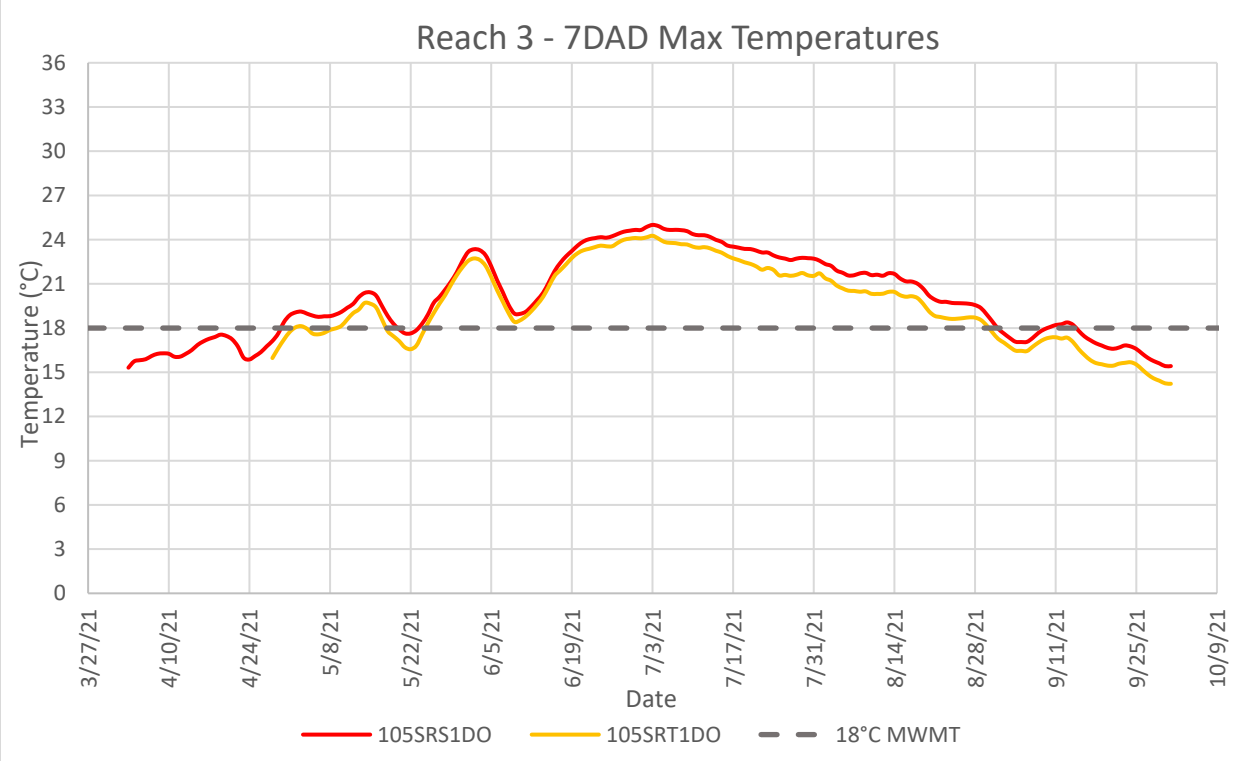

FIGURE 6. 2021 7-DAD MAX TEMPERATURES FOR SHASTA RIVER, REACH 3.

REACH 4

Figure 7 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 4. These sites are located downstream of the Big Springs Creek confluence, which adds a large volume (52 cfs average during July and August) of cold water to the Shasta River (Nichols et al. 2010). Consequently, 7-DAD Maximum water temperatures within this reach are consistently cooler throughout irrigation season than in all other reaches within the Shasta River. Because temperature data cannot be collected at every site in a single day, the malfunction impacting temperature sites effected two sites within this reach beginning on August 14, and percentage of days in exceedance are slightly inflated. It is therefore likely that 7-DAD Maximum temperatures at all sites within this reach exceeded 18°C for 45% of the days occupied. Due to budget constraints, the long-term DO monitoring site 105SRN1DO was not measured in 2021. 7-DAD Maximum temperatures increased in the downstream direction in this reach.

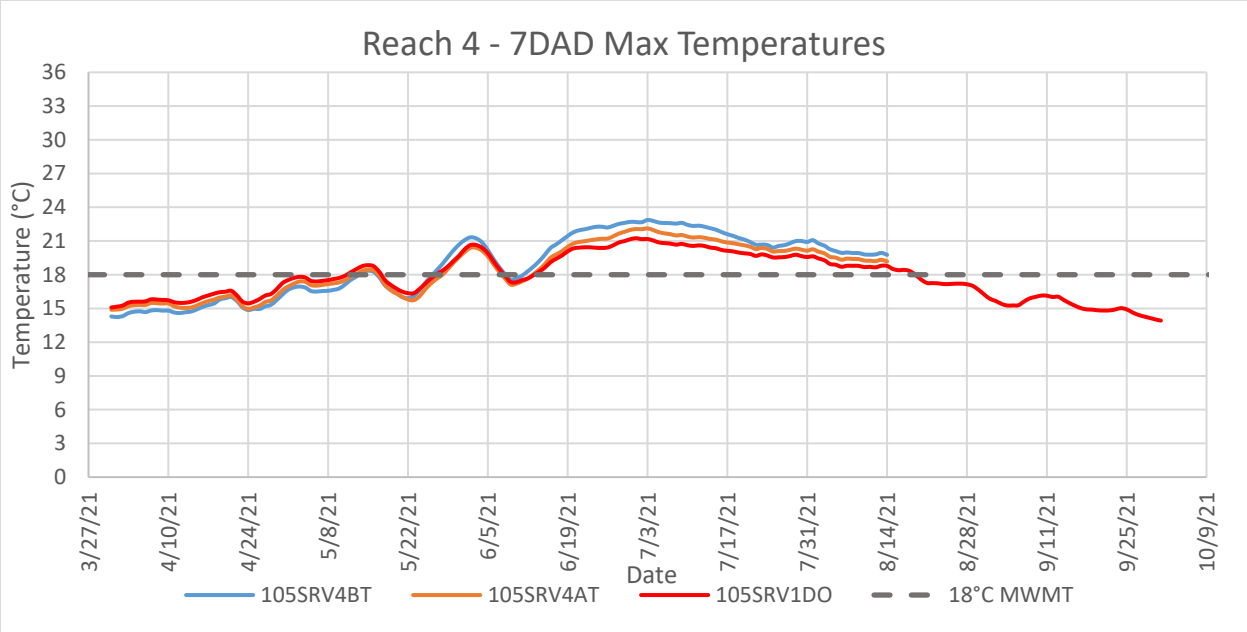

FIGURE 7. 2021 7-DAD MAX TEMPERATURES FOR SHASTA RIVER, REACH 4.

REACH 5

Figure 8 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 5. The Shasta River is supplemented by flows from Parks Creek, and Hole in the Ground Creek in Reach 5. All sites within this reach are located on Parks Creek. Due to budget constraints, the long-term DO site 105SRP1DO was only monitored for a portion of the latter part of the season. This site also experienced an equipment malfunction on September 2, and no data was collected after that time. Additionally, due to an instream construction project adjacent to site 105PCFPDO the equipment was pulled from the water and no data was recorded between June 22 and July 15, 2021. Coho salmon utilize Parks Creek for migration, spawning and juvenile rearing (Chesney et al. 2009). Recent projects on Parks Creek, including the SVRCD's completion of the Parks Creek Fish Passage Project at the Intersetate-5 bridge, are expected to improve water quality, habitat, and the mobility of aquatic species. Monitoring sites on Parks Creek span nearly twelve river-miles. 7-DAD Maximum temperatures demonstrate a downstream warming trend in the upstream end of this reach. 105SRP1DO is about 3°C cooler. This can be partially attributed to several groundwater inputs to Parks Creek between 105SRP1DO and 105PCFPDO. This can also be partially attributed to recent in stream work.

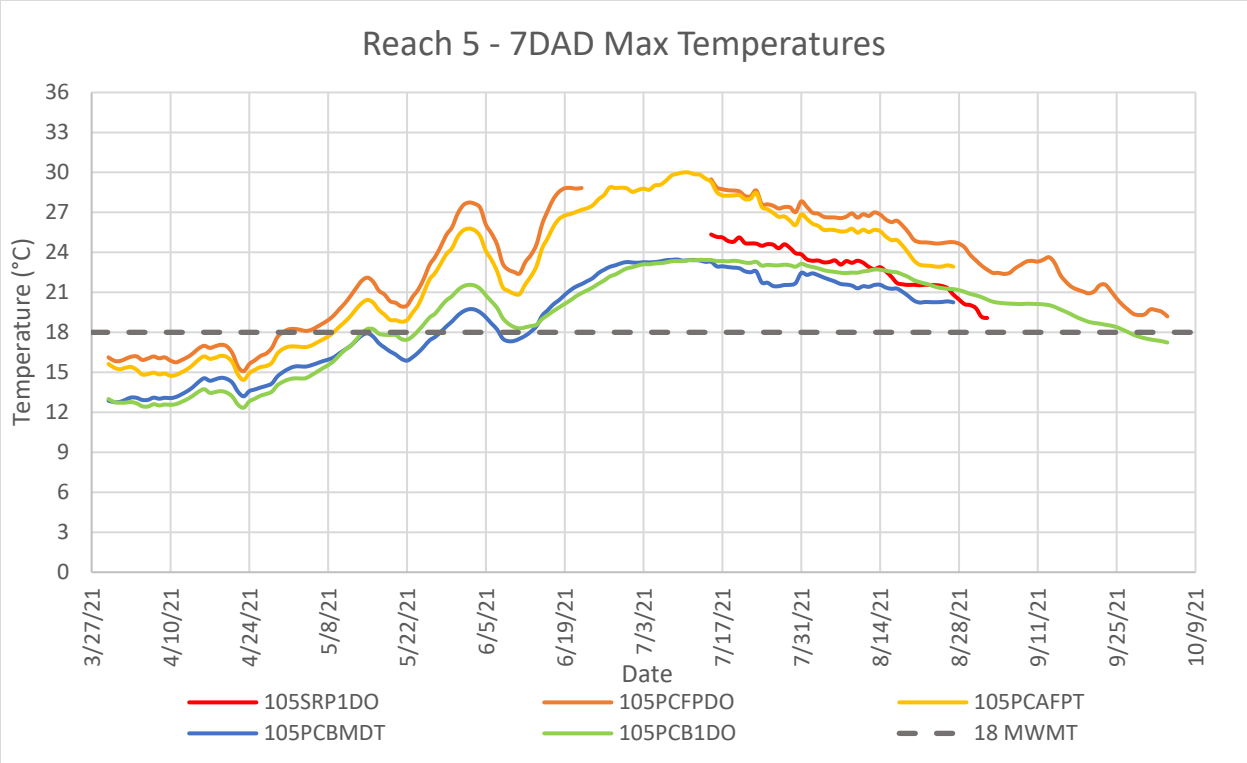

FIGURE 8. 2021 7-DAD MAX TEMPERATURES AT PARKS CREEK REACH 5. ALL SITES ARE ON PARKS CREEK, TRIBUTARY OF SHASTA RIVER.

REACH 6

Figure 9 displays MWMT criterion for juvenile coho salmon rearing and 7-DAD Maximum water temperatures at sites within Shasta River Reach 6. This reach experienced a significant reduction in natural cold-water inputs as a result of drought conditions. A recent instream project adjacent to 105SRHVPOD removed a small impoundment and improved water quality, habitat, and channel function. Prior to construction which began on June 22, the equipment was often submerged in soft sediment which attenuated temperature fluctuations. While the temperature increased after construction began, it is likely the post construction data is more accurate and tracks more closely with the other sites within the reach. Temperatures at most sites exceeded the Shasta River TMDL 18 °C by mid-April and consistently remained above the TMDL from the end of April until early-September. 7-DAD Maximum temperatures generally increased in the downstream direction in this reach, with the exception of 105SRHVRALC which is located adjacent to a cold spring and likely records subsurface cold-water inputs to the Shasta River.

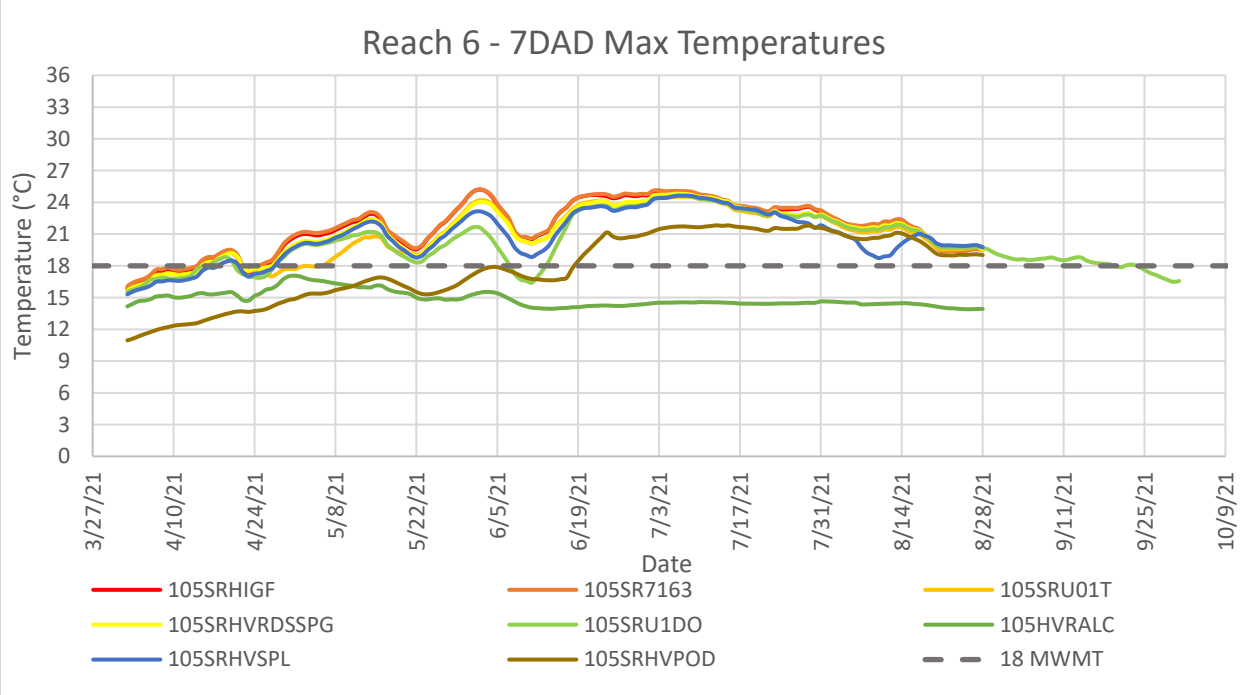

FIGURE 9. 2021 7-DAD MAX TEMPERATURES AT MONITORING LOCATIONS IN THE SHASTA RIVER AT REACH 6.

DISSOLVED OXYGEN RESULTS

Dissolved oxygen (DO) levels in surface waters are not constant, but change throughout the day as oxygen is added (by photosynthesis and reaeration) and removed (by carbonaceous and nitrogenous deoxygenation, sediment oxygen demand, and respiration) from the water. Salmonids such as coho and Chinook salmon are particularly sensitive to low DO concentrations as DO regulates metabolic activity in these and many fish species (Fry 1971). The 2015 North Coast Water Quality Control Plan states that the minimum dissolved oxygen concentration in the Shasta River should not fall below 6 mg/L.

Diurnal DO fluctuations were recorded at nine monitoring sites on the Shasta River and its tributaries. Lowest DO concentrations were between 23:00 and 7:00 when respiration occurs without photosynthesis, while the highest concentrations of DO were between 12:00 and 15:00 when peak photosynthesis occurs.

Figure 8 and Figure 9 display 2021 daily minimum dissolved oxygen measurements at all sites on the Shasta River and Parks Creek, respectively. The general trend among all Shasta River sites measured was a continuous reduction in the daily minimum DO from early April through late July due to seasonal warming and reduced flow volumes and velocities. The general trend among all Parks Creek sites measured was slight increase in daily minimum DO from the beginning of the period of record through the end of April. The slight increase is likely from increased flows from spring runoff, and is followed by a steep reduction in the daily minimum DO level from the end of April through late July and August due to seasonal warming and reduced flow volumes and velocities, General trends for all Shasta River and Parks Creek sites are characterized by increasing DO levels from late July and August through early October due to cooling temperatures, decreased solar radiation from regional wild fires and increased production of instream vegetation (e.g., macrophytes).

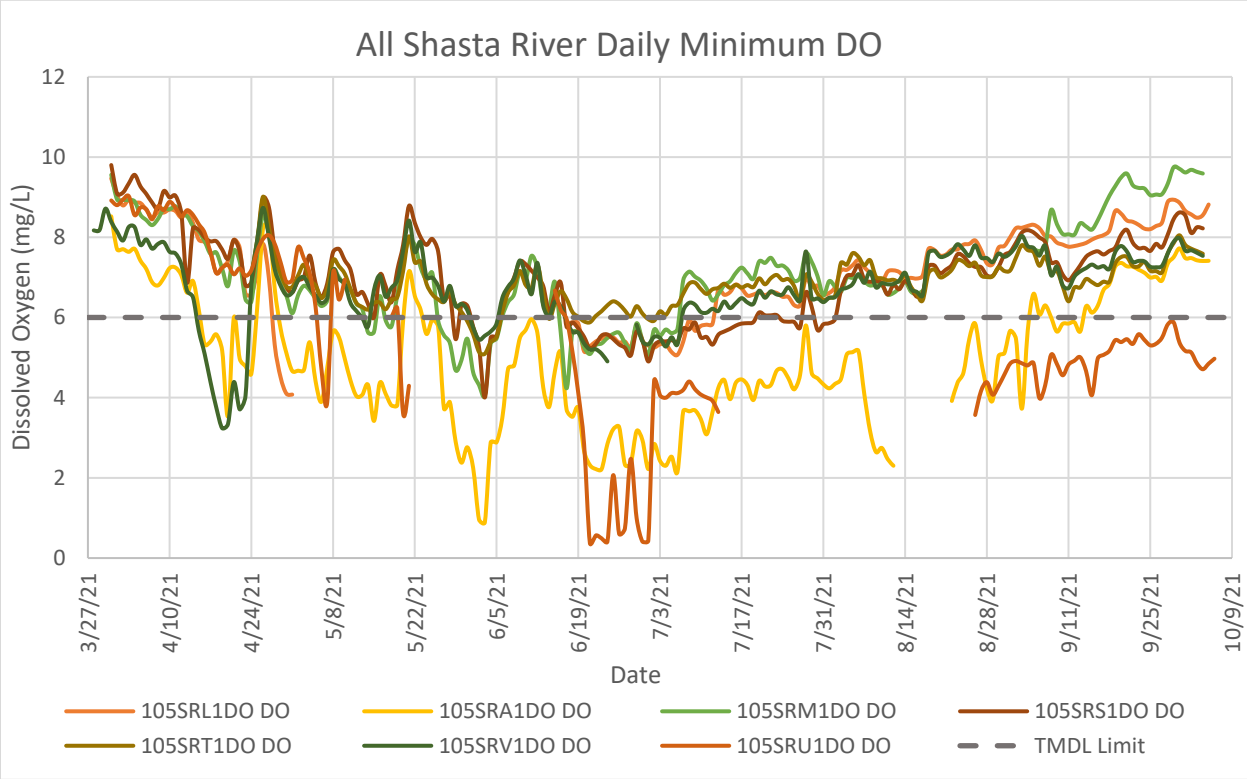

FIGURE 10. 2021 DAILY MINIMUM DO AT ALL SHASTA RIVER SITES.

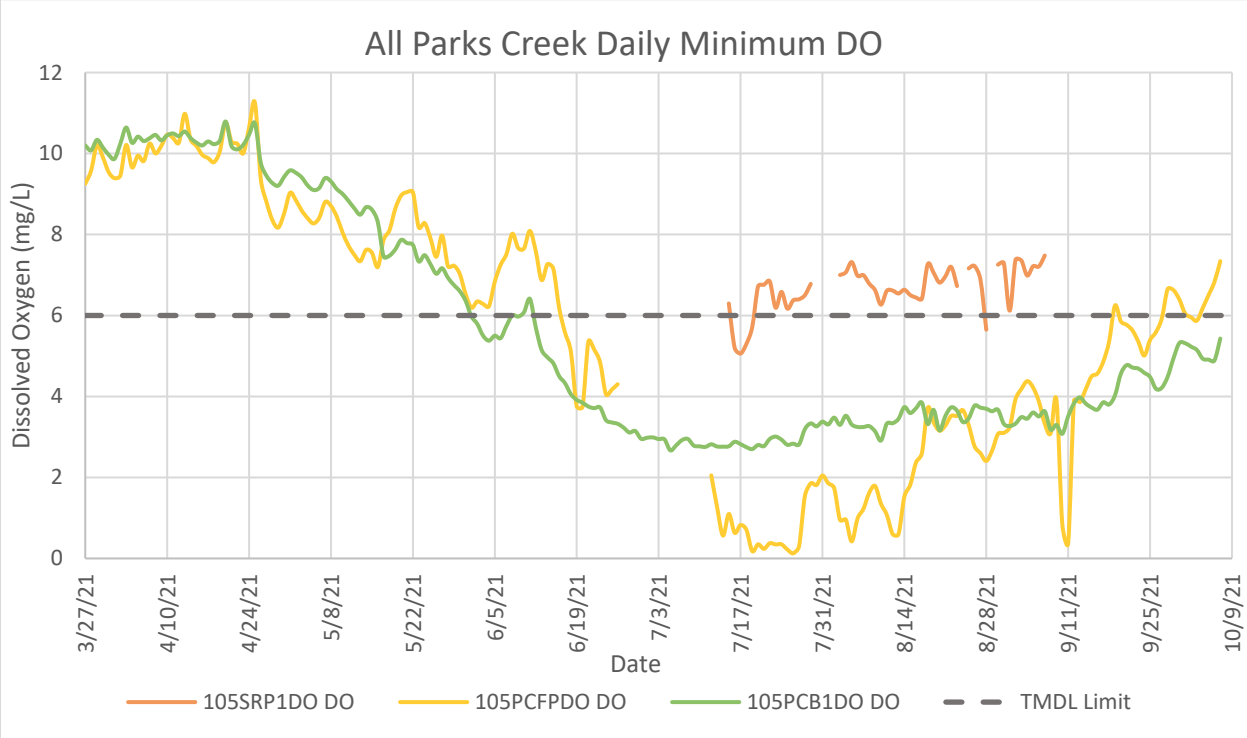

FIGURE 11. 2021 DAILY MINIMUM DO AT ALL PARKS CREEK SITES.

Table 4 displays the percentage of days that each site fell below the TMDL (6 mg/L) during the 2021 irrigation season. Upstream sites on the Shasta River (105SRU1DO) and Parks Creek (105PCB1DO) experienced a high percentage of days below the TMDL. Middle River site (105SRA1DO) also experienced a significant percentage of days below the TMDL. Persistent drivers of dissolved oxygen demand within the Shasta River Watershed are all exacerbated by drought conditions.

TABLE 8. PERCENTAGE OF DAYS MONITORED WHERE DO LEVELS FELL BELOW THE TMDL OF 6 MG/L.

Reach	DO Monitoring Site	Percentage of Days DO Fell Below TMDL Limit*	Days Site Occupied	Days of Quality Data
1	105SRL1DO	21.1	188	142
2	105SRA1DO	72.3	189	180
	105SRM1DO	21.2	188	170
3	105SRS1DO	25.0	188	188
	105SRT1DO	6.7	191	164
4	105SRV1DO	17.1	191	187
5	105SRP1DO**	10.2	82	49
	105PCFPDO†	49.4	195	180
	105PCB1DO	64.6	195	195
6	105SRU1DO	63.8	190	116

*Percentage of days where TMDL was exceeded is based on number of days where quality data was collected, not based on total number of days monitored.

**105SRP1DO was occupied between July 15, 2021 through October 4, 2021. Equipment malfunction prevented data collection from September 7, 2021 until October 4, 2021.

†105PCFPDO was removed from the water between June 26, 2021 through July 11, 2021.

Reach 1

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRL1DO is shown in Figure 10. DO and temperature equipment were deployed for 186 days, between March 31 and October 4, 2021. The Missing DO data between May 2 through June 14, 2021 is caused by a DO sensor malfunction. The sensor was pulled on June 14, and replaced with a functioning sensor on June 17, 2021. DO levels fell below the TMDL criterion of 6 mg/L in 30 of the 142 days for which quality DO data was recorded.

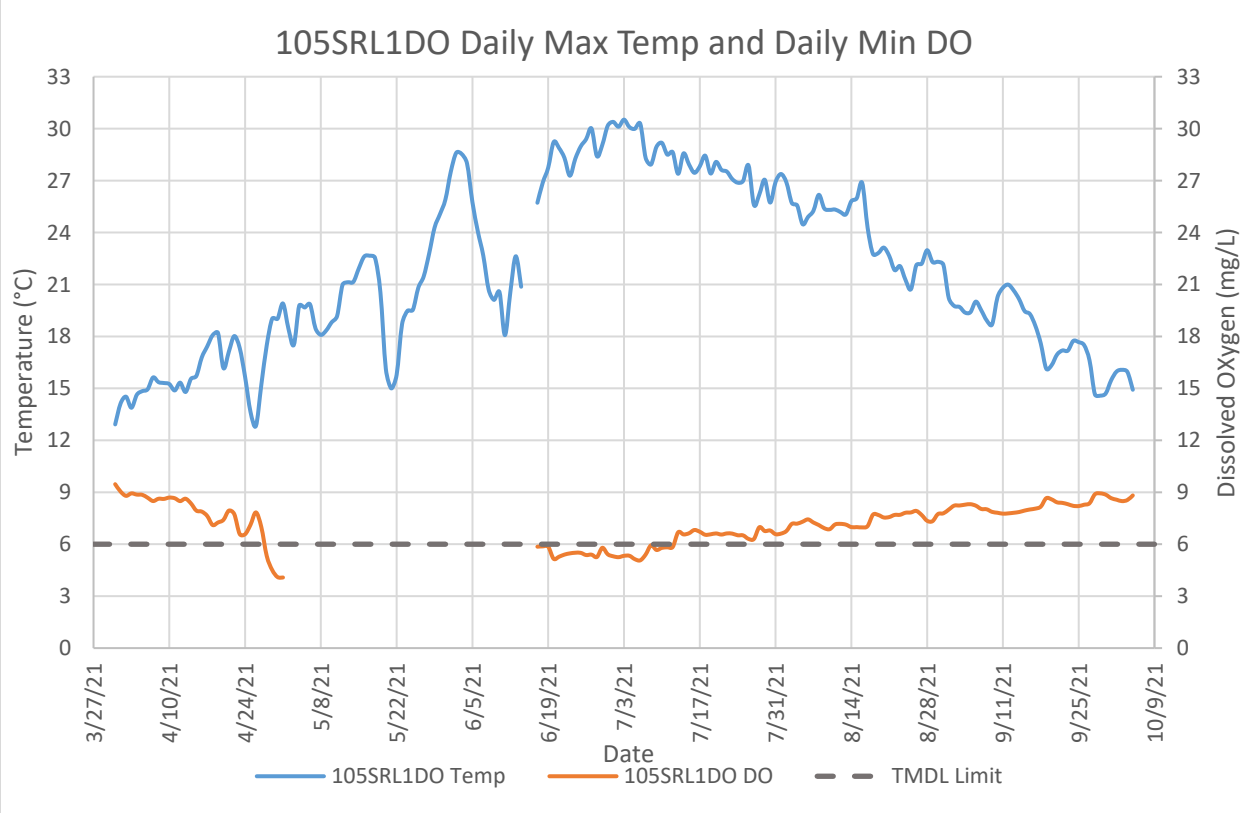

Figure 12. 2021 daily maximum temperature, daily minimum DO, and TMDL DO criterion at 105SRL1DO, Shasta River.

Reach 2

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRA1DO is shown in Figure 11. DO and temperature equipment were deployed for 189 days, between March 31 and October 5, 2021. The DO data was obscured from biofouling from August 13 through August 21 and has been removed. DO fell below the TMDL criterion of 6 mg/L in 131 of the 180 for which quality DO data was recorded.

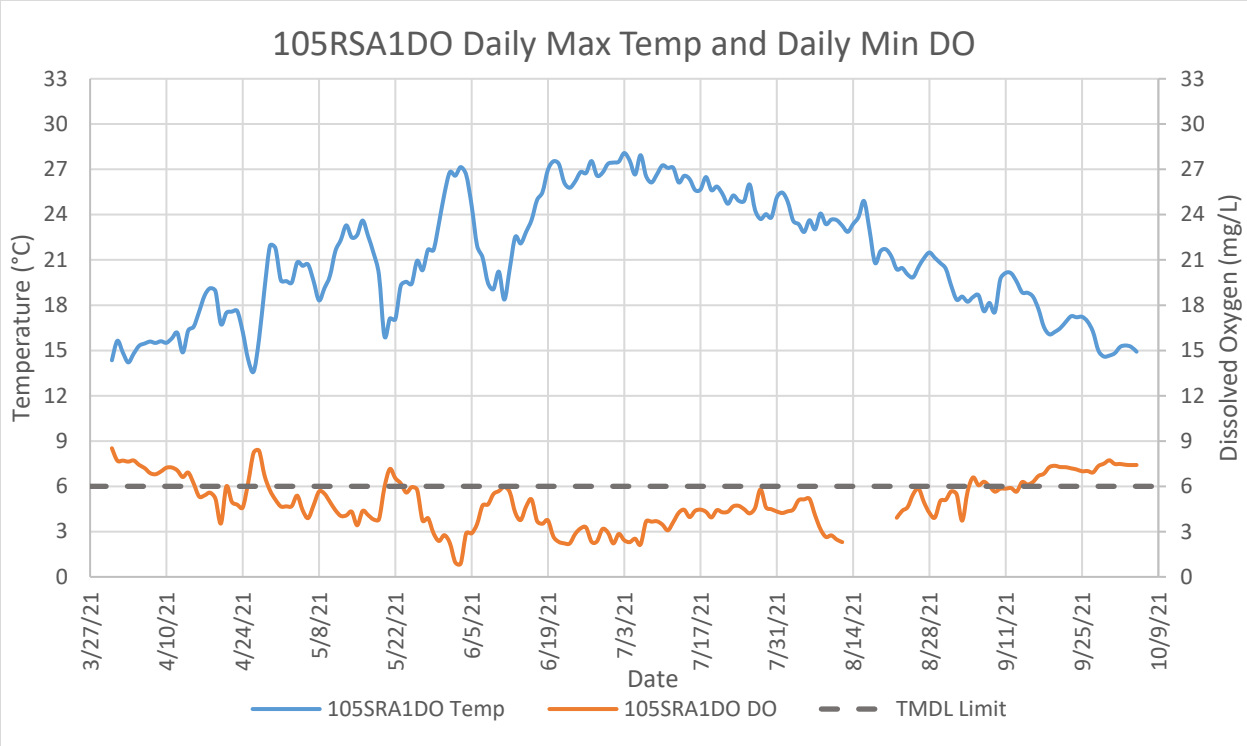

FIGURE 13. 2021 DAILY MAXIMUM TEMPERATURE, DAILY MINIMUM DO, AND TMDL DO CRITERION AT 105SRA1DO, SHASTA RIVER.

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRM1DO is shown in Figure 12. DO and temperature equipment were deployed for 188 days between March 31 and October 4, 2021. Between August 18 and September 4, 2021, an instream construction project adjacent to the monitoring site was implemented. During the time of construction, the DO and temperature equipment was removed from the stream and no data was collected. DO fell below the TMDL criterion of 6mg/L in 36 of the 170 days for which quality DO data was recorded.

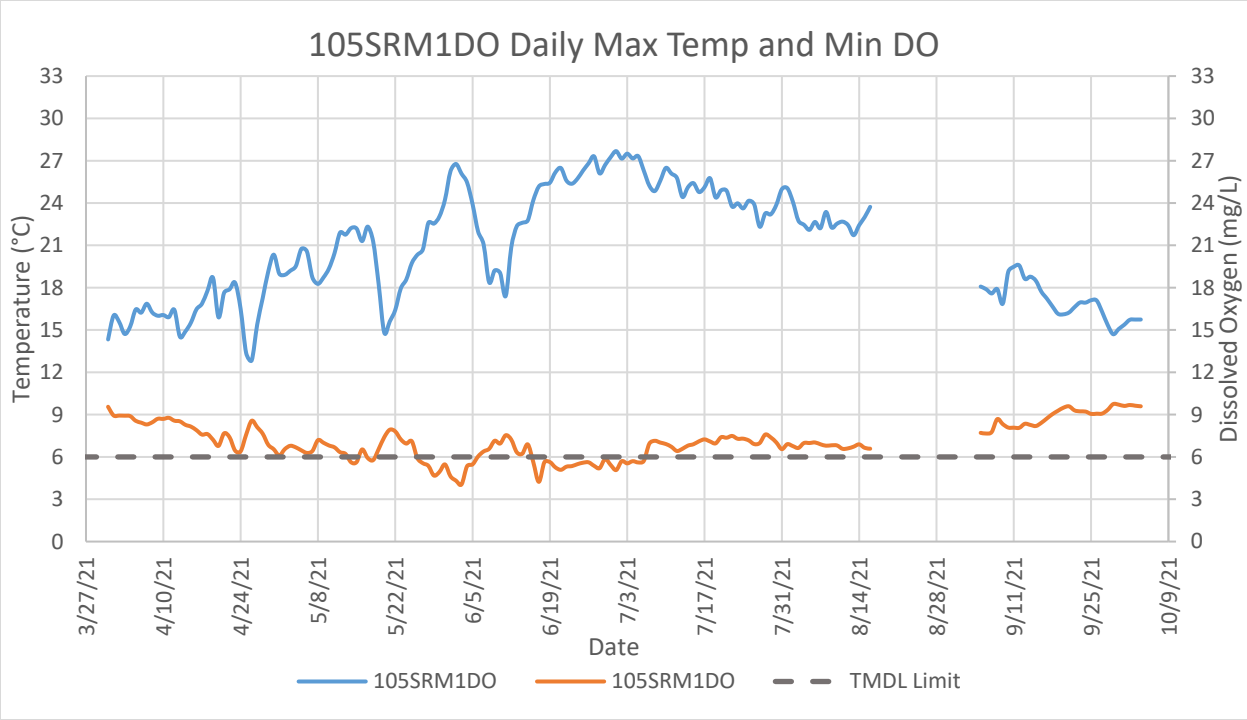

FIGURE 14. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRM1DO, SHASTA RIVER.

REACH 3

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRS1DO is shown in Figure 13. DO and temperature equipment were deployed for 188 days between March 31 and October 4, 2021. DO fell below the TMDL criterion of 6 mg/L in 47 of the 188 days for which quality DO data was recorded.

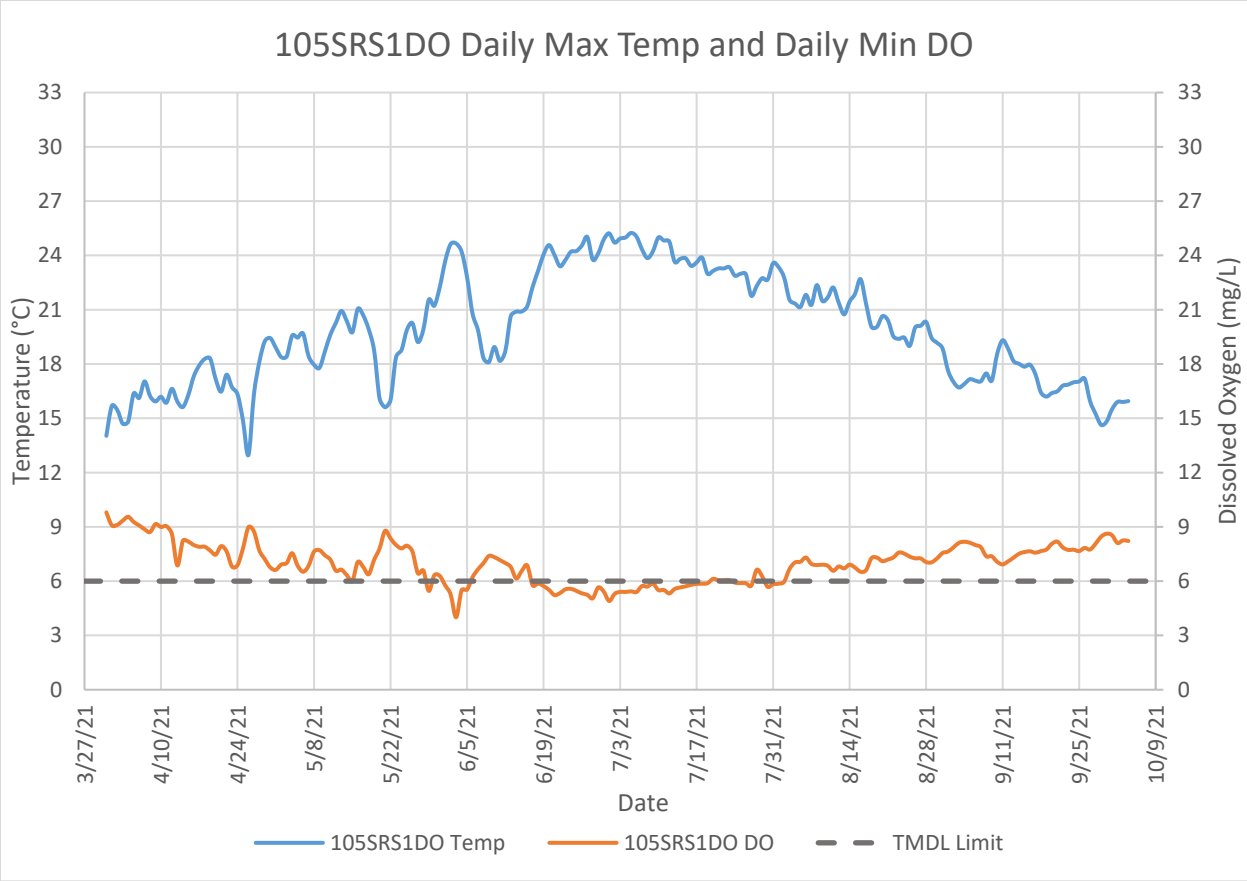

FIGURE 15. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRS1DO, SHASTA RIVER.

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRT1DO shown in Figure 14. DO and temperature equipment were deployed for 191 days between March 28 and October 4, 2021. DO and temperature data were removed from March 28 to April 23, 2021 due to vandalism. DO fell below the TMDL criterion of 6mg/L in 11 of the 164 days for which quality DO data was recorded.

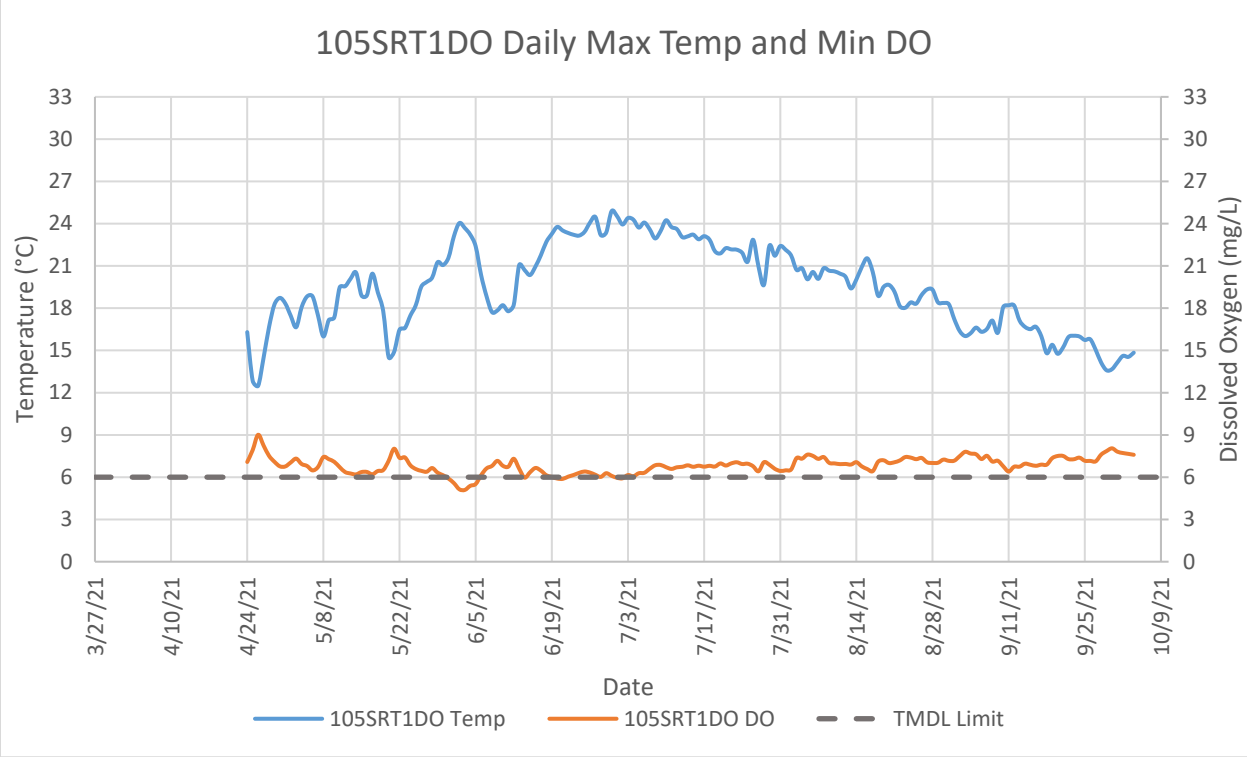

FIGURE 16. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRT1DO, SHASTA RIVER.

REACH 4

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRV1DO are shown in Figure 15. DO and temperature equipment were deployed for 191 days between March 28 and October 4, 2021. DO data was obscured by biofouling from June 25 through June 28 and has been removed. DO levels fell below the TMDL criterion of 6 mg/L in 32 of the 187 days for which quality DO data was recorded.

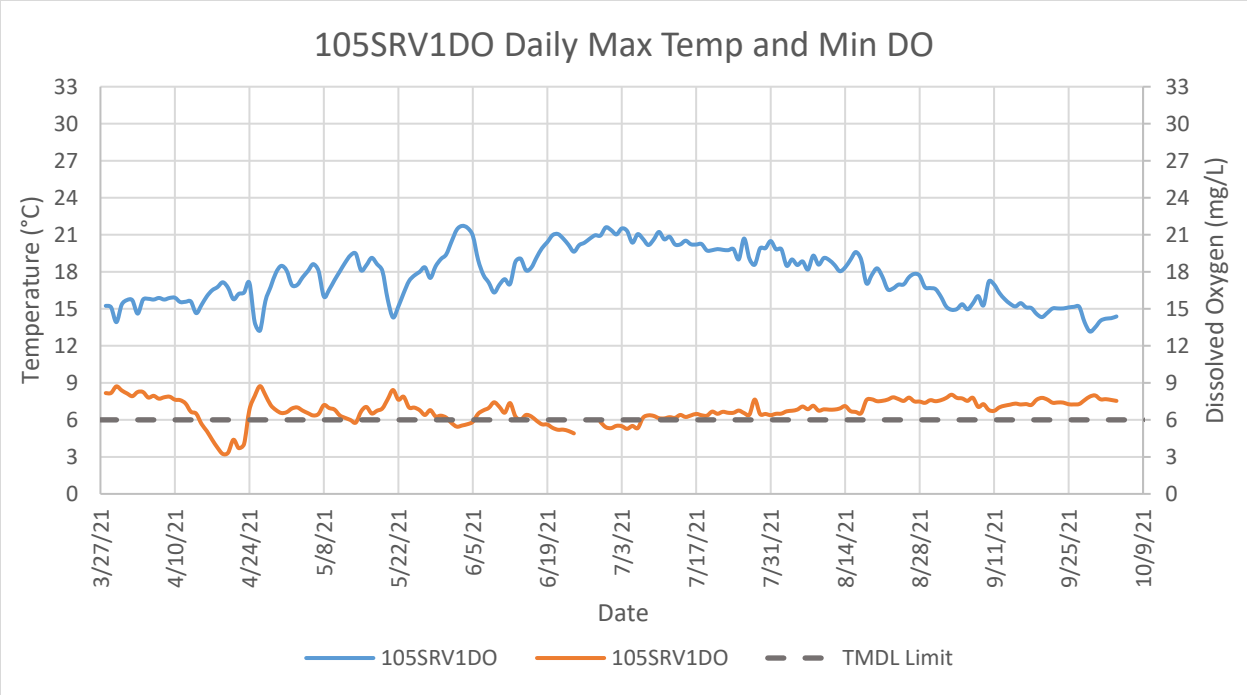

FIGURE 17. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRV1DO, SHASTA RIVER.

REACH 5

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRP1DO are shown in Figure 16. DO and temperature data were deployed for 82 days from July 15 to October 4, 2021. DO data was obscured by biofouling from July 30 to August 2, August 24, and August 29 and was removed. DO and temperature data were not collected from September 7 until the equipment was pulled due to equipment failure. DO levels fell below the TMDL criterion of 6 mg/L in 5 of the 49 days for which quality DO data was recorded.

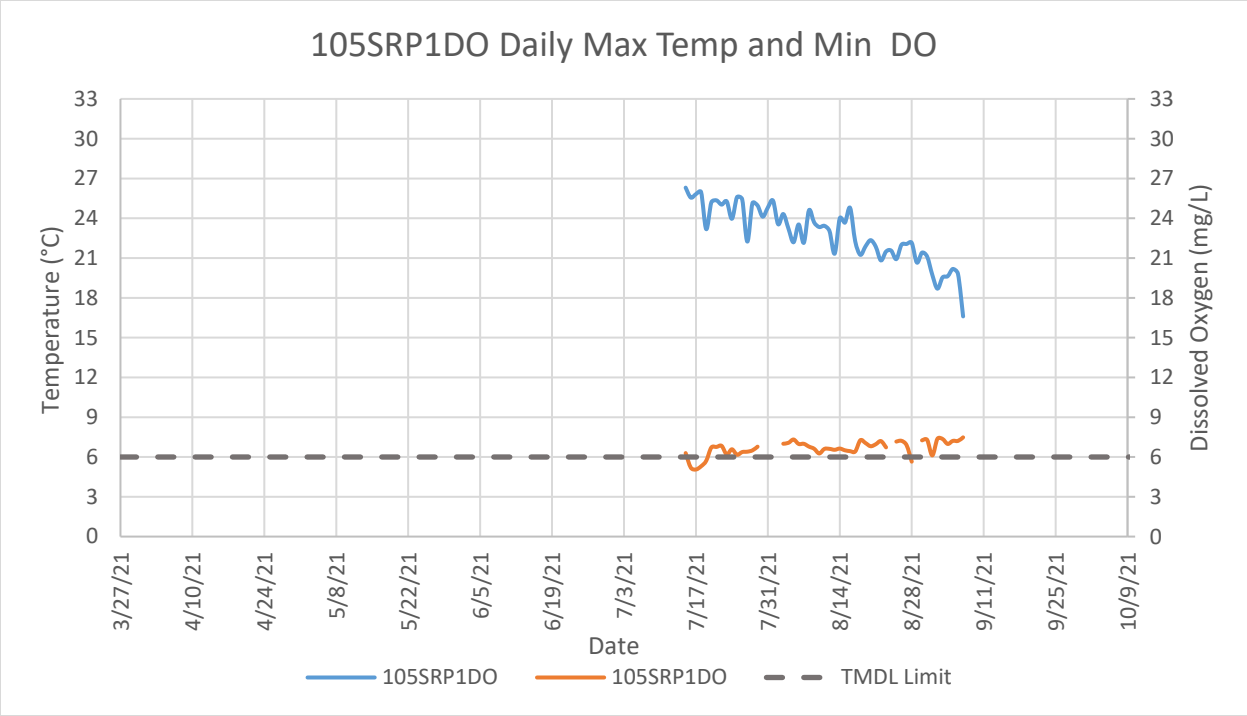

FIGURE 18. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRP1DO, PARKS CREEK.

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105PCFPDO are shown in Figure 17. DO and temperature equipment were deployed for 195 days from March 27 to October 7, 2021. Between June 27 and July 11, 2021, an instream construction project adjacent to the monitoring site was implemented. During the time of construction, the DO and temperature equipment were removed from the stream and no data was collected. DO levels fell below the TMDL criterion of 6 mg/L in 89 of the 180 days for which quality DO data was recorded.

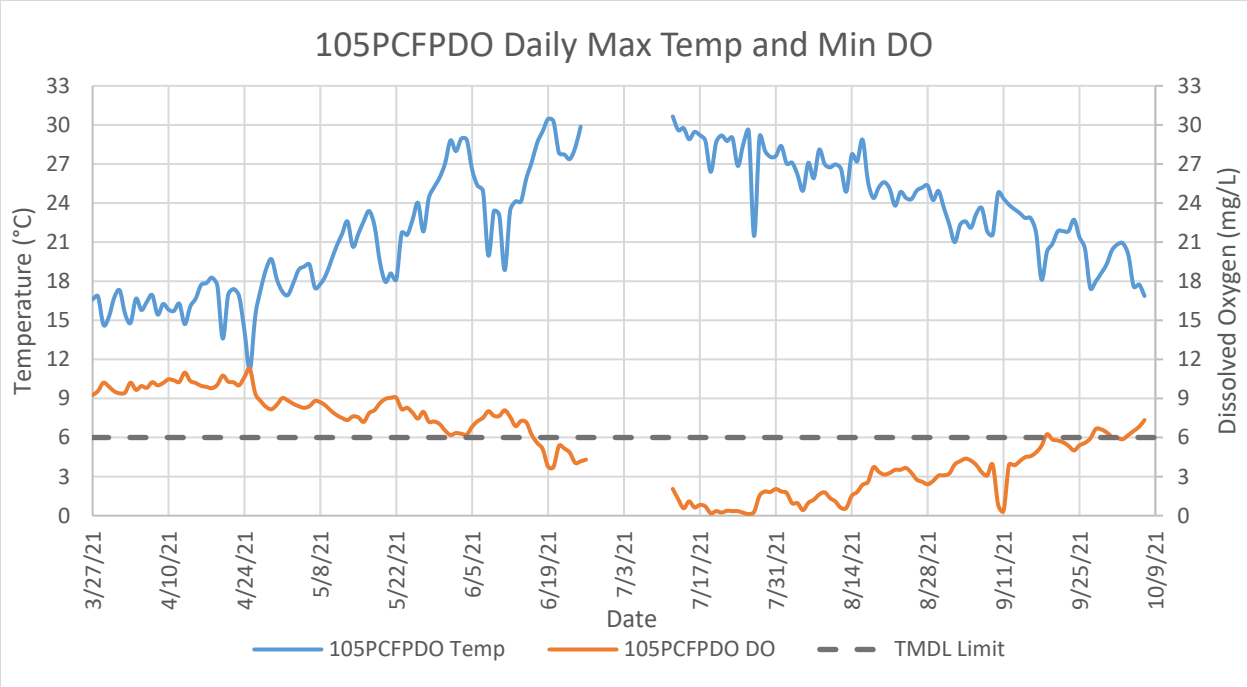

FIGURE 19. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105PCFPDO, PARKS CREEK.

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105PCB1DO is shown in Figure 18. DO and temperature equipment was deployed for 195 days from March 27 to October 7, 2021. Large gravels to cobbles make up the substrate at this reach and channel morphology becomes isolated pools in the latter part of the summer, with flow percolating through the large rocky substrate. There is limited macrophyte growth in the late summer, which when present, can be a source of DO. DO fell below the TMDL criterion of 6 mg/L in 126 of the 195 days for which quality DO data was recorded.

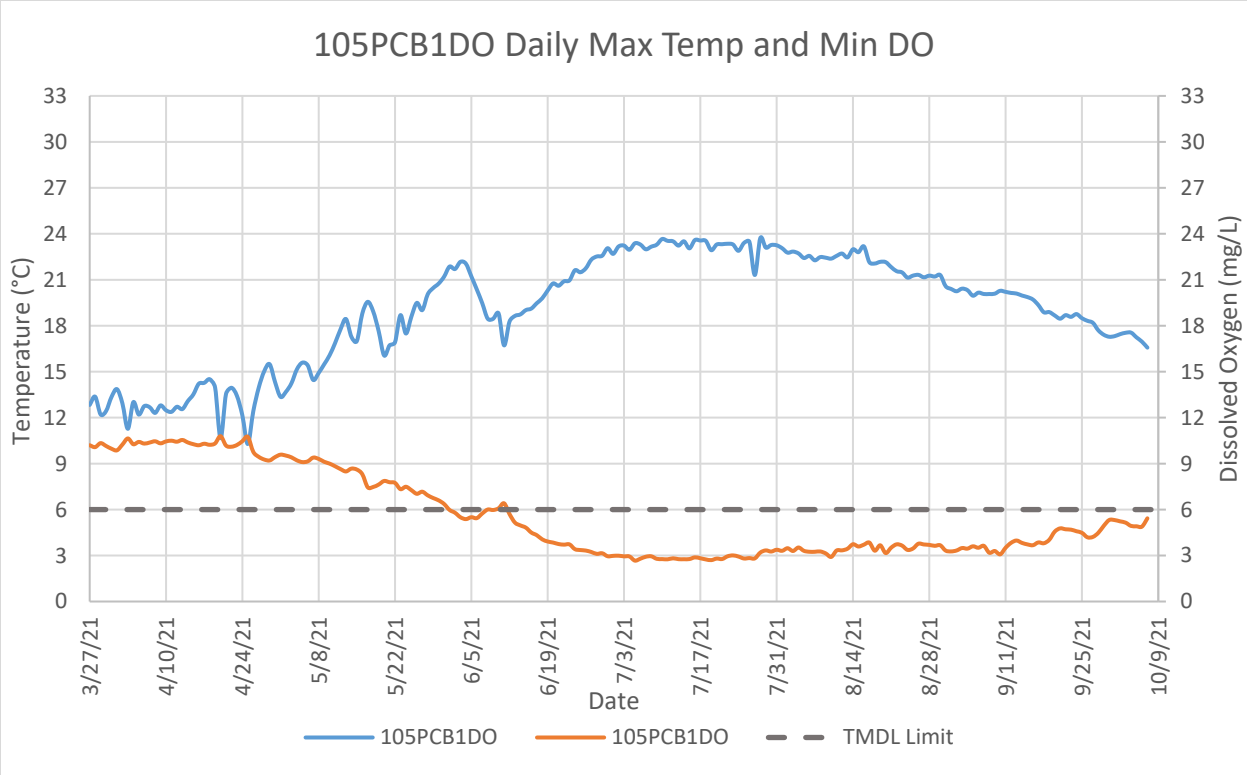

FIGURE 20. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105PCB1DO, PARKS CREEK.

REACH 6

Daily maximum temperature, daily minimum DO, and the TMDL DO criterion for site 105SRU1DO are shown in Figure 19. DO and temperature equipment were deployed for 190 days from March 31 to October 6, 2021. DO data was obscured by biofouling between May 11 through May 17, May 22 through June 14, and July 14 to August 25, 2021, and was removed. This site experience more frequent and intense biofouling due to drought which limited flow volumes and velocities, a near absence of spring water inputs typical of this site, and low flow velocities leading to an abundance of macrophyte growth. DO levels fell below the TMDL criterion of 6 mg/L in 74 of the 116 days for which quality DO data was recorded.

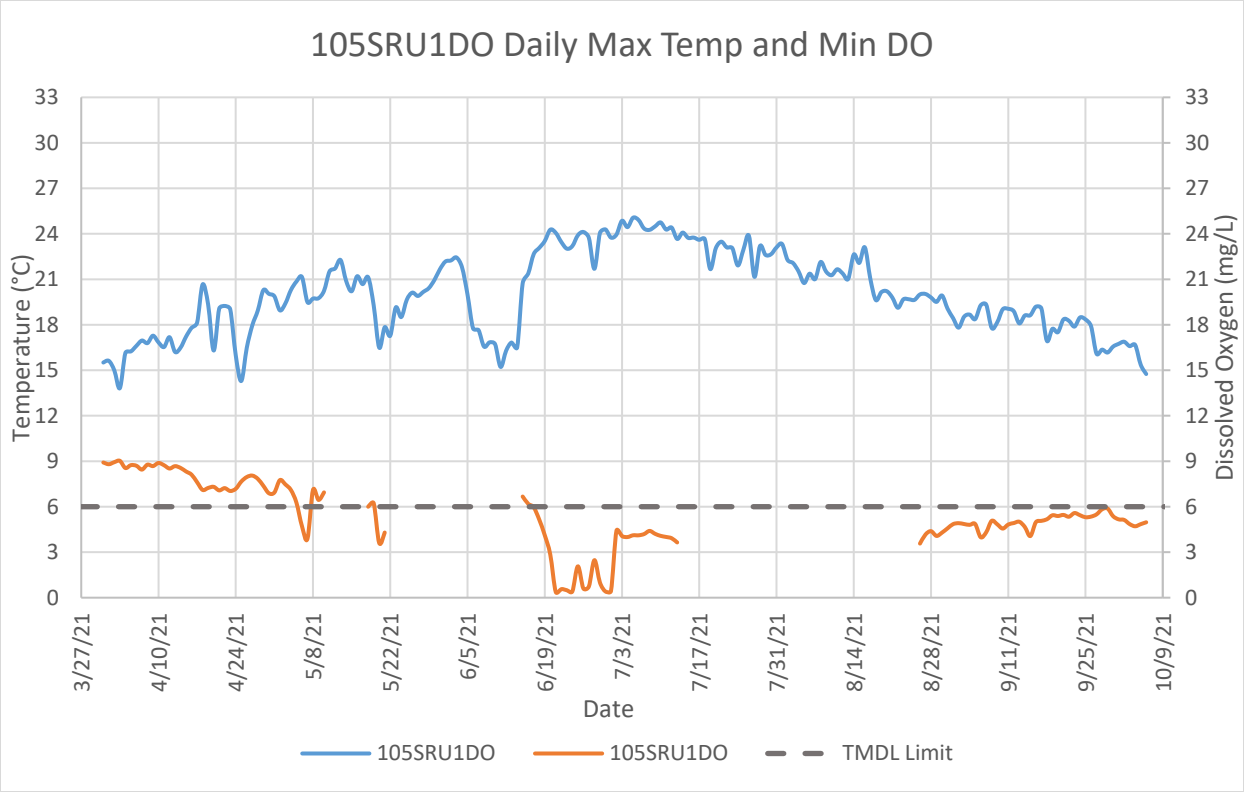

FIGURE 21. 2021 DAILY MAXIMUM TEMPERATURE AND DAILY MINIMUM DO AT 105SRU1DO, SHASTA RIVER.

CONCLUSION

In general, consecutive years of drought conditions and below average precipitation have strained total water supply, and reduced certain cold groundwater inputs. Water temperature on the Shasta River exceeded TMDL and MWMT objectives in 2021, while DO levels were above minimum objectives at most sites but fell below those objectives at others. These mixed results suggest that, in general, DO and especially temperature did not meet NCWQCP objectives in 2021, but long-term monitoring results have shown positive impacts of ongoing resource management and restoration projects on the Shasta River and its tributaries.

A multi-year analysis of consecutive dry years and the impacts on total discharge and spring discharge would further guide restoration and management activities. Additionally, with the curtailment orders in place throughout most of 2022, future reports may help determine the impact of such actions on Shasta River TMDL objectives.

Increased coordination between water users proved effective at increasing flows in May of 2021 and should be a priority in 2022 as this coming water year is shaping up to be below average, and curtailment orders remain in place.

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The SVRCD would like to give sincere thanks to all of the landowners who provided access to the Shasta River and its tributaries through their properties. The data gathered year after year serves as an invaluable tool to help inform the watershed and provide the basis for solutions that benefit all of its stakeholders. Our appreciation for your ongoing cooperation and participation cannot be overstated.

APPENDIX

Public Data Access

California Irrigation Management Information System (CIMIS)

- Station 260 – Montague
- Station 261 – Gazelle

https://cimis.water.ca.gov/

California Data Exchange Center (CDEC)

- Hydrologic Data Acquisition System (HyDAS)
    - Station SVG – Goosenest
        - https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=SVG
    - Station SVB – Bolam
        - https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=SVB

California Data Exchange Center (CDEC)

- Shasta River Discharge and Stage
    - Station SRM – Near Montague
        - https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=SRM
    - Station SRY – Near Yreka
        - https://cdec.water.ca.gov/dynamicapp/staMeta?station_id=SRY