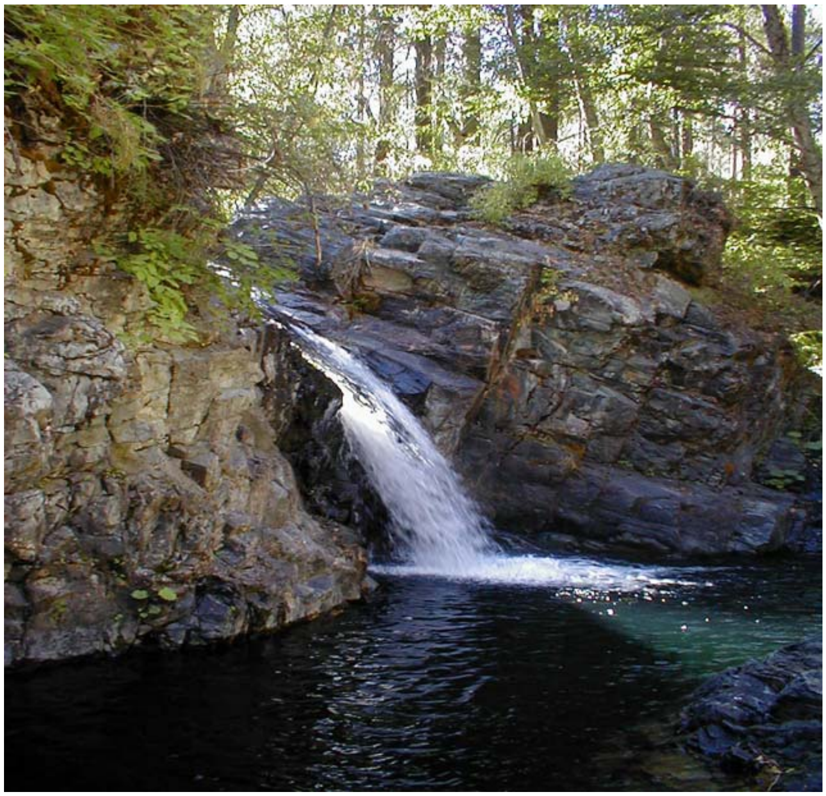
Quartz Valley Indian Reservation
Water Quality Monitoring and Assessment Report 2011



Prepared by the Quartz Valley Indian Reservation Environmental Department Staff

December 30, 2011

Position	Name
Technical Assistance	Rebekah Sluss
Field Biologist	Sarah Schaefer
Environmental Outreach Coordinator	Marla Bennett
Environmental Assistant	Cecilli Kelley
Environmental Director	Kim Mattson, Ph.D.

Special Thanks for making this project possible:

- US Environmental Protection Agency (US EPA)
- North Coast Water Quality Control Board (NCRWQCB)
- US Forest Service (USFS) – Salmon/Scott Ranger District
- Timber Vest, Mason Bruce & Girard
- Quartz Valley, CA landowner participants
- Klamath Basin Tribal Water Quality Workgroup

TABLE OF CONTENTS

List of Figures

List of Tables

1. Introduction

This document describes the water quality monitoring performed during 2011 by the Quartz Valley Indian Reservation (QVIR) Environmental Department. Our work is funded by Federal grants from the U.S. Environmental Protection Agency (USEPA) and is intended to help fulfill intentions of the Clean Water Act. Our efforts are designed to monitor the health of our local water bodies and to help protect waters for a variety of beneficial uses.

The QVIR Environmental Department began the process of developing a Water Pollution Control Program in accordance with the Clean Water Act (CWA) in 2005. The Tribe set primary goals of ensuring salmonid spawning and rearing habitat, fishing, swimming, other wildlife habitat and cultural needs. The objective is to ensure these goals are met for the future protection and sustained use of valuable Reservation water resources, protection of public health and welfare, and the enhancement of water quality resources. The Tribe intends to protect and improve water resources through water quality monitoring, habitat evaluation, education and community outreach, planning and implementation.

A Quality Assurance Project Plan (QVIR 2006a) for water quality monitoring was developed by the Tribal Environmental Program and approved by U.S. Environmental Protection Agency (U.S. EPA) in 2006. Current water quality conditions are annually evaluated using the water quality objectives developed from various state, federal and tribal entities. The North Coast Regional Water Quality Control Board (NCRWQCB) Basin Plan water quality objectives are determined for the protection of beneficial uses (e.g., salmonids, agriculture, and recreation) established for the Scott River and its tributaries. U.S. EPA's (2000a) Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II provides general guidance to analyze nutrient values, but is not intended to be directly translated into standards. U.S. EPA 2007 Edition of the Drinking Water Standards and Health Advisories and the NCRWQCB Basin Plan were used to analyze groundwater results. For parameters without current water quality objectives established by either state or federal agencies, the QVIR Tribe has adopted their own objectives based on published research. Tables 1 and 2 lists the water quality standards used to assess surface water quality and ground water quality as monitored in 2011.

Table 1: Water quality standards used to assess surface water quality sampled by QVIR.

Parameter monitored	Units	Water quality criteria		Source of standard
Temperature	°C	MWAT [1] < 16.8°C < 19 C		Welsh et al., 2001; Sullivan et al., 2000, U.S. EPA, 2003
pH	pH	Min	Max	North Coast Regional Water Quality Control Board (NCRWQCB). 2007 *Basin Plan*, Scott River Objective
		7	8.5	
Conductivity	mS/cm	50% Upper Limit	90% Upper Limit	North Coast Regional Water Quality Control Board (NCRWQCB). 2007 *Basin Plan*, Scott River Objective
		0.275	0.350	
Turbidity	NTU	< 5 above ambient turbidity levels		Berg, 1982; Lloyd, 1987
Dissolved Oxygen	mg/L	Min	50% Upper Limit	North Coast Regional Water Quality Control Board (NCRWQCB). 2007 *Basin Plan*, Scott River Objective
		7.0	9.0	
Total Phosphorus	µg/L	10		U.S. Environmental Protection Agency. 2000a. Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II.
Total Nitrogen	mg/L	0.12		U.S. Environmental Protection Agency. 2000a. Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II.

[1] MWAT: maximum weekly average temperature = highest of the 7-day period of moving average of daily temperatures.

Table 2: Drinking water standards used to assess ground water samples taken by QVIR.

Parameter	Units	Water Quality Objectives		Source
pH	pH units	Max	Min	North Coast Regional Water Quality Control Board (NCRWQCB). 2007 Basin Plan, Scott River Objective
		8	7	
Conductivity	mS/cm	90% Upper Limit	50% Upper Limit	North Coast Regional Water Quality Control Board (NCRWQCB). 2007 Basin Plan, Scott River Objective
		0.500	0.250	
E. coli	MPN/ 100 ml	1 MPN or Presence		US EPA 2006.

2. Methods

As mentioned above, we have developed a Quality Assurance Project Plan (QVIR 2006a) that guides collection and analysis procedures and this has been approved through a review by the U.S. EPA. We also have formal written Standard Operating Procedures (SOP's) that guide our collection, sampling handling, analysis, and equipment calibration and maintenance. Following these plans, data collection began during the late spring of 2007 and continues into 2011.

Our major collection effort is being performed by a multi-channel, data recorder (YSI Datasonde 6600). This datasonde records a range of parameters on 30-minute intervals and is deployed on the mainstem Scott River at the U.S. Geologic Survey (USGS) flow gage site located about 10 miles downstream of the community of Fort Jones (USGS gage 11519500). The datasonde records temperature, specific conductivity, dissolved oxygen, pH and turbidity. The results are available for real-time viewing at the California Data Exchange Center (CDEC) website using the tab labeled "Query Tools" and requesting data for "SFJ" (Scott River at Fort Jones). (Or click on this link: http://cdec.water.ca.gov/cgi-progs/plotReal2?staid=sfj).

In addition to the datasonde data, we collect bi-weekly grab samples of surface water quality at five locations near the QVIR. This year, the grab samples began in July and finished in October. Sampling locations were three on Shackleford Creek and two on the mainstem Scott River below Shackleford Creek.

The grab samples collected at these eight sites were analyzed for eight water quality parameters: total nitrogen, nitrate (plus nitrite), total phosphorus, bacteria (*E. coli* and total coliform), pH, dissolved oxygen, specific conductivity, and turbidity. Nitrogen and phosphorus were sent out and analyzed by Aquatic Research Inc., Seattle, WA. Bacteria analyses are done in-house. The Quartz Valley Indian Reservation operates its own bacteria lab, which is ELAP certified by the State of California. (The QVIR lab is also certified and available to perform tests for the public on bacterial contamination of drinking water samples from wells or other sources.) The remaining analyses were performed on site using a hand held YSI datasonde.

In addition to the above water chemistry efforts, we collected continuous temperature data at fifteen sites over the Scott River basin. We sampled temperature at the four of the five sites used for water chemistry (the Scott River gage already had continuous temperature) plus an additional ten sites. Thirteen sites are reported since two sampling devices were lost. The temperature sites were three in the mainstem Scott River below Fort Jones, seven in the tributaries near the QVIR, and five in the upper Scott River tributaries. Temperature is measured and recorded at 30-minute intervals using HOBO continuous recording temperature devices (Onset Corp.). Additional details on the sampling methods and laboratory methods for each parameter are included in the QAPP (QVIR 2006a).

The distribution of our surface water sampling array for both water chemistry and temperature is shown in Figures 1 and 2.

In addition to the surface water program, groundwater is also being monitored. We have performed periodic sampling of a set of drinking water wells and a newly establish set of ground water monitoring wells. Bacteria sampling, depths to water, and a handheld datasonde analysis is performed on the drinking water wells. Water level depths are just being initiated on a set of newly established monitoring wells on the QVIR land holdings. The locations of the drinking water wells and the ground monitoring wells are shown in Figures 3 and 4.

Table 3: Various sampling sites monitored by QVIR.

Site Code	Location Description	Land owner
Streams near the QVIR for water chemistry and temperature		
SRGA	Scott River at the USGS Gage Continuous Monitoring	Private
SRJB	Scott River @ Jones Beach	USFS
DEEP	Deep Creek in Scott River canyon area	USFS
SHTH	Shackleford at wilderness trailhead	Wilderness - USFS
SHFL	Shackleford at Falls	Private
SRES	Shackleford at Quartz Valley Indian Reservation	USA Indian Trust
SHML/MICR	Mill Creek above Shackleford Confluence	Private
SNCR	Sniktaw Creek	USA Indian Trust
CHTH	Shackleford at Tribal Trust parcel near mouth	USA Indian Trust
CAMO	Campbell Lake Outlet in Shackleford basin	Wilderness - USFS
SUCC	Summit Lake Outlet in Shackleford basin	Wilderness- USFS
Drinking water/surface water sampled mostly for bacteria		
12912_YAM	Drinking well QVIR – 12912 Yamitch	US Bureau of Indian Affairs
12839_YAM	Drinking well QVIR – 12839 Yamitch	US Bureau of Indian Affairs
12837_KUU	Drinking well QVIR – 12837 Kuut	US Bureau of Indian Affairs
100_QVD	Drinking well QVIR abandoned – 100 Quartz Valley Drive	US Bureau of Indian Affairs
9117_SNIK	Drinking well QVIR – 9117 Sniktaw	US Bureau of Indian Affairs
9021_SNIK	Drinking well QVIR – 9021 Sniktaw	US Bureau of Indian Affairs
9024_KEET	Drinking well QVIR – 9024 Keet	US Bureau of Indian Affairs
9009_BIGM	Drinking well QVIR – 9009 Big Meadows Road	USA Indian Trust
COM1	Drinking well Fire House Old well	USA Indian Trust
COM2	Drinking well Fire House New well	USA Indian Trust
ADBLDG	Drinking well Administration Building	USA Indian Trust
CC	Drinking well Culture Camp	USA Indian Trust
RIVER	Drinking well Shackleford Bridge	USA Indian Trust
EPA	Drinking well QVIR – 13824 Quartz Valley Road	USA Indian Trust
13824_DIT	Irrigation Ditch – 13824 Quartz Valley Road	USA Indian Trust
14208_DAN	Drinking well private – 14208 Dangle Lane	Private
Surface water in the south portion of Scott Valley sampled for water chemistry and/or temperature		
SRSF	Scott River South Fork	USFS
SREF	Scott River East Fork	USFS
KANG	Kangaroo Creek tributary to EF Scott River	USFS
GROU	Grouse Creek tributary to EF Scott River	USFS
MULE	Mule Creek tributary to EF Scott River	USFS

Figure 1: Water quality sampling locations used by QVIR in the north portion of Scott River Basin. SRGA (Scott River gage) is the continuous recording datasonde. SRGA, SCJB, SRES, SHTR, and CHTH are grab sample sites (N and P). All sites had continuous temperature monitoring (HOBO sites).

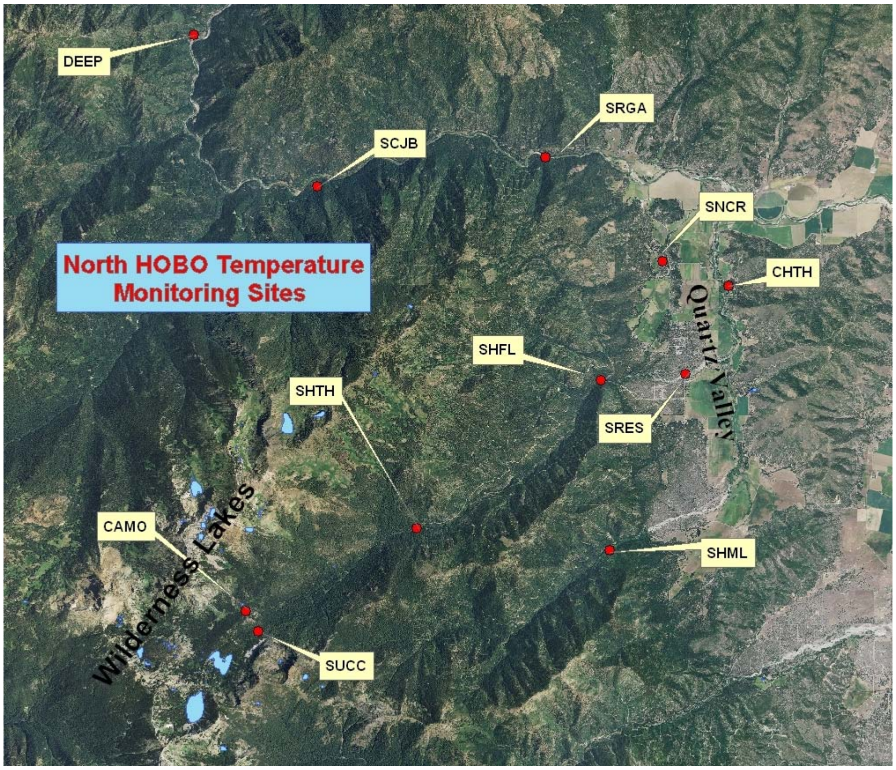


Figure 2: Water quality monitoring sites used by QVIR in the southern portion of the Scott River Basin. All sites were used for continuously temperature monitoring (HOBO sites).

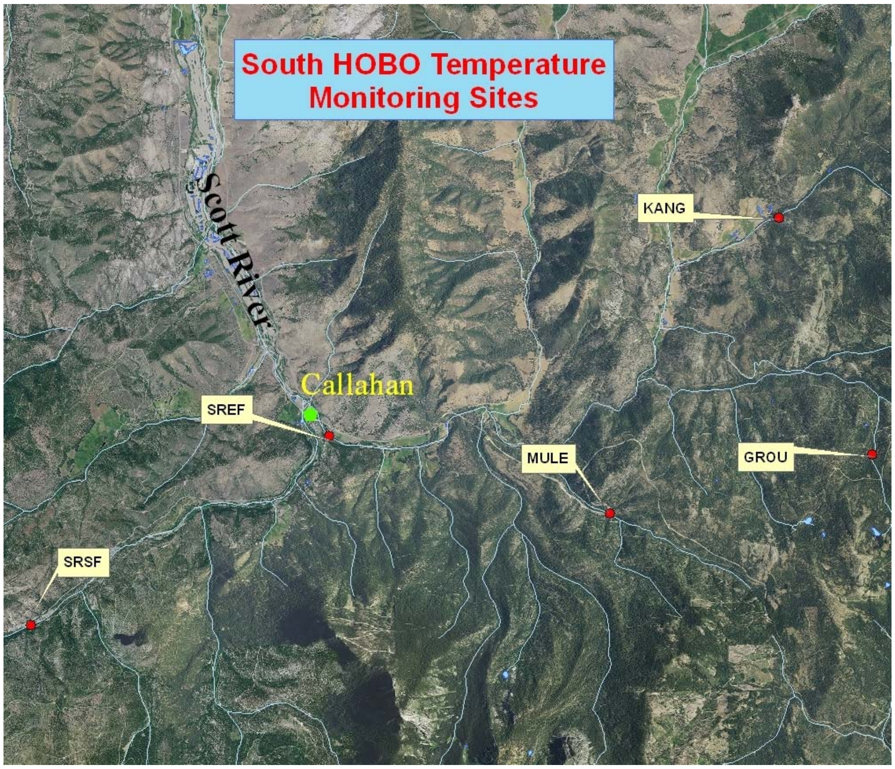
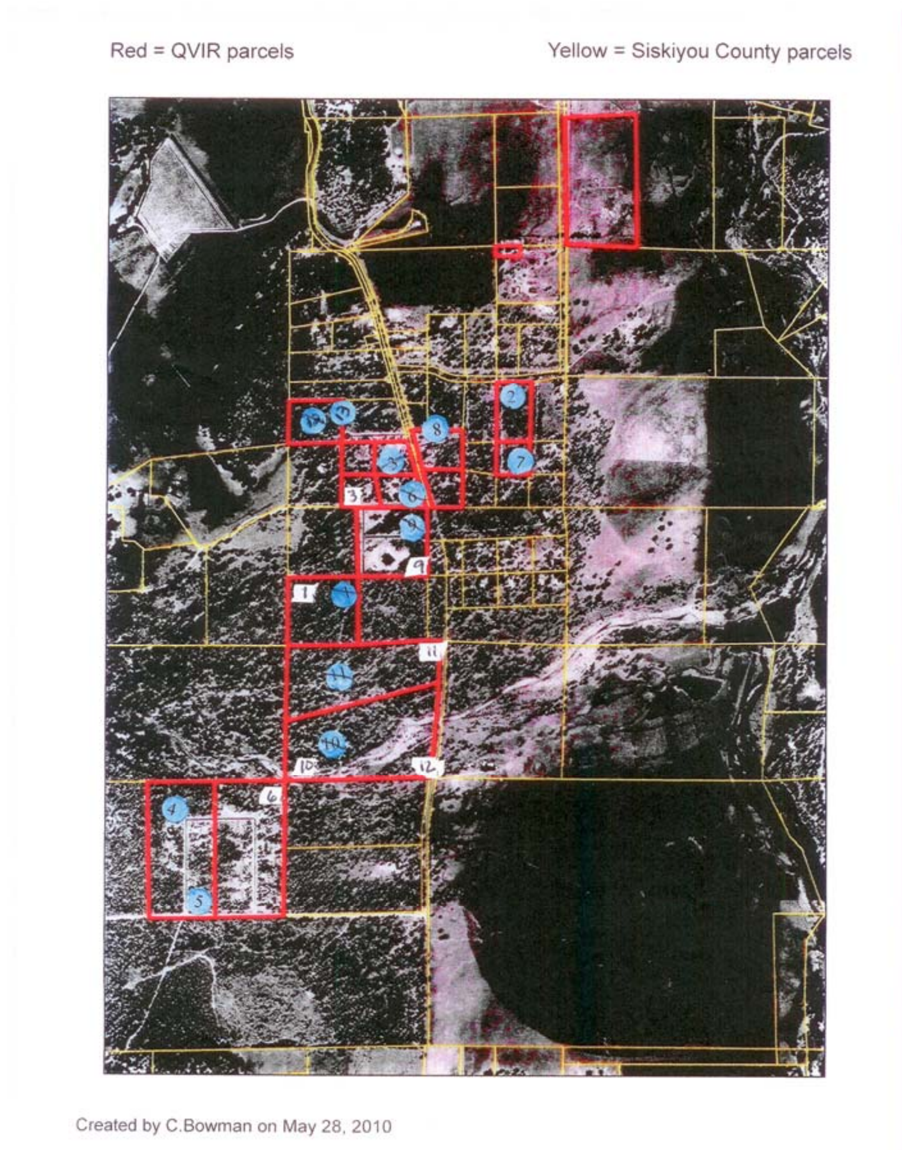


Figure 3: Locations of the drinking water wells monitored by QVIR for bacteria, chemistry, and depths.

Figure 4: Locations of thirteen, 40-foot deep, ground-water monitoring wells installed during 2011. The general area is the Quartz Valley Indian Reservation—Shackleford Creek flows from left to right in the lower half of the photo. The blue dots are the original planned locations; the white squares show where adjustments were made to specific wells in order to achieve a more uniform spatial arrangement.



Background on surface water flows in the Scott River basin

As the surface water chemistry and ground water depths are a function of the over all hydrology of the basin, some discussion of hydrology is warranted so to better to evaluate surface and ground water quantity and chemistry patterns. Streamflow in the Scott River and most non-spring discharges in Northern California clearly show seasonal patterns, that is in turn, modified by temperature, rainfall, river bed morphology. These patterns are further modified by landuse (e.g., roads, vegetation, forest harvests) and by direct water use and management in the basin.

Most of California is in a Mediterranean climate regime where most precipitation occurs during the winter and the summers are characterized by drought. Figure 5 shows the 30-year trends of precipitation for two periods 1961to 1990 and 1981 to 2010 at Greenview, CA in the western portion of the Scott Valley. These two patterns show 1) low rainfall (averaging just over 20 inches per year), 2) the characteristic Mediterranean pattern of summer droughts, and 3) a slight increase in rainfall in recent years. Given the latitude and elevation of most of the Scott Valley, snow and freezing conditions are common during winter. As a result, the higher elevations (e.g. above 3,000 ft above sea level) collect a snowpack during the winter and the lower elevations will have intermittent snow mixed with rain. By June rainfall and snowmelt tails off and the next two to three months will have little water for streams.

The result of the climate on streamflow patterns is one of increasing high winter flows and low summer flows as evident in the daily average flow (discharge) for the Scott River measured at the USGA gage since 1942 (Figure 6). Figure 6 shows a fairly consistent and unchanging pattern of peak flows over 20,000 cfs occurring nearly every 10 years and low flows of less than 10 cfs starting about 1977. The increased frequency of these extremely low flows in recent years is of interest as lowered flows likely contribute to changes in the stream character. The last three years of flow at the Scott River gage show the details of the seasonal pattern (Figure 7). These show the generally high flows during winter with punctuated storm peaks, a steep decline during June and July to a low flow during August, September and into October followed by increased flows by November. The last three years of flow show this year had relatively high summer flows but a relatively dry fall. This year had high summer base flow and a late-arriving fall rain.

The increased frequency of low flows during summer shown in Figure 6 may be related to increased low flow and drying of smaller tributaries in the Scott Valley. It has been suggested that a long-term drought is responsible for the recent low summer flows. But this does not appear to be drought-related as Figure 5 indicates that overall rainfall has increased in recent years. However, Figure 6 also indicates that the increases in rainfall have occurred mostly during the wet winter months and the summer periods appear to be nearly as dry now as in earlier years. Lack of a climatic cause suggests that changes in land use that have increased winter run off (and decreased summer low flow) or to increased intensity of water use that has presumably occurred since the mid 1970's. These questions are currently subjects of hydrologic studies started in the basin.

In an early, but detailed, hydrologic study of the Scott Valley, Mack (1958) estimated 8-10 % (ca. 40,000 acre-feet) of the annual discharge of the Scott River was diverted from streams or pumped from ground water. He estimated that nearly all was used as irrigated agriculture; 55 % of the water was lost as evapotranspiration and 45 % percolated back to the aquifer. At that time, the 22,000 acre-feet lost was only 5 % of the total annual flow. However, since most was used during the summer, the amount would be larger, though he did not estimate this.

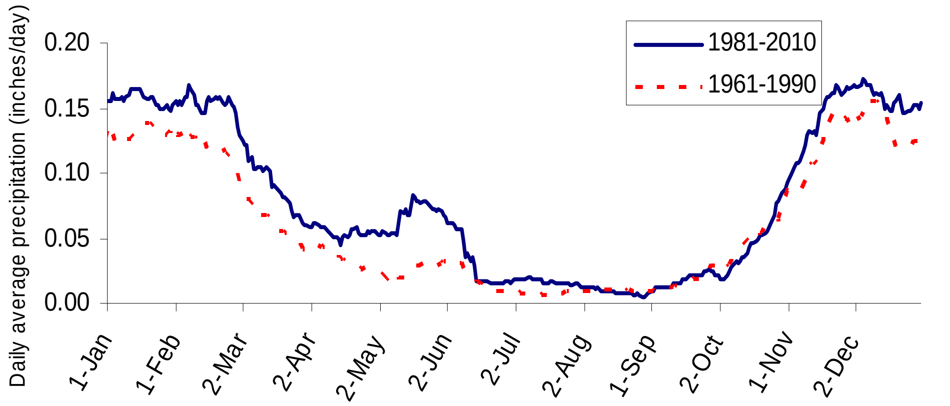


Figure 5: Precipitation for two 30-year periods Greenview CA climate station 043614. Data are are the daily averages for each 30-year period. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca3614

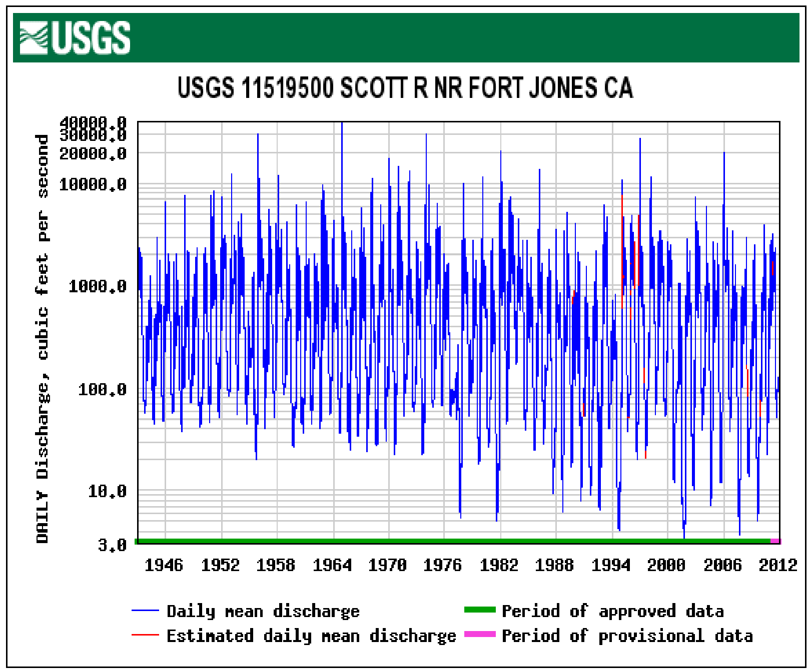


Figure 6: Scott River flow (discharge) since 1942 at the Scott River USGS gage. The blue line shows the seasonal peaks from storms or spring snowmelt and the summer-time low flows. The y-axis is a log-scale to show both the low and high flows. Highest flows (over 20,000 cfs) appear to occur periodically during the years 1955, 1964, 1978, 1982, 1996, and 2006. A shift appears to occur at 1977 when extremely low flows began to occur with greater frequency.

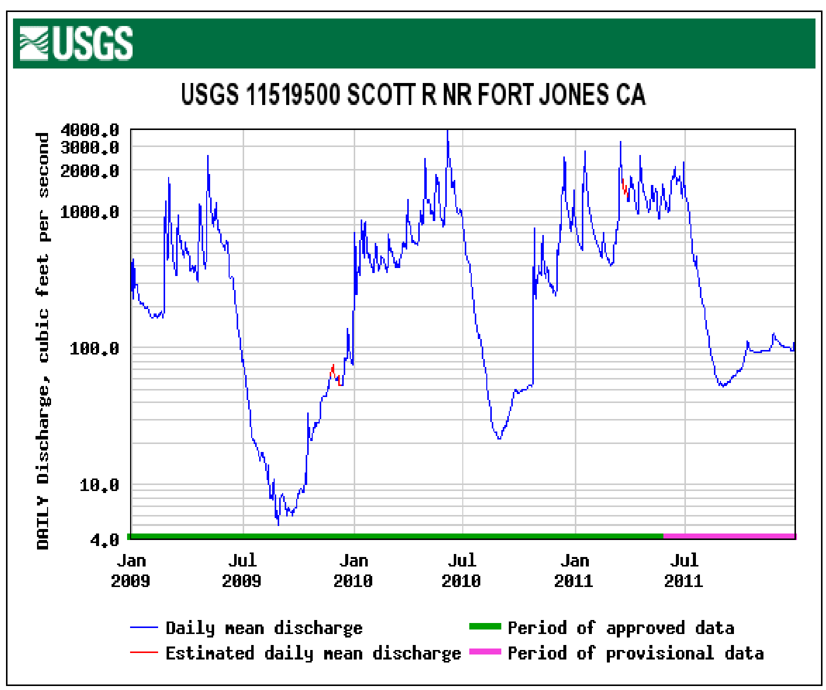


Figure 7: Scott River flows since 2009 at the USGS gage. These show more detail regarding the daily average discharge. The last three years show the typical annual variation in low flow in summer-time. 2009 had low flows of 5 cfs, 2010 had 20 cfs, while 2011 had low flow of 50 cfs. The day this data was downloaded, 12/30/11, the winter flows had just increased to about 500 cfs. The widths of the high flows give a good index of how much water went past the gage. 2011 appears to have the highest volume.

3. Results

Scott River continuous monitoring at USGS Gage

We monitored the water quality on a continuous basis at the Scott River USGS gage near Fort Jones starting in 2007 and have continued monitoring through 2011. Water quality is monitored by a YSI datasonde (YSI 6600 Series) with data recorded every 30 minutes. Real-time data are available online at http://cdec.water.ca.gov/cgi-progs/queryF?sfj. After downloading at the sites, the data are finalized each year and the 2011 data are included in this report. Water quality parameters monitored by the datasonde are temperature, specific conductivity, dissolved oxygen, pH and turbidity.

Temperature

The Scott River at the Scott River gage warms evenly through the year to maximum 7-day mean (MWAT) of 19.6 C that ended on August 10 (Figure 8). The highest daily mean temperature recorded was 19.9 C on August 7. During this day the peak temperature was 23 C at 5:30 PM and the minimum was 17 C at 8:30 AM. The highest instantaneous 30-minute temperature was 23.3 at 6:00 PM on August 26.

The two thresholds of concern we compare the river temperatures to are MWATs of 16.8 C and 19 C (Table 1). The 16.8 C threshold is a proposed upper limit for 7-day average temperature that represents the upper level for coho suitability (Welsh et al 2001) and is where optimal conditions for growth began to decline. The second 19 C threshold is the 7-day average temperature where salmonids begin to encounter stress (Sullivan et al. 2000). The MWAT exceeded 16.8 for about 2 months from July 24 to September 18. The MWAT stayed at or just above 19 C for two weeks from August 1 to August 15 and again for 10 days from August 21 to August 31.

The instantaneous temperatures exceeding 22 C first begin to occur on last week of July and the lasted until mid September. The daily peaks tended to occur in late afternoon from5:30 to 7:00 PM. During this period of high afternoon temperatures, the river would cool back down to below 17 C during 8:00 to 9:30 AM. On a typical August day, the temperature exceeded 22 C for 7 hours from 2:30 PM to 9:30 PM.

The four days of spiking temperatures evident in Figure 8 is when the datasonde was taken out of the water for cleaning and do not represent water temperatures.

The salmon risk assessment study approach used by (Sullivan et al. 2000) found that an MWAT of 19 º C reduces growth of both coho and steelhead by 20 %. In addition, the MWAT causing death or elimination from an area can range from 21.0 - 25.0 º C for coho and 21.0 - 26.0 º C for steelhead. Elliot (1981) also found these MWAT values can block migration, inhibit smoltification and cause disease problems. Welsh et al. (2001) found a lower MWAT of 16.8 C as being a coho suitable threshold (see also U.S. EPA, 2003).

Infrequent observations from the bank indicated that steelhead were in this reach of the Scott River and were likely under temperature stress during August. No coho were observed from the bank though the physical habitat looked suitable for coho (K. Mattson pers. comm.).

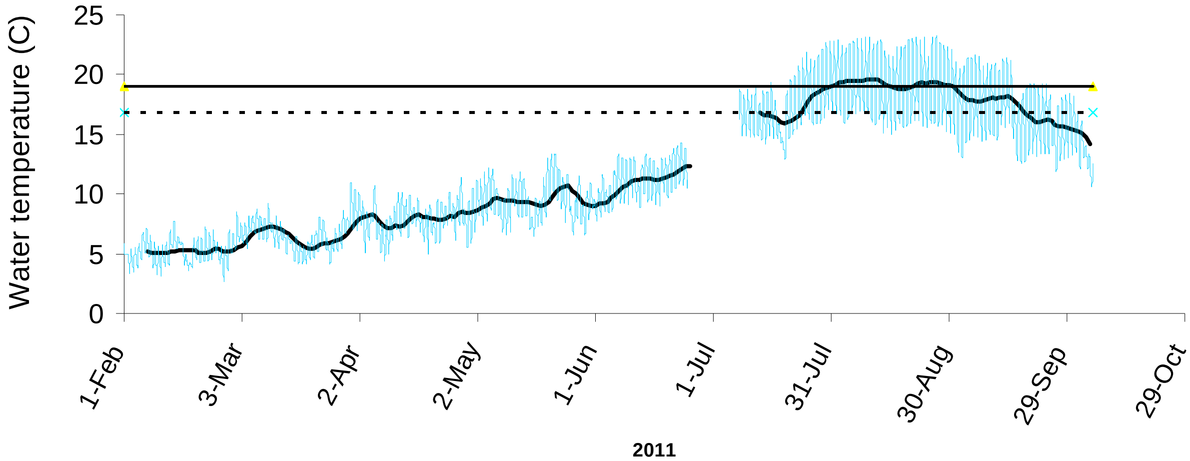


Figure 8: Water temperature for Scott River at Scott River gage collected at 30 minute intervals (light blue dots) and 7-day moving average of daily average temperatures (red solid line). The two horizontal dashed lines are the 16.8 C suitable level for coho (Welch et al 2001) and 19 C incipient stress for salmonids (Sullivan 2000) (see text).

Specific conductivity

Specific conductivity followed an inverse pattern of streamflow—being lower during the spring period of high streamflow and increasing as streamflow declined in late summer (Figure 9). The small dips in the line are normally thought to be increases in flow or storm events. Specific conductivity ranged from a low of 0.100 mS/cm to a high of 0.300 mS/cm. Basin Plan (NCRWQCB 2007) water quality objectives for the Scott River are a monthly mean below 0.350 and 0.250 mS/cm (90% upper limit and 50% lower limit, respectively; see Table 1). The month of September had 100 % of the values above 0.250 mS/cm, but none above 0.350.

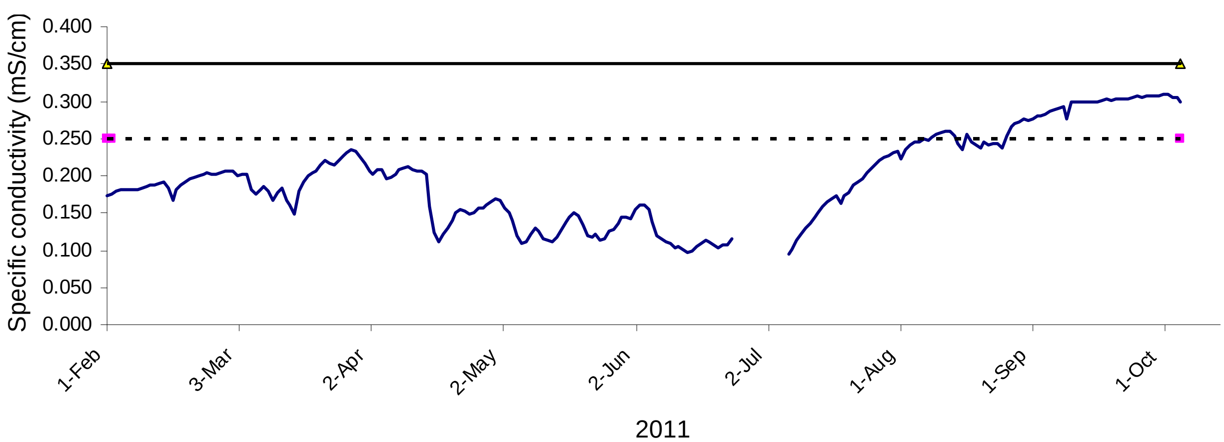


Figure 9: Specific conductivity at the Scott River USGS Gaging Station 2011. These are 30-minute interval readings. Fifty percent of the values monthly mean must be less than 0.250 mS/cm (dashed line).

The pattern of specific conductivity showed an interesting switch in July when it began to consistently increase with time. This was following a period of about 14 days when the datasonde was out of order and was sent back to the factory for adjustment. This same period of time is associated with possible bio-fouling of the sensor membranes (see below). However, this specific conductivity does not appear to be affected by bio-fouling. The increase in conductivity is thought to be real and may be associated with low flow and greater amounts of streamflow being composed of ground water with higher dissolved solids.

Note that one mS/cm equals 1,000 microS/cm or 1,000 µmhos/cm. Also one micros/cm is equal to about 0.67 mg/l of dissolved solids. Therefore the concentrations of dissolved solids (Na, K, Mg, and Ca) ranged from about 67 during July to 200 mg/L in September during the lowest flows. Mack (1958) reported dissolved solids (as salinity) for streams in the Scott Valley as ranging from 100 mg/L in spring to 132 mg/L in the autumn.

Dissolved oxygen

Daily average dissolved oxygen slowly declined from 11 mg/L to 8 mg/L over the summer; the daily average measured as a percent saturation showed a nearly steady level of about 90 % over the year (Figure 10). The daily mean mg/L values never fell below the minimum threshold of 7 mg/L (Table 1) and the daily means of percent saturation ranged from 87 to 95 %. The 30-minute measures of percent saturation showed large diurnal variation which substantially increased in the fall. Although, this could possibly indicate the effects of algal growth on the sensors or bio-fouling, QVIR staff followed QA/QC and SOP protocols and cleaned the sensors as per schedule. More investigation is needed to determine if these readings indicate biofouling or not. The diurnal patterns of percent saturation followed temperature well, peaking at about 5 to 6 PM and declined to their lowest values by earlier morning. This could suggest algal photosynthesis and production of oxygen during the day and consumption during the night. If the algae grew directly on the sensors, the sensor could have measured the micro-zone immediately around the algae cells. The daily means values calculated from these variable 30-minute measures are thought to represent the stream values fairly accurately since the daily means captures the temporal highs and lows in concentration. These same sorts of highly variable 30-minute measures were observed in previous water quality monitoring (QVIR 2008) and will be addressed this winter. This is apparently a common problem with continuous monitoring devices and one solution is to use a copper alloy screen surrounding the sensors (see http://www.ysi.com/media/pdfs/YSI-Data-Quality-Webinar-Aug10-Slides-Notes.pdf).

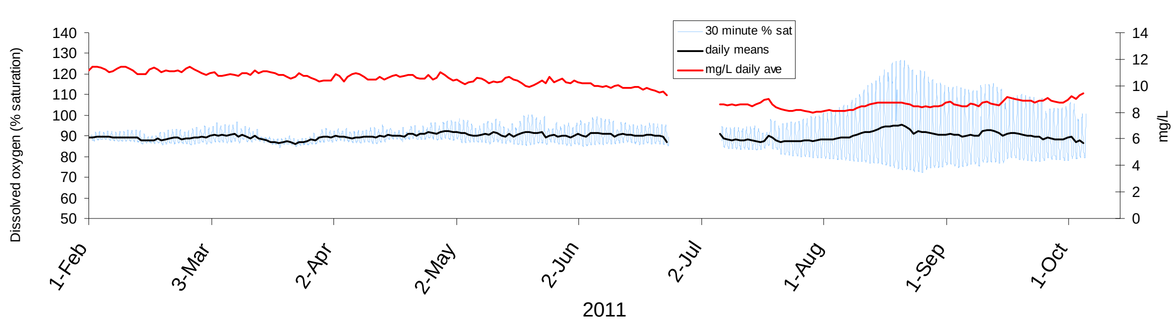


Figure 10: Dissolved oxygen at the Scott River USGS Gaging Station 2011. Daily mean dissolved oxygen concentration never fell below the minimum threshold value of 7mg/L.

pH

Daily mean pH values ranged from 7.5 to 8; the 30-minute readings ranged from 7.4 up to 8.4 and showed increased variability in the fall. The thresholds of a minimum pH of 7.0 or a maximum pH of 8.5 were not exceeded (Figure 11). The pH did not show a very clear pattern with streamflow. The pH pattern followed that of specific conductivity (Figure 9). As with the dissolved oxygen, the highly variable 30-minute readings in the fall are viewed with some level of suspicion. This same pattern was observed for our turbidity readings and we suspect it is possible the sensors were becoming affected by bio-fouling (growth of algae on the sensors, see Turbidity discussion below). Indeed, the diurnal pattern was one of high pH peaking just an hour earlier than temperature at about 5 to 6 PM about the time the sunlight would be decreasing. More investigation is needed to determine whether the sensors experienced biofouling or not. pH swings might be expected from algal photosynthesis driven by sunlight. Algal growth on the sensor surface would absorb the carbon dioxide from the water and low concentrations of carbon dioxide near the sensor would also reduce the carbonic acids, thus raising pH. It may be likely that the lowest values be taken to be the best representation of background pH in the fall.

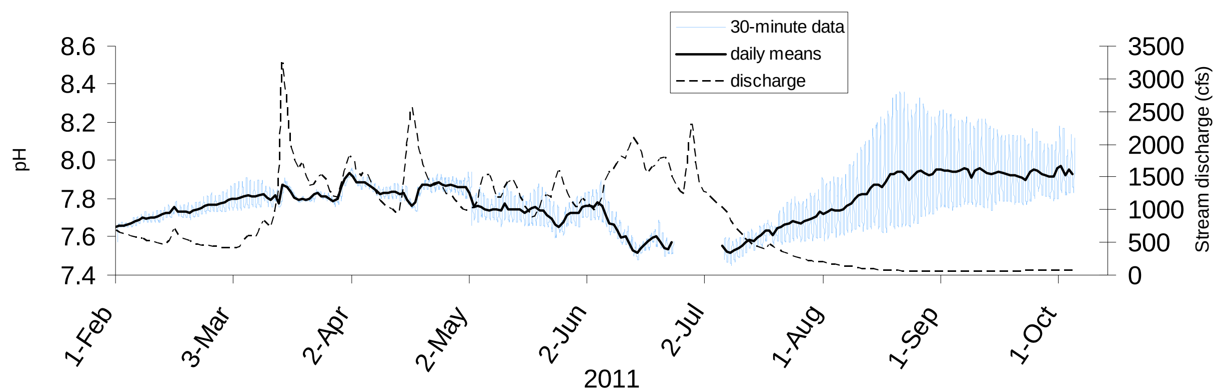


Figure 11: pH and at the Scott River USGS Gaging Station 2011. The upper or lower thresholds of minimum pH 7 and maximum pH 8.5 were not exceeded. The high variation in the fall could possibly be due to algal bio-fouling on the sensor and the lowest values during the fall are thought to be the best representation of pH (see text).

Turbidity

Turbidity showed variable patterns of seasonal change and periods of highly variable change (Figure 12). Turbidity generally increased seasonally with increased streamflow during the spring and decreased in the fall with low flows. The periods of highly variable turbidity shown in the 30-minute interval collections are suspect, particularly those in the fall. It is likely the turbidity readings were compromised by algae growth on the surface of the detector. This is supported by the less variable readings that are evident after the maintenance on April 19, and July 7. The data are less variable and after about one month the variation appears to begin to return.

The Tribe adopted a water quality objective of <5 NTU above the natural turbidity level (see QVIR QAPP 2006). The action level was determined using coho salmon research results from Berg (1982) and Lloyd (1987). There is not a water quality objective for turbidity established by either EPA or NCRWQCB. But during the periods when we can trust the readings, they are generally less than 10 NTUs and increase to 50 NTUs during storm events.

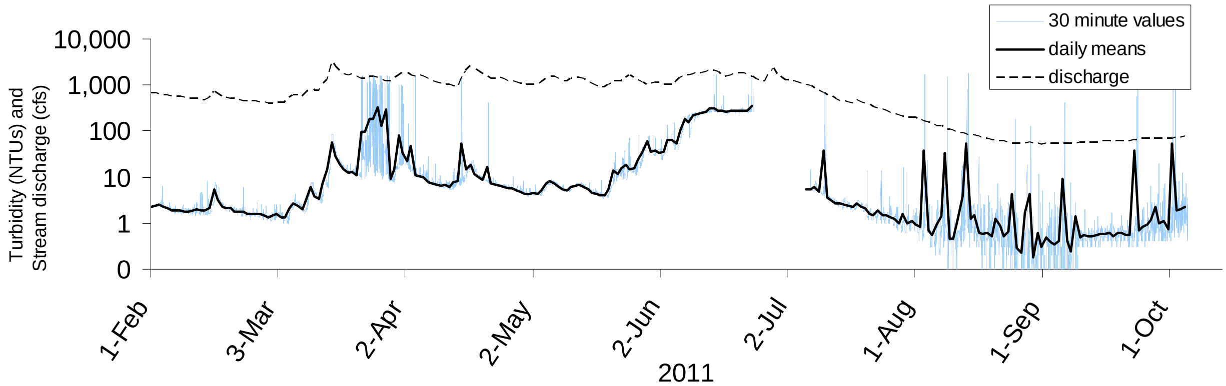


Figure 12: Turbidity at the Scott River USGS Gaging Station 2011. The high variation in the fall could possibly be due to biofouling on the sensor.

Basin wide water quality monitoring

Nitrogen and phosphorus

In addition to the continuous datasonde collections we made at the Scott River Gage site, we collected grab samples of surface water quality samples at several sites near the QVIR. We measure chemistry at the field site with a hand-held datasonde (temperature, dissolved oxygen, pH, specific conductivity, and turbidity). Samples were also analyzed for bacteria in our own laboratory. Samples were sent out to commercial labs for analysis of nitrogen (total N and NO_3+NO_2) and phosphorus (total P).

Nitrogen is an important element for all living systems. Nitrogen is generally not abundant in soils or surface waters as it is not normally a product of mineral weather of bedrock. Nitrogen enters ecosystems mainly by "fixation" from the atmosphere and once it is in the living systems, it is conserved relatively tightly via recycling mechanisms such as uptake by plants, fungi, or bacteria and is stored in organic tissues and soil organic matter. Presence of moderate to high concentrations in surface waters can be due to natural conditions (high amounts of nitrogen fixers or some marine sediments can contain nitrogen). High nitrogen in surface waters normally indicates a "leaky ecosystem" and may be due to ecosystem disturbance. Sources of nitrogen may be forest fires, harvests, soil erosion. Presence of high nitrogen in surface water may also be due to pollution such as poorly designed domestic leachfields, runoff from farmyards, cattle accessing streams, excessive fertilizer use near stream courses, or industrial effluents discharging to streams. Total N measures all forms of nitrogen and normally is composed of mostly of organic forms (various proteins or other organic compounds containing nitrogen), and lesser amounts of inorganic forms such as ammonium (NH_4^+), nitrate (NO_3^-) and nitrite (NO_2^-). Nitrate and nitrite are often included together or sometime only reported as nitrate. Nitrite is an unstable form that is of low concentration and is normally quickly transformed to nitrate or ammonium. Both nitrate and nitrite are negatively charged forms of inorganic nitrogen and because of their negative charges, are not readily held by soils and are therefore soluble and leach easily to surface waters. They are readily taken back up by algae, plants, and bacteria and fungi and can increase plant and algae growth and turn streams and lakes green (eutrophication). Very high concentrations can result in fish kills. We have chosen 0.12 mg/L of total N as our threshold level for surface waters (Table 1). We also track the presence of nitrate and nitrite but do not have a threshold established. Though it normally may be considered to be about 1/5 to 1/3 the amount of total N.

Phosphorus is also an important element for living systems. It is not as limiting to plant growth in temperate ecosystems as nitrogen as it is a product of mineral weathering and is found naturally in the soil, though at somewhat low or limiting levels. Phosphorus tends to be relatively high in Northern California, probably due to the volcanic nature of the bedrock. Total P includes all forms of dissolved phosphorus and includes organic forms in organic compounds and also inorganic forms (PO_4^{2-}) which is the most readily used forms by plants and is what can also cause eutrophication or green color to waters. Our threshold for total P is 12 micrograms per liter or µg/L. Note that one microgram equals 1,000 milligrams. So 12 µg/L is the same as 0.012 mg/L.

The results of our summer grab samples in streams near the QVIR are shown in Figure 13. The tributaries are low in N and P. Areas where possible pollution N sources are Shackleford Creek near the QVIR and the Scott River downstream. At these sites, the majority of N was nitrate and nitrite, which also suggest N pollution.

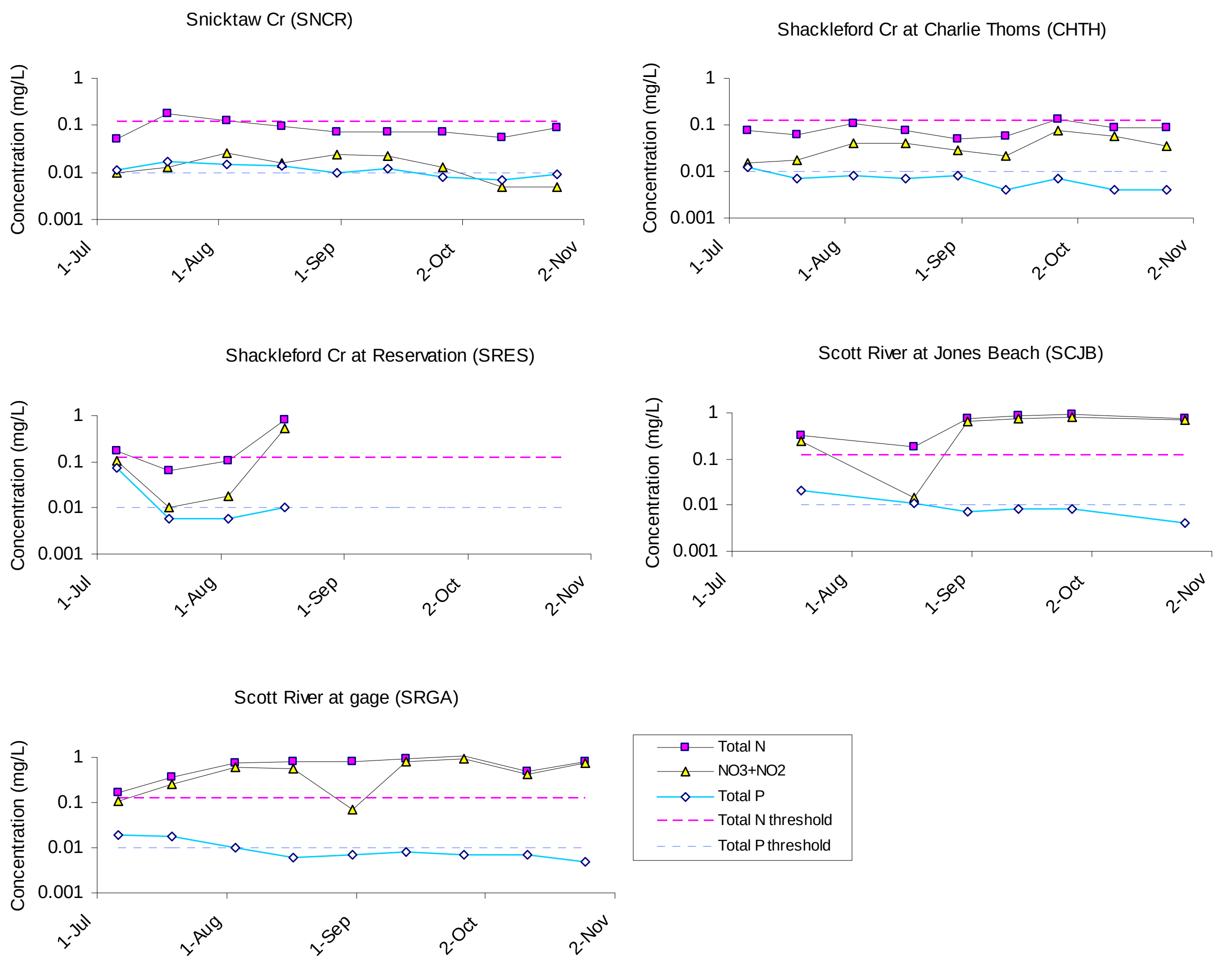


Figure 13: Nitrogen and phosphorus from grab samples of streams near the Quartz Valley Indian Reservation during 2011.

Continuous stream temperature

Continuous stream temperature monitoring shows the importance of the tributaries as summertime cool water sources to the mainstem Scott River (Figures 14 and15). The high elevation tributaries (Figure 14) had low 7-day running average temperatures during late August and were nearly all below the 16.8 C threshold (most were 13 C). Campbell Lake outlet ran warmer at about 17 C. The nearby Summit Lake site stayed cool; it is about ¼ the size of Campbell. Grouse Creek ran slightly warmer at 16 C.

The low-elevation sites had 7-day running averages in late August of about 15 C (Figure 15). The warmest tributary was Shackleford Creek at the Reservation which went dry September 4. The mainstem Scott River at Jones Beach (last graph in Figure 15) showed August average temperatures exceeding both the 16.8 C and the 19 C thresholds, similar to the Scott River site at the gage (Figure 7). Jones Beach average during late August was nearly 21 C which is too warm for salmonids. Being 2 miles downstream of the gage, suggests downstream warming.

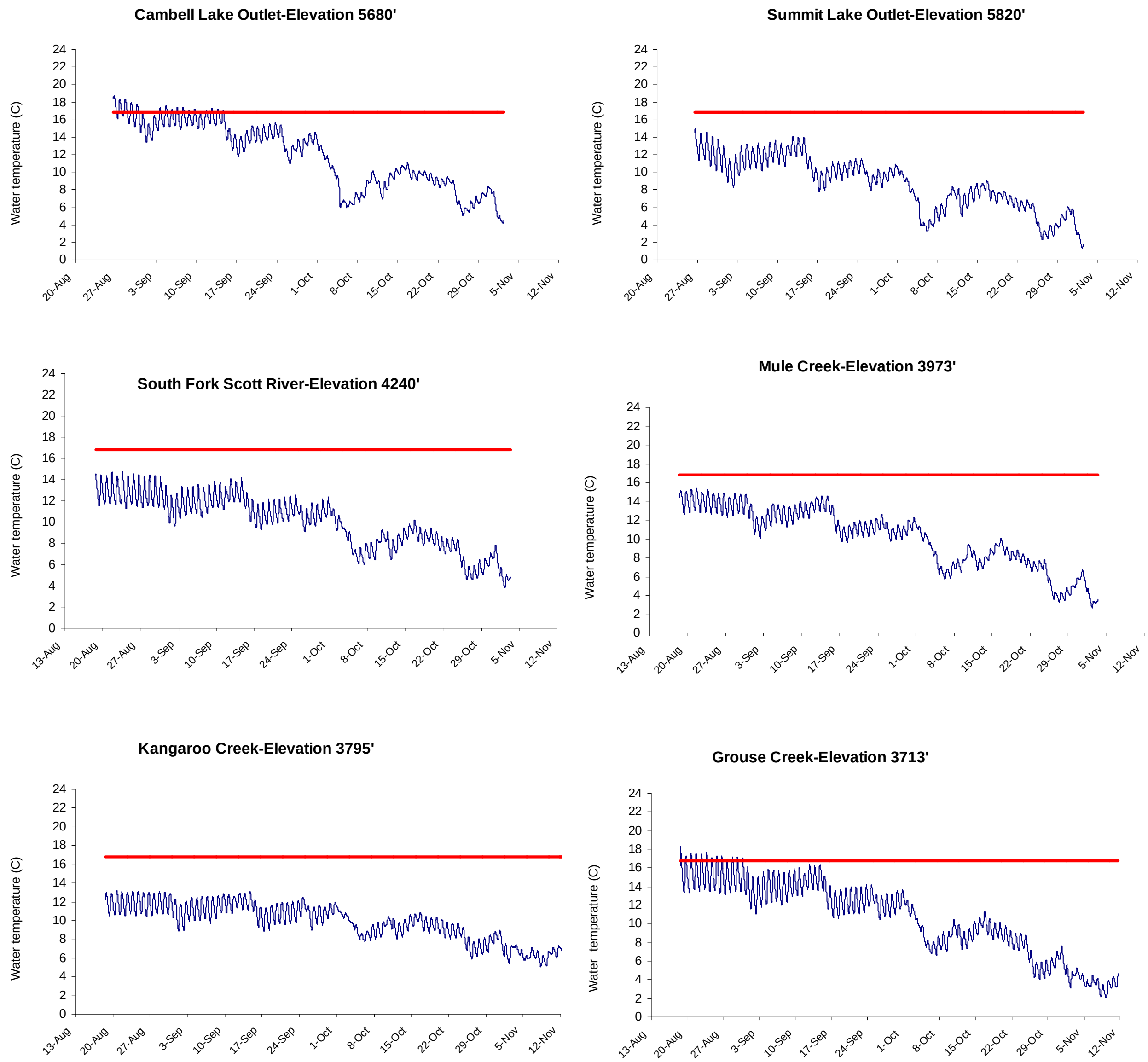


Figure 14: Stream temperatures from high elevation sites in the Scott Valley, 2011. These are 30-minute recordings; the red line is the 16.8 C threshold from Table 1.

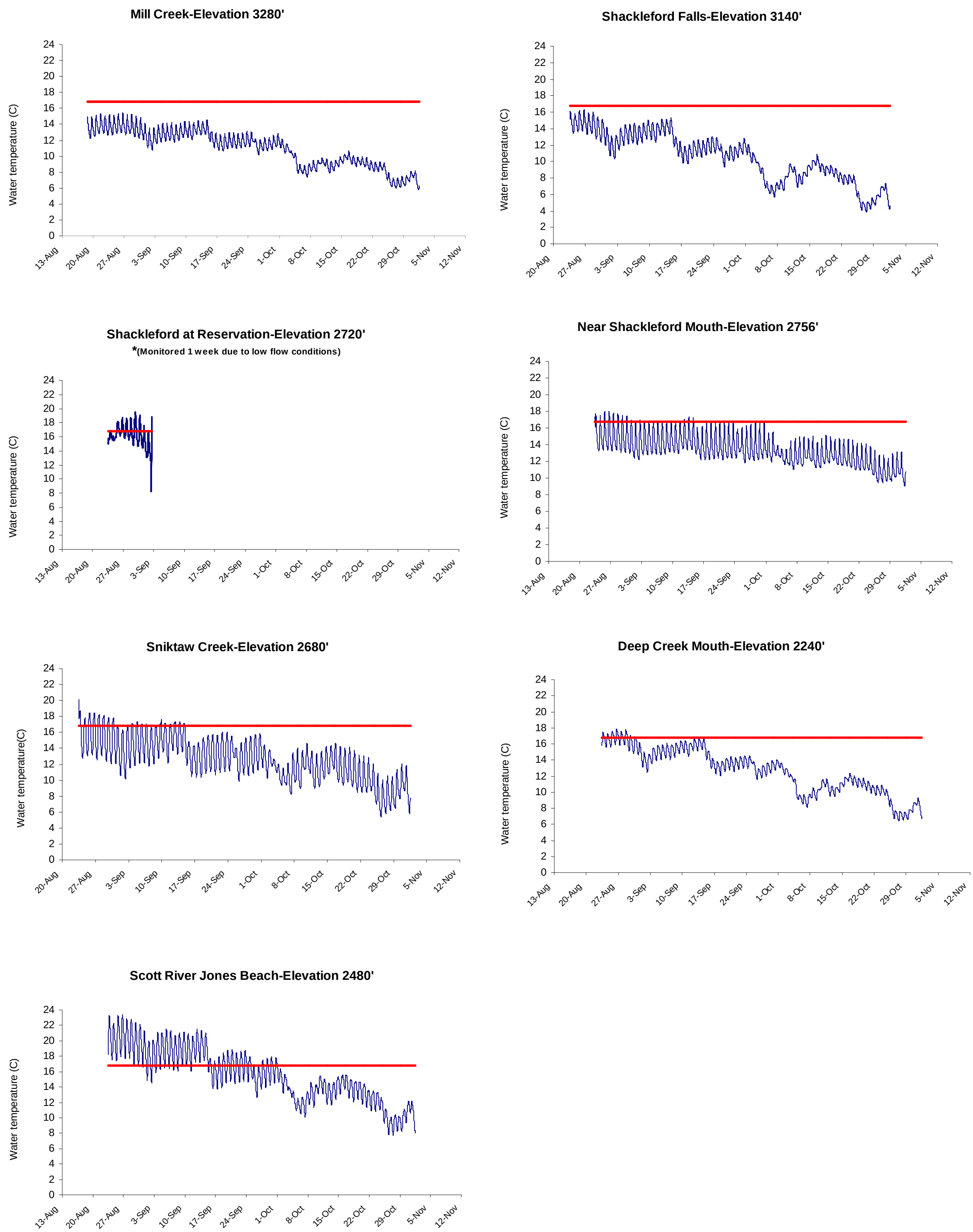


Figure 15: Stream temperatures from low elevation sites in the Scott Valley, 2011. These are 30-minute recordings; the red line is the 16.8 C threshold from Table 1.

Bacteria in surface waters

Bacteria sampling occurred in 2011 bi-weekly from July through October in streams in the Scott Valley. Samples were analyzed in QVIR labs for two types of bacteria—total coliform and *Escherichia coli* (*E. coli*). Total coliform are a general class of bacteria that occupy soils and waters and may come from intestinal tracts of mammals or be naturally free-living. Total coliform are generally harmless but they do indicate possible surface contamination of ground water. *E. coli* are a species of coliform bacteria that are generally obligate associates with mammal intestinal tracts (humans, cattle, or other warm-blooded animals). They normally can survive for only a limited time outside the gut and this makes them ideal indicators for fecal contamination. Not all strains (specific lines of the species) are pathogenic, but some are. Even if the *E. coli* detected in the sample is not pathogenic or disease causing, it is serious concern that other sorts of pathogens may also be present in the sample.

The North Coast Basin Plan objective for bacteria cites the California Public Health Department's draft objective:

> "In waters designated for contact recreation (REC-1) the median fecal coliform concentration based on a minimum of not less than 5 samples during a 30-day period, shall not exceed 50/100 ml…….."
> The US EPA has a single sample maximum value of 235 MPN/100 ml and/or 5 equally-spaced samples, over a 30-day period, with a geometric mean of 126 MPN/100 ml.

These objectives are for fecal coliform, a subclass of coliform that includes *E. coli* and other organisms. The QVIR lab tests for total coliforms would generally be expected to run higher than fecal coliform and *E. coli* would be expected to run lower. It has been stated that 60 to 90 % of total coliforms are often fecal and, 90 % of fecal coliforms are *Escherichia* and typically *E. coli* (APHA 1992). However, in our samples, total coliforms were commonly 1,000 MPN/100 ml whereas E. coli were typically 100 MPN/100 ml.

The Tribe has adopted the more protective standard from the draft state objective of <50 MPN/100 ml over a 30-day period, equally spaced, as well as the EPA single sample maximum value of 235 MPN/100 ml. Because we did not sample for fecal coliforms, we used the objectives for *E. coli* concentrations here as they would be expected to be slightly lower than fecal coliforms.

Total coliform in streams near the QVIR was always present and concentrations ranged from just over 100 to over 2500 MPN/100 mL (Figure 16). 2,500 is as high as our IDEXX system will count and therefore, the highest values in Figure 16 could be somewhat higher. Next year, we will introduce a protocol to dilute samples that exceed 2,500. The sites that produced samples that at least 2,500 were the two sites on the Scott River (gage SRGA and Jones Beach SCJB), Sniktaw Creek (SNCR), Mill Creek (MICR), and East Fork Scott River (SREF). The sites with low counts were South Fork Scott River (SRSF) and Shackleford at Reservation (SRES).

E. coli counts ranged from zero to over 1,000 MPN/100 mL (Figure 17). Sniktaw Creek had the highest counts and about half were over the threshold of 235. East Fork Scott River had consistently the second highest concentrations, but none were over 235—its highest value was 198 on August 3. Scott River at Jones Beach had one high sample nearly at the threshold—228 on August 3. This site is of concern since it is used for public swimming during the summer.

Figure 16: Total coliform in streams in Scott Valley, 2011. Abbreviations for streams are in Table 2.

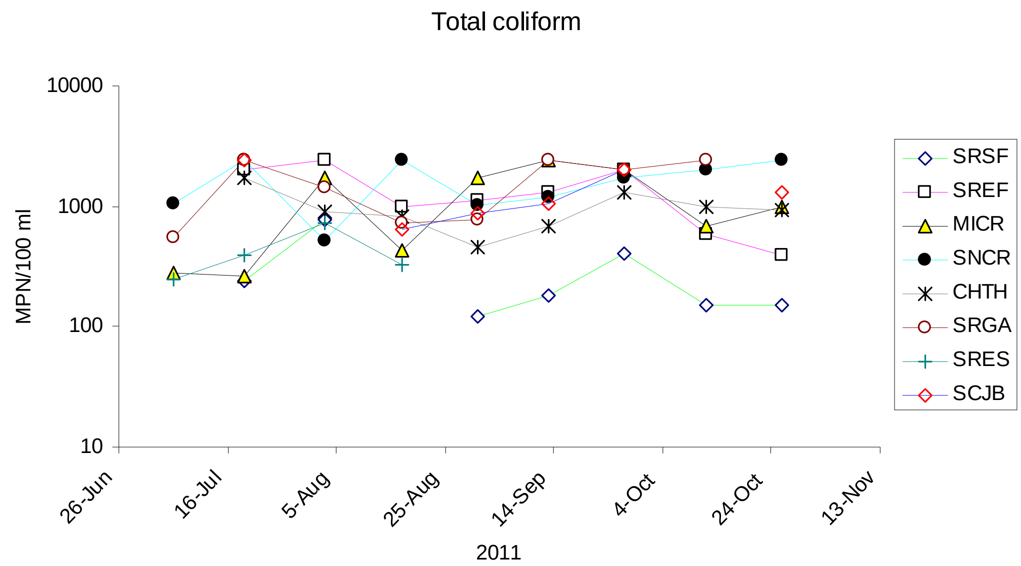
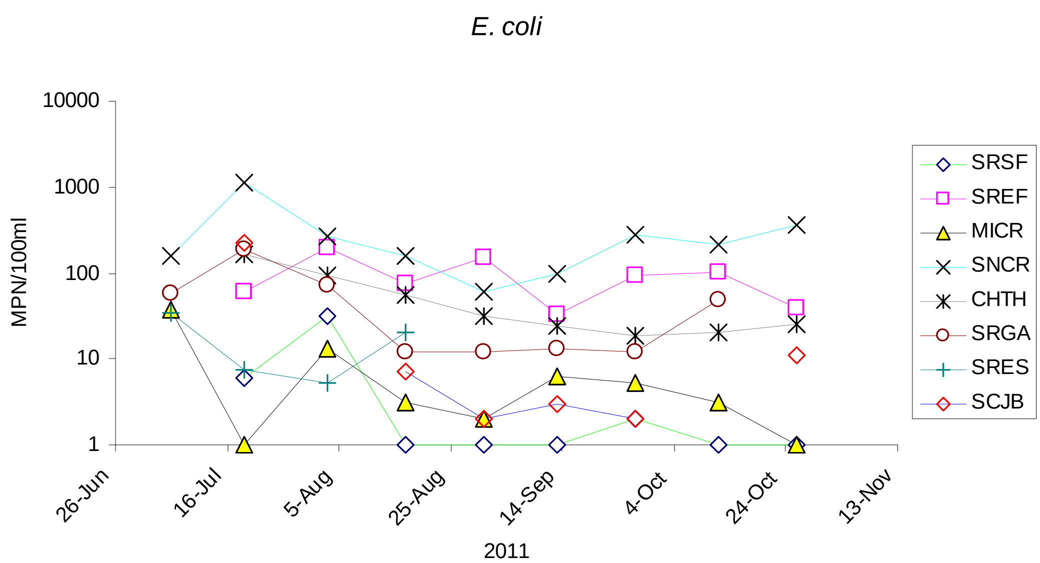


Figure 17: *E. coli* in streams near the Quartz Valley Indian Reservation, 2011.



Groundwater sampling

Well water sampling was conducted monthly. Measures were made for static water levels, chemistry was checked using the hand held datasonde, and samples were collected for total coliforms and *E. coli*. The depth to water in the wells was collected to assist the current groundwater model being developed to satisfy TMDL recommendations. The chemistry and bacterial samples were compared to the quality standards for drinking water from the NCRWQCB (2007) Basin Plan and from USEPA (Table 2).

Static water level

Static water levels were collected on nine wells in 2011 located both on and off the Reservation near Shackleford Creek. The locations of the wells are shown in Figure 3 and site codes are given in Table 3. The depth to water ranged from 10 to 100 feet (Figure 18). The depth to water in the wells increased over the year from February to December. This suggests a net drawdown of water. Longer-term sampling will help to determine if the wells recharge during the winter periods or if there is a long-term decline in water levels. A set of 13 ground water monitoring wells were established this year on the QVIR. These will be instrumented with pressure transducers to provide continuous monitoring of water level depths. The data will eventually be useful for ground water models.

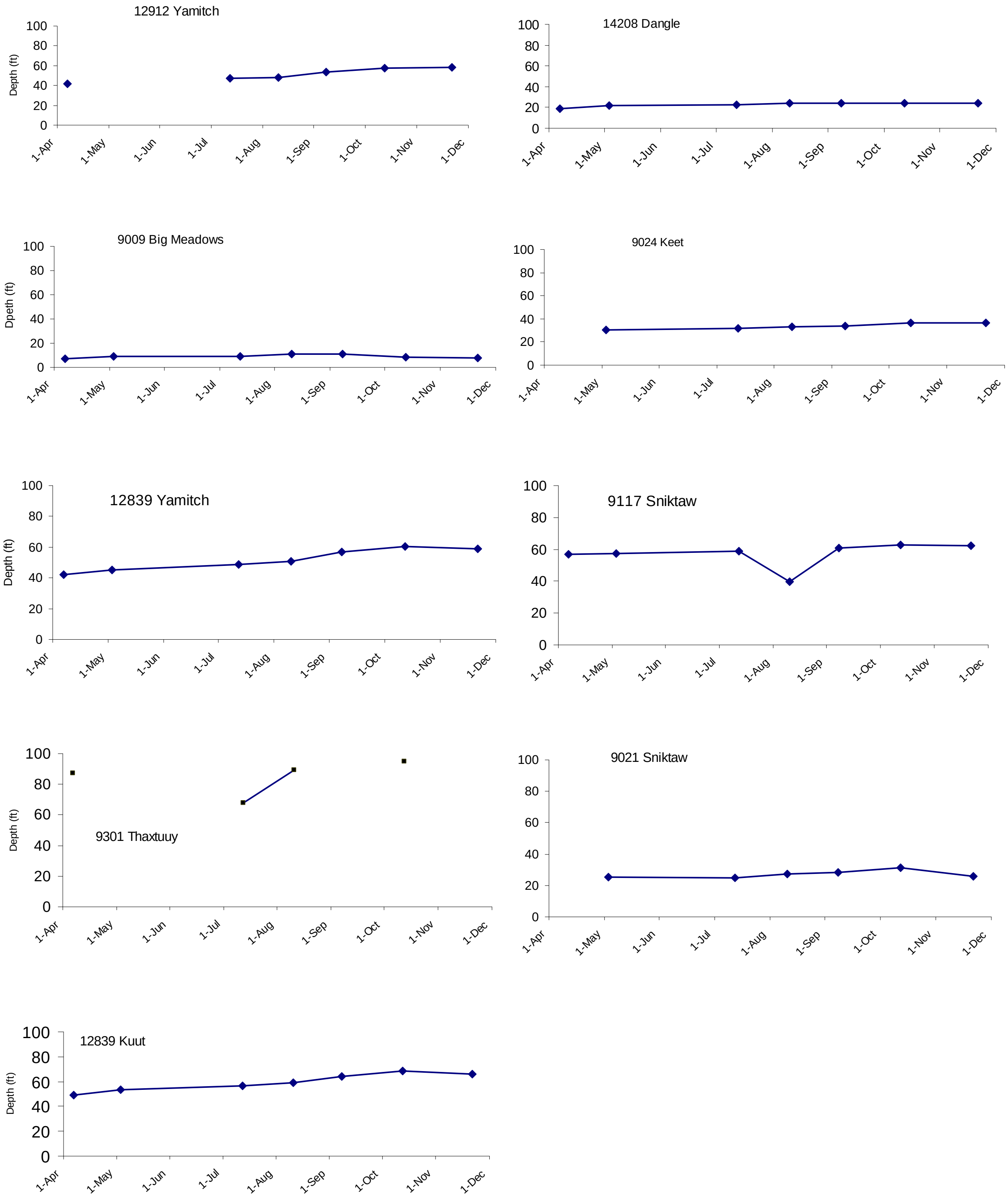


Figure 18: Static water levels in drinking water well on and near the QVIR in 2011.

Ground water bacteria

All drinking water wells were free of *E. coli*. The only positive findings were in an open irrigation ditch (Reservation Ditch) that ran through next to the Environmental Department Building at 13824 Quartz Valley Road (Table 4). The ditch was thought to run near pens containing animals upstream. This ditch was within 50 feet of the drinking water well on the Environmental Department property.

About one-half the drinking water wells had detectable levels of total coliform bacteria (Table 5). The irrigation ditch that ran through the Environmental Department property had high levels of total coliform. The drinking water well of the Environmental Department was within 50 feet of the ditch and this well had the highest measures of total coliform of all the drinking water wells. The soils in the area are recent alluvial deposits and are thought to be highly permeable. It is likely that the source of total coliform in the Environmental Department well was the irrigation ditch.

Table 4: *E. coli* counts (MPN/100 mL) in drinking water wells and one irrigation ditch.

Well address	12-Apr	13-Jul	11-Aug	8-Sep	14-Sep	13-Oct
12837 Kuut	0	0	0	0		0
12839 Yamitch	0	0	0	0	0	0
12912 Yamitch	0	0	0	0		0
13824 Ditch	13			921		308
13824 Quartz V. Rd	0	0		0	0	0
14208 Dangle	0	0	0	0		0
9009 Big Meadows	0	0	0	0	0	0
9021 Sniktaw	0	0	0	0		0
9024 Keet	0	0	0	0		0
9117 Sniktaw	0	0	0	0		0
9301 Thaxtuuy	0	0	0	0		0

Table 5: Total coliform counts (MPN/100 mL) in drinking water wells and one irrigation ditch.

Well address	12-Apr	13-Jul	11-Aug	8-Sep	14-Sep	13-Oct
12837 Kuut	0	0	0	0		0
12839 Yamitch	0	0	0	3	3	0
12912 Yamitch	0	0	0	0		0
13422 Quartz V. Rd			0			
13806 Quartz V. Rd			49			
13824 Ditch	125			2500		866
13824 Quartz V. Rd	3	144		5	1	0
14208 Dangle	0	0	33	0		6
9009 Big Meadows	0	0	0	0	3	1
9021 Sniktaw	0	0	0	0		194
9024 Keet	0	0	0	0		0
9117 Sniktaw	0	0	0	0		0
9301 Thaxtuuy	0	0	0	0		0

Ground water chemistry

Measures of chemistry made with a hand-held datasonde showed that wells were quite consistent over time. Though individual wells showed differences relative to each other. pH of drinking water was quite stable over time in individual wells but ranged from 6 to 7.5 among the wells. The irrigation ditch had slightly higher pH than wells. The lowest pH was 9021 Sniktaw which was one of the shallower wells (Figure 18).

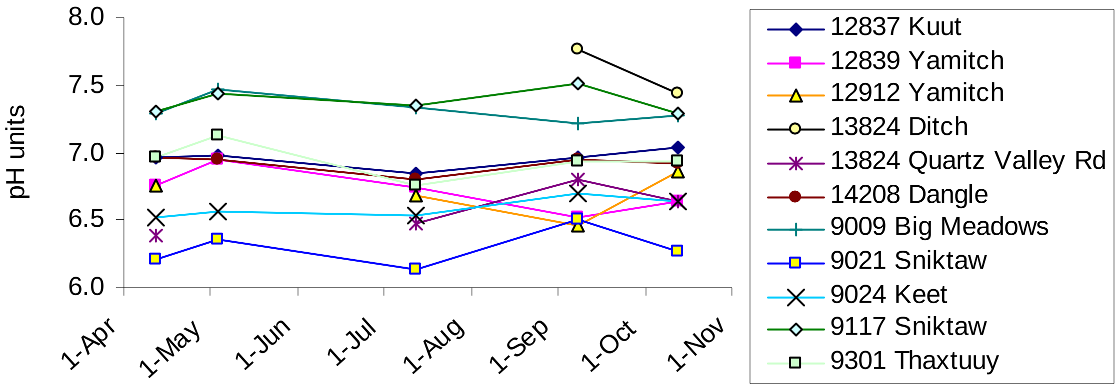
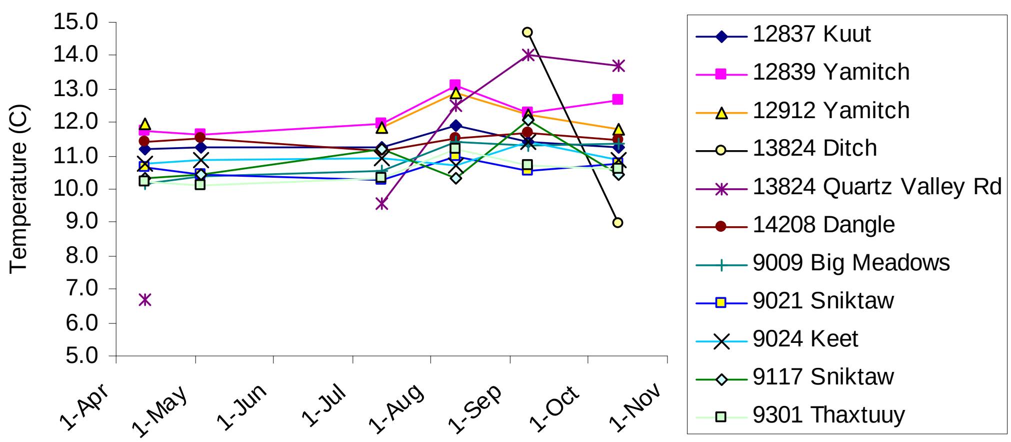


Figure 19: pH in drinking water wells and one ditch at various street addresses in 2011.

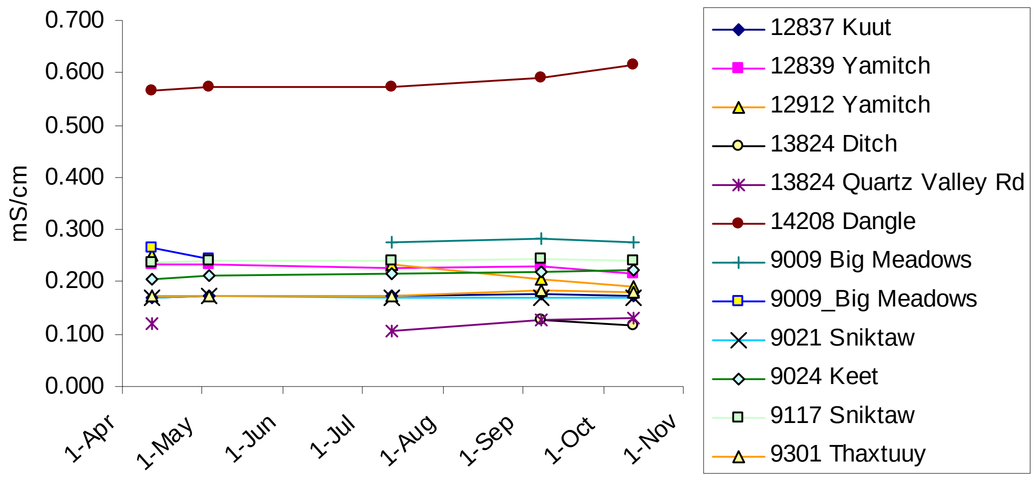
Temperature of well water was generally fairly constant over time but individual wells showed differences among themselves (Figure 20). Temperature generally fell within a tight range from 10 to 12 C. One notable exception was the well at the Environmental Department at 13824 Quartz Valley Road—this well showed increased temperature over the summer. A couple of possible explanations are that this well was not used as much as other wells because it served a business office and this office was using bottled water for drinking and may have had less water use (no clothes washing, no irrigation, little dish washing, mostly flushing toilets). The water may not have turned over in the pressure tank as quickly as other wells. And unless the water was thoroughly run before sampling, it may have warmed up in the pressure tank which was located above ground. Another explanation is that this well was also near the irrigation ditch and showed possible contamination from the ditch. Possibly warmer surface water from the ditch was percolating down to the well and warming the water.

Figure 20: Temperature in drinking water wells and one ditch at various street addresses in 2011.



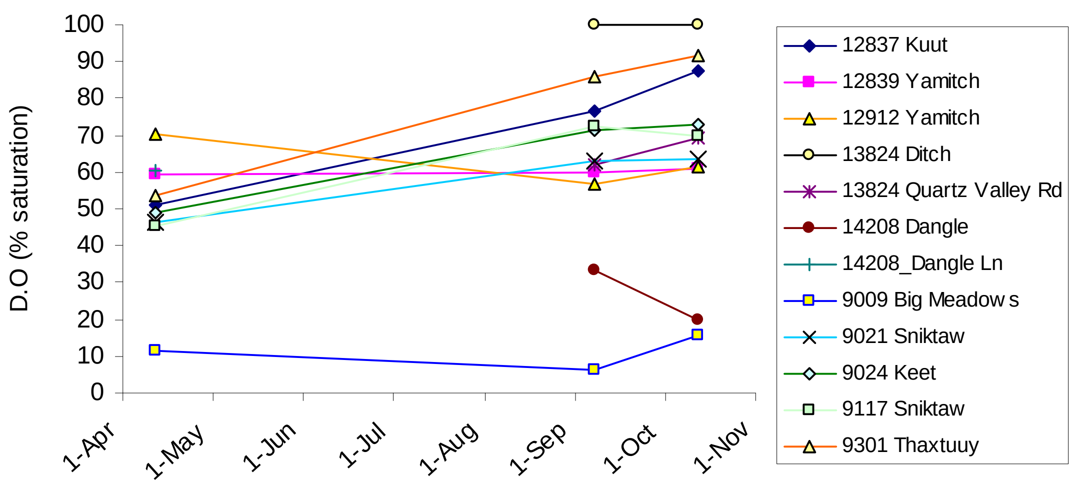
Specific conductivity in wells followed the same pattern as pH and temperature—showing little seasonal variation but showing differences among individual wells (Figure 21). Most wells ranged from 0.100 to 0.300 mS/cm. The well at Dangle Lane showed very high conductivity and suggests high dissolved solids, possibly iron.

Figure 21: Specific conductivity in drinking water wells and one ditch at various street addresses in 2011.



Dissolved oxygen was more variable among wells and many appeared to uniformly change over from spring to fall (Figure 22). Most showed increases, but two showed no change and two showed decreases. Two wells showed quite low levels of dissolved oxygen. For most wells, the % saturation generally ranged from 50 to 70 % in the spring and increased to 60 to 90 % by fall. The ditch at the surface ran at 100 %; the well at Big Meadows and that at Dangle Lane very low oxygen, suggesting reducing conditions. It is generally presumed that the soil reactions will consume oxygen and deeper wells are expected to have lower oxygen. That the two shallow wells had the lowest oxygen may suggest that oxidizing reactions are occurring there.

Figure 22: Dissolved oxygen in drinking water wells and one ditch at various street addresses in 2011.



4. Discussion

Temperature

The mainstem Scott River warms slightly above the standards of 16.8 and 19 C during August. 7-day mean temperatures reached 19.3 on August 10 and were at or above the 19 threshold for about three weeks and peaks reached 23 C (Figure 8). High temperatures were also recorded downstream on the Scott River at Jones Beach during August. Here the 7-day average was about 20 C (Figure 15). These high temperatures were confirmed by spot measures made during August and September when maximum temperature of 21 C were observed during the afternoons at the gage. It is likely the entire canyon reach and likely other areas of the mainstem in the valley are too warm for coho and probably steelhead rearing during the months of July through September. Though the early morning temperatures cool to about 16 C and juveniles may be able to find refuge in amongst the cobbles where subsurface flow may provide cooler water.

The tributaries appear to be important sources of cool water during the summer. All tributaries generally had 7-day average temperatures in August of 15 C (Figure 15) and could be important temperature refuges for rearing coho juveniles. Indeed large numbers of coho juveniles were observed in Patterson Creek in pools that were nearly dry but were being maintained by mostly subsurface flow. Shackleford Creek had coho in isolated pools in September that were surviving on subsurface flow. 300 coho and about 100 steelhead juveniles were rescued by QVIR staff before the stream went entirely dry at Quartz Valley Road. Access to these cool water refuges will depend on maintaining connectivity during the low flow period.

Temperature in wells near QVIR in August was 12-14 C (Figure 20) and indicated that the ground water is slightly cooler than the small tributaries. Interflow of surface water with ground water may be one way tributaries stay as cool.

Dissolved Oxygen

Dissolved oxygen was good throughout the basin in 2011. The daily mean concentration stayed above 8 mg/L at the Scott River mainstem at the gage site during the warm period of August (Figure 10). Severe diurnal fluctuations were observed during August through October. These fluctuations may have been due to bio-fouling of the sensors, but require further investigation.

Spot checks of dissolved oxygen in the mainstem and tributaries where grab sampling was performed confirmed that dissolved oxygen was above 8 mg/L throughout August to September.

Dissolved oxygen in wells indicated that two shallow wells may have some biological oxygen demand and may be compromised by surface sources (Figure 22).

pH

No problems with pH were observed in surface or groundwater. The mainstem Scott River at the gage stayed between 7.4 and 8.0 (Figure 11). The large diurnal fluctuations observed in August to October may be to be due to bio-fouling but require further investigation.

A review of spot checks of pH made with the hand held datasonde when grab sampling was performed (data not presented) showed most sites were between 7 and 8. However, several sites on the mainstem Scott River or the East Fork did show pH measures above 8 during later summer and during the afternoon. For example, Jones Beach had the highest measures of 8.45 and 8.41 during a two week interval in September. These data suggest that the fluctuations in Figure 11 may be real and not due to bio-fouling of the sensor. It is possible that the swings are due to eutrophication and excessive algae in the system (though this was not observed in the field). We will be following up on this as pH over 8.5 at temperatures over 25º C converts ammonium ions to highly lethal dissolved ammonia (Goldman and Horn 1983). While ammonium is not thought to be high in the Scott River, these fluctuations are still a concern as they may suggest a failure to maintain stable chemistry.

pH in wells showed no problems or concerns (Figure 19). Perhaps the 9117 Sniktaw well may be examined because it had low pH of near 6.0. This may be simply a mineral source or it may suggest acidifying conditions such as organic acids.

Nitrogen and phosphorus

Nitrogen was slightly elevated (e.g., 1 mg/L) in the mainstem Scott River at the gage site and at Jones Beach (Figure 13). These sites showed that much of the total N was in the nitrate form. Shackleford Creek at the Reservation also had elevated total N and nitrate during August. There is human access to the stream here. The high measure was about two weeks before the stream went subsurface and elevated N may have been due to dead and decaying fish or decaying attached algae. The other sites had low levels of N (e.g. 0.1 mg/L).

Phosphorus was generally low (e.g. 0.01 mg/L) at the grab sample sites (Figure 13).

Nitrogen can indicate sources of pollution or disturbance and can stimulate the growth of algae and aquatic macrophytes to nuisance levels that can adversely impact water quality (diurnal swings in dissolved oxygen and pH as seen during base flow with the continuous data at the gage site). The concentration of nutrients required to cause nuisance levels of periphyton varies widely from one stream to another (U.S. EPA, 2000b; Tetra Tech, 2004, 2006). The U.S. EPA's (2000a) Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II provides general guidance.

Specific Conductivity

Specific conductivity showed few issues in 2011. Specific conductivity increased to over 0.250 mS/cm at the gage site in September (Figure 9). Spot checks of specific conductivity made during the grab sampling showed that the gage site and Jones Beach on the mainstem and the East Fork Scott River all had a trend of higher conductivity but typically in the range from 0.200 to 0.300 mS/cm.

Specific conductivity was high (0.600 mS/cm) in the well at Dangle Lane. Other wells were below 0.300 mS/cm. The well at Dangle Lane has a higher water level and also showed presence of total coliforms twice this year.

Bacteria

Bacteria was not a large problem in 2011. Total coliform and *E. coli* were present in nearly all surface water. Total coliform is not thought to pose a problem. *E. coli* were generally below the 235 MPN/100 mL threshold (Figure 17). *E. coli* may indicate low levels of contamination from humans or cattle. The highest levels were found at Sniktaw Creek, East Fork Scott River, and Jones Beach. Sniktaw and East Fork may have low level contamination by cattle, whereas Jones

Beach does not appear to have cattle grazing nearby and could be been showing low level effects from leachfields. UC Davis is performing a study of sources of *E. coli* in the Shackleford basin in cooperation with the US Forest Service and QVIR.

Turbidity

Turbidity showed highly fluctuating measures at the gage site on the mainstem Scott River (Figure 12). High turbidity is expected during stormflow in winter and spring. Turbidity can be easily confounded by bio-fouling of continuous sensors. This is suspected to have occurred during August to October on the datasonde. Otherwise, most measures from the datasonde showed values less than 10 NTUs. No turbidity measures were taken with the hand held datasonde during the grab sampling.

Water level changes

Water levels in most wells show declines over the summer of 2011 of a few feet to up to 20 feet, such as 12839 Kuut (Figure 18). Shackleford Creek also dried up and went subsurface about September 4. It regained flow about one month later and dried up a second time. 2011 was a wetter year as indicated by the low flow discharges measured at the Scott River gage (Figure 7). Though, it appears that since 1977, the Scott River has experienced more frequent very low flows (Figure 6). We will be instituting a ground water monitoring project using continuously recording water levels in the 13 ground water monitoring wells established this year.

Overall Integrated Summary

Our data suggests that water quality on Shackleford Creek in 2011 was relatively good for fish in the upper basin and in the lower sections that are able to retain surface flows. Shackleford Falls located one mile upstream of the reservation, is about 12-feet high and is a barrier to upstream migration to all fish, except perhaps steelhead in years with high flows. However, trout are present upstream. The greatest challenge to Shackleford Creek is that it does not maintain flow over the entire year. Casual observations indicated that the section at Quartz Valley Road went dry about the first week of September for about four weeks. Coho and steelhead juveniles were stranded in pools maintained by subsurface flow for about one week until these went dry. Flow likely resumed at the confluence with Mill Creek (~1 mile downstream) as the flow at the lower Quartz Valley Road bridge (near the junction with Dangle Lane) never went dry this year.

Ways to resolve the issue of drying stream channels would be the most important management priority. Either analyses of water use or studies of the channel bed and permeability may shed light on ways to maintain minimal surface flows for coho and steelhead juveniles during summer.

Groundwater used to have total coliform and *E. coli* contamination as documented by the tribe in previous year's data and reports. Groundwater wells are the Tribe's primary drinking water source. But this year, no wells had detected *E. coli* and 6 wells had total coliform. A series of new wells were drilled this year and depths were increased to over 100 feet. These deeper wells have all showed no bacteria in sampling so far. Also these wells have shown very little drawdown during pumping tests and are thought to be able to deliver high rates of water (up to 100 gallons per minute). The well logs showed deep permeable alluvium and this is thought to hold large reserves of groundwater.

The Scott River datasonde showed large diurnal fluctuations of pH, turbidity, and dissolved oxygen during August through October. It is thought this was due to bio-fouling, but this needs to be verified. If bio-fouling is the cause, either copper alloy screens should be tried or more frequent maintenance is needed. If bio-fouling is not the cause, the aquatic system may be showing instability that could be due to eutrophication (nuisance algal growth).

Nitrogen concentrations show some evidence of low level contamination as does the low levels of *E. coli* that was detected in most streams. *E. coli* should be closely monitored as it may begin to pose problems for contact recreation at Jones Beach.

Overall, water quality in the tributaries is much more suitable to salmonids than the mainstem. Tributaries are much cooler while the mainstem Scott River reaches summer time temperatures over 20 C. The main problem is many of the tributaries along the west side of the valley were observed to go dry as flow went subsurface into the large alluvial deposits that occur at where the tributaries enter the valley floor.

Future Sampling

Surface water

Water chemistry will be monitored using the continuous recording datasonde at the gage site. Grab samples will also continue for chemistry and bacteria. The Hobo temperature array will be continued with minor modifications to sites selected.

We have funding to establish a new stream gaging site somewhere in the basin. A site closer to the mouth of the Scott or one on Shackleford Creek is being considered.

Because of staff turnover in 2011, periphyton (benthic algae) samples were not collected. In 2012, periphyton will be collected in the Scott River in collaboration with the Tribal Water Quality Work Groups basin wide efforts. As noted, pH and D.O. levels in the Scott River indicate high levels of periphyton are probably present at the Scott River gage and/or in areas upstream. Sampling and analyzing benthic algal levels will help identify factors that contribute to increased algal growth, so that potential restoration efforts can be targeted. Algae sampling protocols from the state SWAMP program will be utilized. Samples should be analyzed for algal species composition and biomass (benthic chlorophyll a concentrations in units of mass per area of streambed, not to be confused with water column chlorophyll a concentrations in units of mass per water volume). If collected at multiple dates through the low-flow summer season, the data will provide information on the timing and magnitude of peak algal biomass.

Groundwater

In 2011, with funding from the Bureau of Reclamation, thirteen monitoring wells were drilled in an array that should provide spatial modeling of ground water flow patterns around Shackleford Creek near the QVIR. In 2012, static water level will be monitoring using continuously recording Onset level-loggers. We will continue the bacterial and chemistry monitoring of wells.

5. References

American Public Health Association (APHA). 1992. Standard methods for the examination of wastes and wastewater, 18th ed. Table 9225:I. p. 9-66. Cited from http://www.cnawater.com/WhatAreColiformsEColi.html

Berg, L. 1982. The effect of short term pulses of suspended sediment on the behavior of juvenile salmonids. Pages 177-196 in G.F. Hartman et al. editors. Proceedings of the Carnation Creek Workshop: a ten-year review. Department of Fisheries and Oceans, Nanaimo, B.C.

Elliot, J 1981. Some aspects of thermal stress on freshwater teleosts. In Pickering, A.D. ed., Stress and Fish: Academic Press, London.

Goldman, C.R. and A.J. Horne. 1983. Limnology. McGraw-Hill, Inc. New York . 464 pp

Lloyd, D.S. 1987. Turbidity as a water quality standard for salmonid habitats in Alaska. North American Journal of Fisheries Management. 7:34–45.

Mack, S. 1958. Geology and ground-water features of Scott Valley Siskiyou County, California. Geological Survey Water-Supply Paper 1462. Prepared in cooperation with the California Dept of Water Resources. Washington Government Printing Office Washington DC. http://www.scottriver.org/wp-content/uploads/2011/10/Mack1958.pdf

North Coast Regional Water Quality Control Board (NCRWQCB). 2007. Water Quality Control Plan for the North Coast Region (Basin Plan). NCRWQCB, Santa Rosa, CA.

Quartz Valley Indian Reservation (QVIR) 2006a. Quality Assurance Project Plan for Water Quality Sampling and Analysis, CWA 106 grant identification # I-96927206-0. Prepared by Quartz Valley Indian Reservation with technical assistance from Kier Associates and Rebekah Sluss.

QVIC Monitoring Plan. 2006b. Quartz Valley Indian Reservation Water Quality Monitoring Plan. Prepared by Kier Associates for Quartz Valley Indian Reservation, Fort Jones, CA.

Quartz Valley Indian Community. 2006c. Review of public draft Shasta River Temperature and Dissolved Oxygen TMDLs. Quartz Valley Indian Reservation, Ft. Jones, CA.

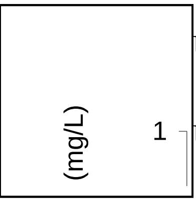
Quartz Valley Indian Community. 2008. Water Quality Assessment Report. Quartz Valley Indian Reservation, Ft. Jones, CA.

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute. Portland, OR. 192 pp.

Tetra Tech, Inc. 2004. Progress Report Development of Nutrient Criteria in California: 2003-2004. Prepared for US EPA Region IX. Tetra Tech, Lafayette, CA.

Tetra Tech, Inc. 2006. Technical Approach to Develop Nutrient Numeric Endpoints for California. Prepared for U.S. EPA Region IX. Tetra Tech, Inc. Lafayette, CA.

U.S. Environmental Protection Agency. 1986. Ambient Water Quality Criteria for Bacteria. Office of Water, Washington D.C. EPA-822-R-99-014.



U.S. Environmental Protection Agency. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. Office of Water, Washington D.C. EPA-440/5-86-001.

U.S. Environmental Protection Agency. 1999b. 1999 Update of Ambient Water Quality Criteria for Ammonia. Office of Water, Washington D.C. EPA

U.S. Environmental Protection Agency. 2000a. Ambient Water Quality Criteria Recommendations for Rivers and Streams in Nutrient Ecoregion II. Office of Water, Washington D.C. EPA 822-B-00-015. 120 p.

U.S. Environmental Protection Agency. 2000b. Nutrient Criteria Technical Guidance Manual: Rivers and Streams. Office of Water and Office of Science and Technology , Washington D.C. EPA-822-B-00-002.

U.S. Environmental Protection Agency (USEPA). 2002. Surface Waters Western Pilot Study: Field Operations Manual for Non-Wadeable Rivers and Streams (Draft). Environmental Monitoring and Assessment Program, Office of Research and Development, U.S. EPA, Washington D.C. 227 p.

U.S. Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA Project # 910-B-03-002. Region 10 U.S. EPA, Seattle WA. 57 p.

U.S. Environmental Protection Agency. 2006. Edition of the Drinking Water Standards and Health Advisories. Office of Water. 11p.

Welsh, H.H., G.R. Hodgson, M.F. Roche, B.C. Harvey. 2001. Distribution of Juvenile Coho Salmon (Oncorhynchus kisutch) in Relation to Water Temperature in Tributaries of a Northern California Watershed Determining Management Thresholds for an Impaired Cold-water Adapted Fauna. In review for publication in the North American Journal of Fisheries Management. 21:464-470, 2001.