SOURCES AND TIMINGS OF WATER QUALITY IMPAIRMENTS IN THE LOWER CALAVERAS RIVER, CALIFORNIA, 2006-2008

SOURCES AND TIMINGS OF WATER QUALITY IMPAIRMENTS IN THE LOWER CALAVERAS RIVER, CALIFORNIA, 2006-2008

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ABSTRACT

Many waterways in California's Central Valley have water quality impairments resulting from urban and agricultural impacts, and the Lower Calaveras River (LCR) is no exception. During both wet and dry seasons measurements of water quality parameters are conducted in the upper reaches of the LCR, with a study goal of identifying the geographic locations of both point and non point sources of these impairments. The LCR begins at the outlet for New Hogan Dam (NHD) near Valley Springs and flows west to Bellota where it is divided into the Old Calaveras River and Mormon Slough. The LCR provides drinking and irrigation water to the City of Stockton and surrounding communities, as well as the majority of Calaveras County. The LCR is habitat for threatened Chinook Salmon and Steelhead Trout.

Water quality measurements have been collected during a number of longitudinal surveys – two during extended dry periods and the remaining immediately following major precipitation events during water years 2006 and 2007. Field measurements of temperature, conductivity, pH, dissolved oxygen, and turbidity were collected at up to 10 monitoring sites. In addition, samples were collected for E. coli, total coliform (TC), and standard geochemical analysis at the University of the Pacific.

Results indicate there a positive correlation between turbidity and bacteria levels. In addition, nitrate concentrations positively correlate to E. coli in some of the tributaries to the LCR. These correlations suggest bacteria may originate from the same source as the turbidity and/or nitrate. Cosgrove creek, a tributary leading into the LCR immediately

downstream of NHD, exhibits the highest levels of bacteria. In addition, two smaller unnamed tributaries also contributed significant levels of bacteria to the LCR. Possible sources of bacteria entering Cosgrove Creek are livestock around the upper reaches of Cosgrove and urban runoff around the lower reach of Cosgrove Creek. Possible sources of bacteria entering the smaller tributaries are leaky septic tanks and agriculture runoff .

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ABBREVIATIONS AND ACRONYMS

µs/cm	Microsiemen per centimeter
USACE	U.S. Army Corps of Engineers
Basin Plan	Water Quality Control Plan, Central Valley Region
CCWD	Calaveras County Water District
CEQA	California Environmental Quality Act
CMS	Cubic meters per second
CRWMP	Calaveras River Watershed Management Plan
CWA	Clean Water Act
DO	Dissolved oxygen
DWR	California Department of Water Resources
EPA	U.S. Environmental Protection agency
GIS	Geographic information system
LCR	Lower Calaveras River Watershed
MCL	Maximum contaminant level
mg/L	Milligrams per liter
MUN	Municipal and Domestic Supply
NEPA	National Environmental Policy Act
NPS	Nonpoint source
REC-1	Water contact recreation
RWQCB	Regional Water Quality Control Board
SDWA	Safe Drinking Water Act
SEWD	Stockton East Water District
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
USGS	U.S. Geological Survey
WMP	Watershed Management Plan
WTP	Water Treatment Plant

INTRODUCTION

With the increase in population and land use intensity throughout California many of California's waterways are experiencing degradation of water quality. An increasing number of watersheds are becoming impaired and the Lower Calaveras River (LCR) is one of them. The LCR has been identified by the California Unified Watershed Assessment and the EPS's 303(d) list as an impaired watershed. It is estimated that population will increase by about 10,000 additional residents every decade for the next four decades in Calaveras County. For San Joaquin County population is expected to increase by between 18-25 percent per decade for the next four. These population increases may have a significant impact on potential sources of contaminants in the LCR.

Stockton East Water District, through existing monitoring protocols identified increases in bacteria levels in the LCR associated with storm events to be a primary water quality impairment. However, SEWD has not conducted a comprehensive survey of microbes in the LCR. Therefore, the source of bacteria to the LCR remains poorly understood. The goal of this project was to monitor basic water quality parameters and bacteria levels in the LCR system to identify possible sources of water quality impairments and correlate them with land use .

The Central Valley RWQCB provides a summary of water quality goals in A Compilation of Water Quality Goals (CVRWQCB 2000). The Central Valley developed water quality control plans (Basin Plan) for each watershed in the Central Valley. The Basin Plan provides water quality objectives for all waters within the Central Valley. Table 1. Summarizes the water quality objectives applicable to the LCR watershed, including the area where the Calaveras River intersects the Sacramento-San Joaquin Delta (Delta).

Parameter	Requirement
Total Coliform Concentration	No one sample shall exceed 10,000 CFU/100 mL
E. coli Concentration	No one sample shall exceed 235 CFU/100 mL
Dissolved Oxygen	The concentration shall not be reduced below 7.0 mg/L
pH	Shall not be depressed below 6.5 nor raised above 8.5 units
Temperature	At no time shall waters be increased more than 5º F above natural temperature
Turbidity	Where natural turbidity is between 0 and 5 NTU, increases shall not exceed 1 NTU Where natural turbidity is between 5 – 50 NTU, increases shall not exceed 20%

Table 1. *Calaveras River water quality standards (adapted from CVRWQCB Basin Plan)*

The Porter-Cologne Water Quality Control Act of 1969 legislates the State Water Resource Control Board (SWRCB) and the Regional Water Quality Control Boards (RWQCB) to preserve and enhance the quality of California's water resources for the benefit of present and future generations (California SWRBR. 2006). The SWRCB implements its water quality protection authority through the adoption of specific Basin Plans.

The scope of this project is to perform a water quality assessment for the upper reaches of the LCR watershed. The following specific goals were set in order to provide beneficial information to the water districts. 1. What is the seasonal and annual variability in basic water quality and bacteria concentrations. 2. What are the sources of pollution? 3. How do current conditions compare to state water criteria for basic water quality and bacteria concentrations?

SITE DESCRIPTION

The Calaveras River originates in the foothills of the Sierra Nevada and flows through Calaveras, San Joaquin, and Stanislaus Counties in California's Central Valley. The Calaveras River continues downstream and directly connects into the San Joaquin River System and the Sacramento – San Joaquin Delta, which ultimately discharges into San Francisco Bay (Figure 1). The lower Calaveras River (LCR) begins downstream (west) of New Hogan Dam and comprises approximately 465 square kilometers. Located near Valley Springs, California, is New Hogan Dam, completed in 1963 by the Army Corps of Engineers (USACE). New Hogan Dam is primarily used for flood control, drinking and irrigation waters are stored in New Hogan for the city of Stockton and surrounding communities. Stockton East Water District (SEWD) maintains control of releases from New Hogan Dam expect for during flood conditions, when the USACE assumes control.

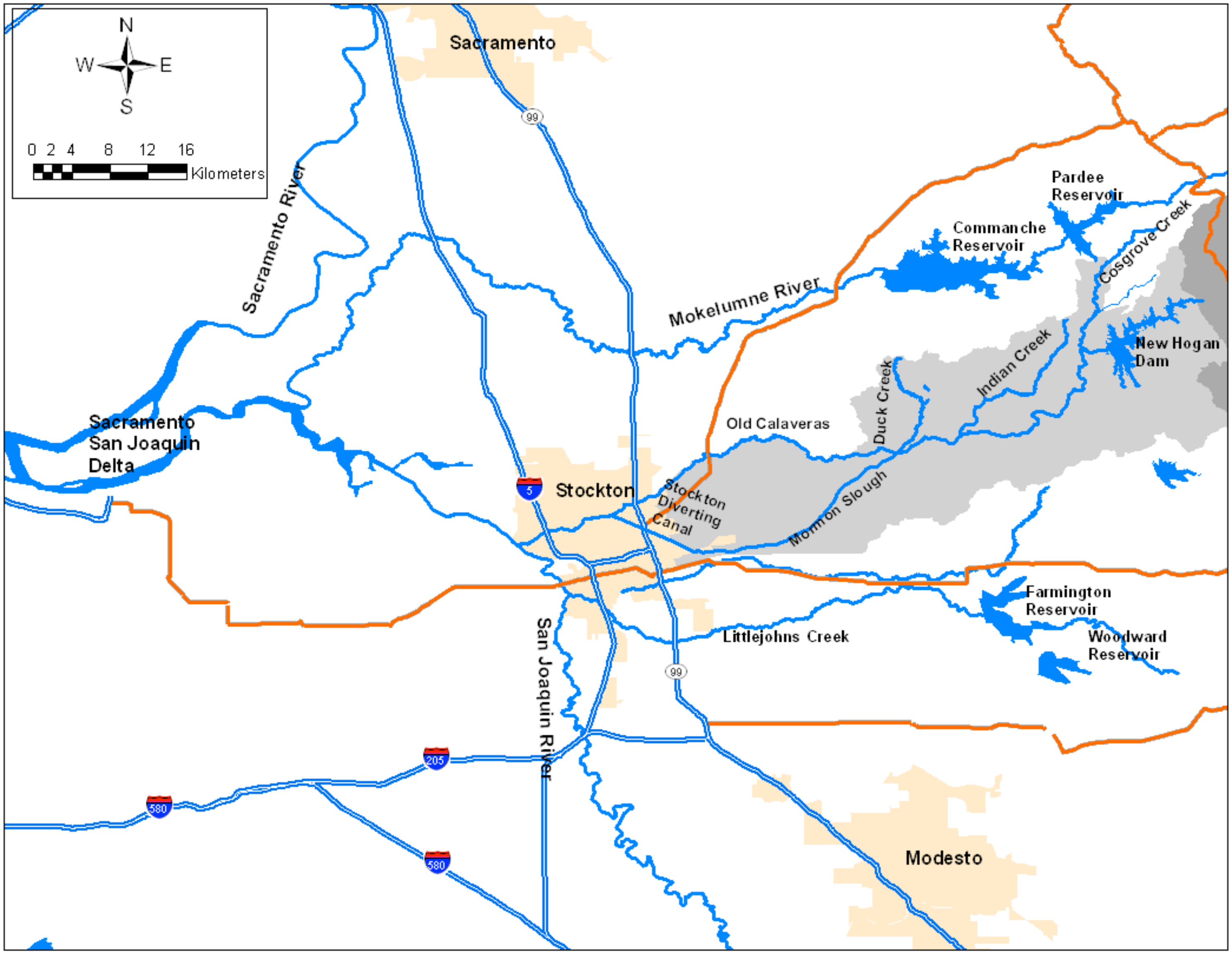


Figure 1. *Location map showing the Lower Calaveras River (LCR) watershed in central California. The LCR begins at New Hogan Dam and flows through Stockton, CA, where the LCR discharges into the San Joaquin River.*

Approximately 29 kilometers downstream from New Hogan Dam, the LCR is divided at Bellota into the Old Calaveras River and Mormon Slough (Figure 2). In the city of Stockton, the Stockton Diverting Canal, an engineered channel, reconnects the Old Calaveras River Channel and Mormon Slough. These diversions are done by SEWD in order to provide water for agricultural purposes below Bellota.

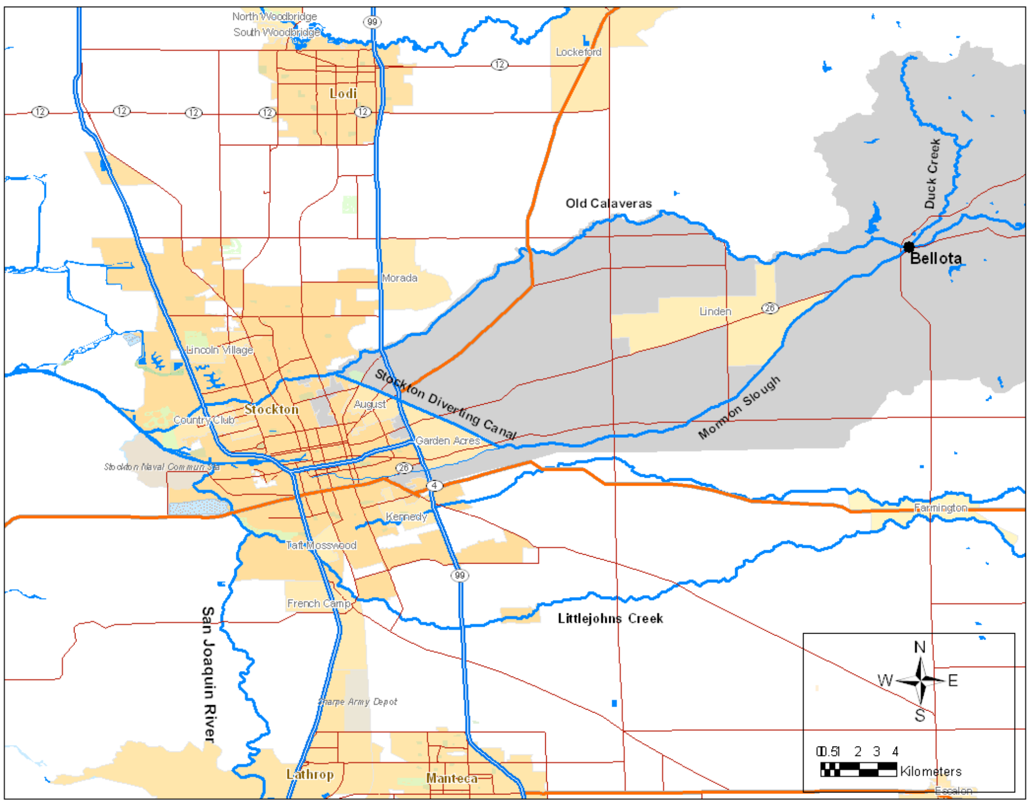


Figure 2. *The Calaveras River splits into the Old Calaveras River and the Mormon Slough at Bellota. They are reconnected in Stockton by the Stockton Diverting Canal. Both the Mormon Slough and the Calaveras River flow into the San Joaquin River.*

Four main tributaries contribute to the LCR downstream of New Hogan Dam and include Cosgrove Creek, South Gulch, Indian Creek, and Duck Creek (Figure 3). Additionally, numerous small-unnamed tributaries contribute flow to the LCR during periods of intense rainfall.

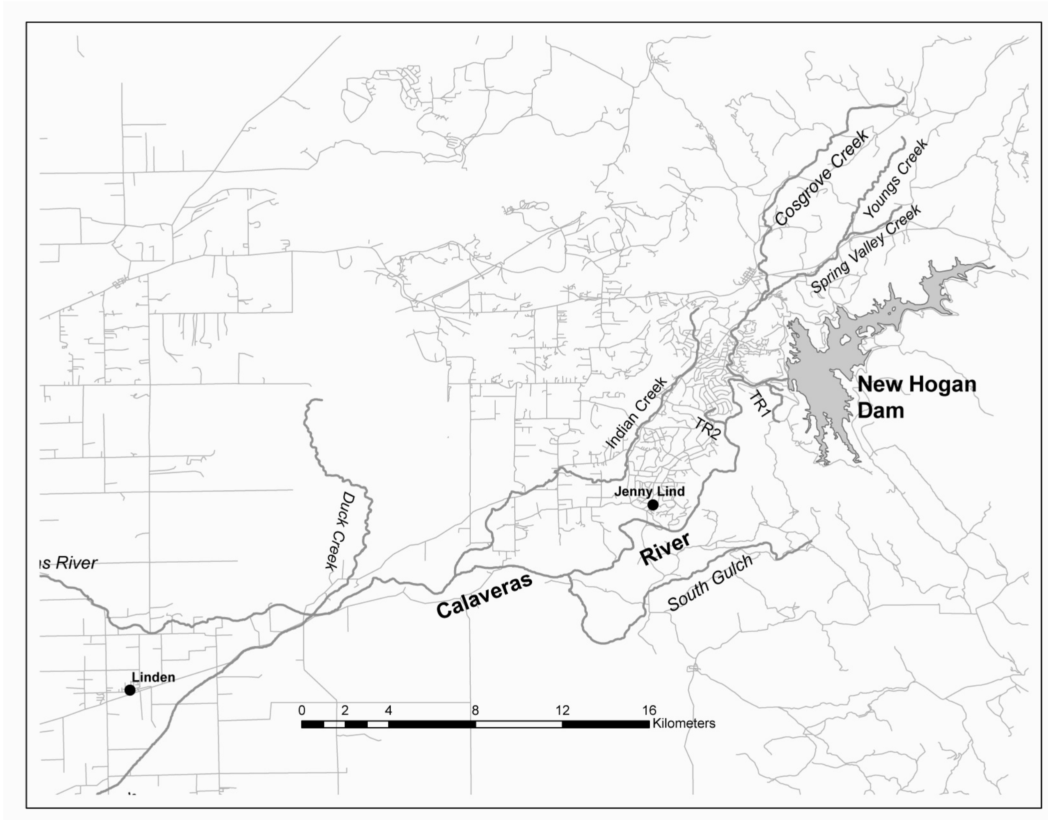


Figure 3. *Location map showing the main tributaries of the LCR (Cosgrove creek, South gulch, Indian creek, and Duck creek) and two un-named tributaries (TR1 and TR2).*

During major precipitation events, Cosgrove Creek follows its natural course and contributes the largest proportion of discharge to the LCR during precipitation events during the rainy season (October-April) (Figure 4). Cosgrove Creek contributes discharge as high as 10,500,000 cubic meters per year to the LCR. Recent studies indicate that when discharge exceeds 2.8 cubic meters per second at Cosgrove Creek, discharge increase downstream on the LCR at Shelton Road, Bellota, and occasionally Mormon Slough (Calaveras River Watershed Stewardship Group 2005).

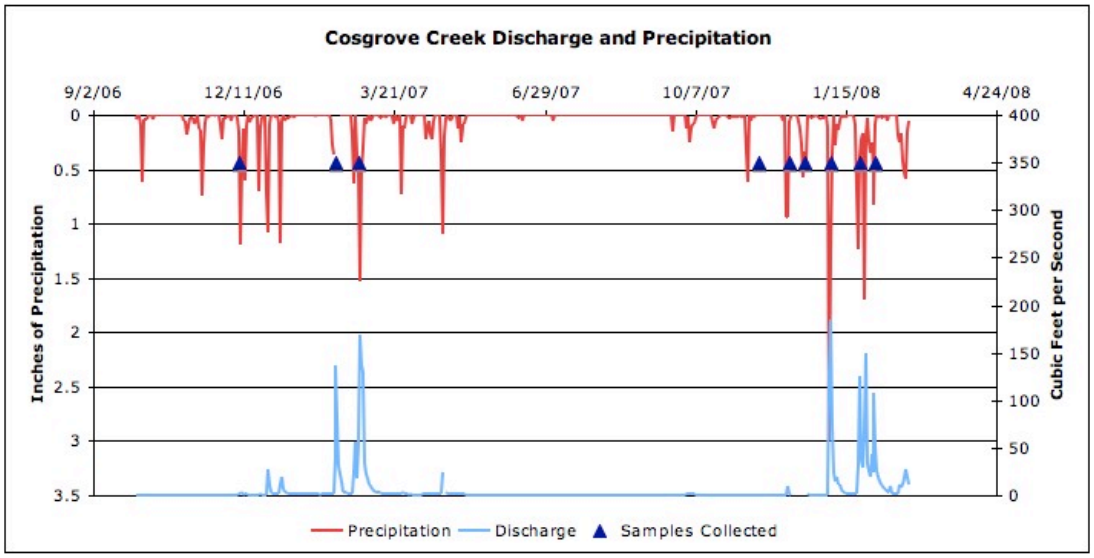


Figure 4. *Discharge and precipitation at Cosgrove creek during the 06-07 water year and partial 07-08 water year. Sampling times are marked with triangles.*

The LCR is a completely rainfed watershed, receiving about 93% of its water from runoff occurring from November through April (CALFED 1999). Flow on the river is controlled by releases from New Hogan Dam and during the rainy season runoff and discharge from tributaries. Releases from New Hogan are made in order to provide enough supply drinking water to CCWD and SEWD, as well as provide irrigation waters for the various crops that grow year round. In order to meet these needs the volume released will change accordingly. For flood control measures the volume released from New Hogan can also change to keep levels in the reservoirs at safe levels. The ACOE operates discharge gauges at New Hogan, Cosgrove Creek, and Bellota sites. Changes to the volume released from New Hogan affect the flow at Bellota as well as significant discharge from Cosgrove. (Figure 5).

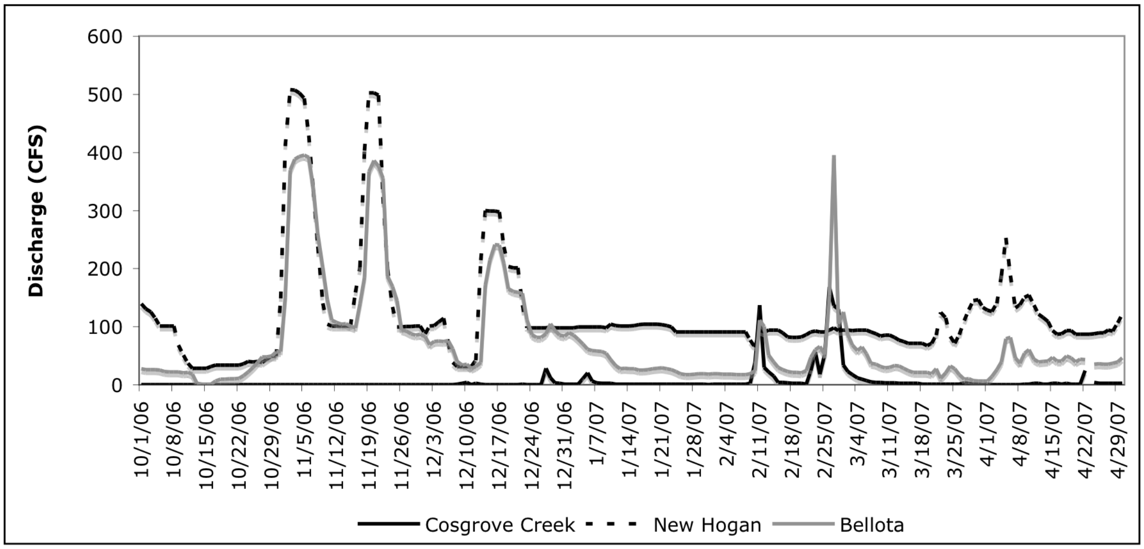


Figure 5. *Comparison of discharge at Cosgrove Creek (black), New Hogan (dashed), and Bellota (gray). In most cases as discharge increases at New Hogan or Cosgrove it affects Bellota.*

Agriculture is the primary use of land in the LCR Watershed. Agriculture in the Calaveras River watershed includes a diverse list of crops, including field crops, apiaries, fruit and nut crops, livestock, poultry, and wine grapes. Agricultural land in the Calaveras River flood plain is very productive and extensively cultivated. Lowlands are used primarily for cultivation of orchards (walnuts, peaches, and cherries), vineyards, and irrigated row and field crops (corn, sugar beets, and vegetables). Other uses include pasture, hay, wheat, range, and dairying. The primary agricultural land use in the lower elevation hillsides of the watershed is cattle ranching. Cattle grazing in small numbers occur throughout the watershed, primarily in the lower rolling foothills. (Brown and Caldwell 1995). Urbanization has been increasing in the watershed and is expected to continue with more housing developments being built. Urban uses, specifically housing is the second largest land use in the watershed and is expected to be the largest in the coming years. The oldest development is Rancho Calaveras built in the 1960's, this dense housing development has over three thousand lots all of which are on septic (Figure 6).

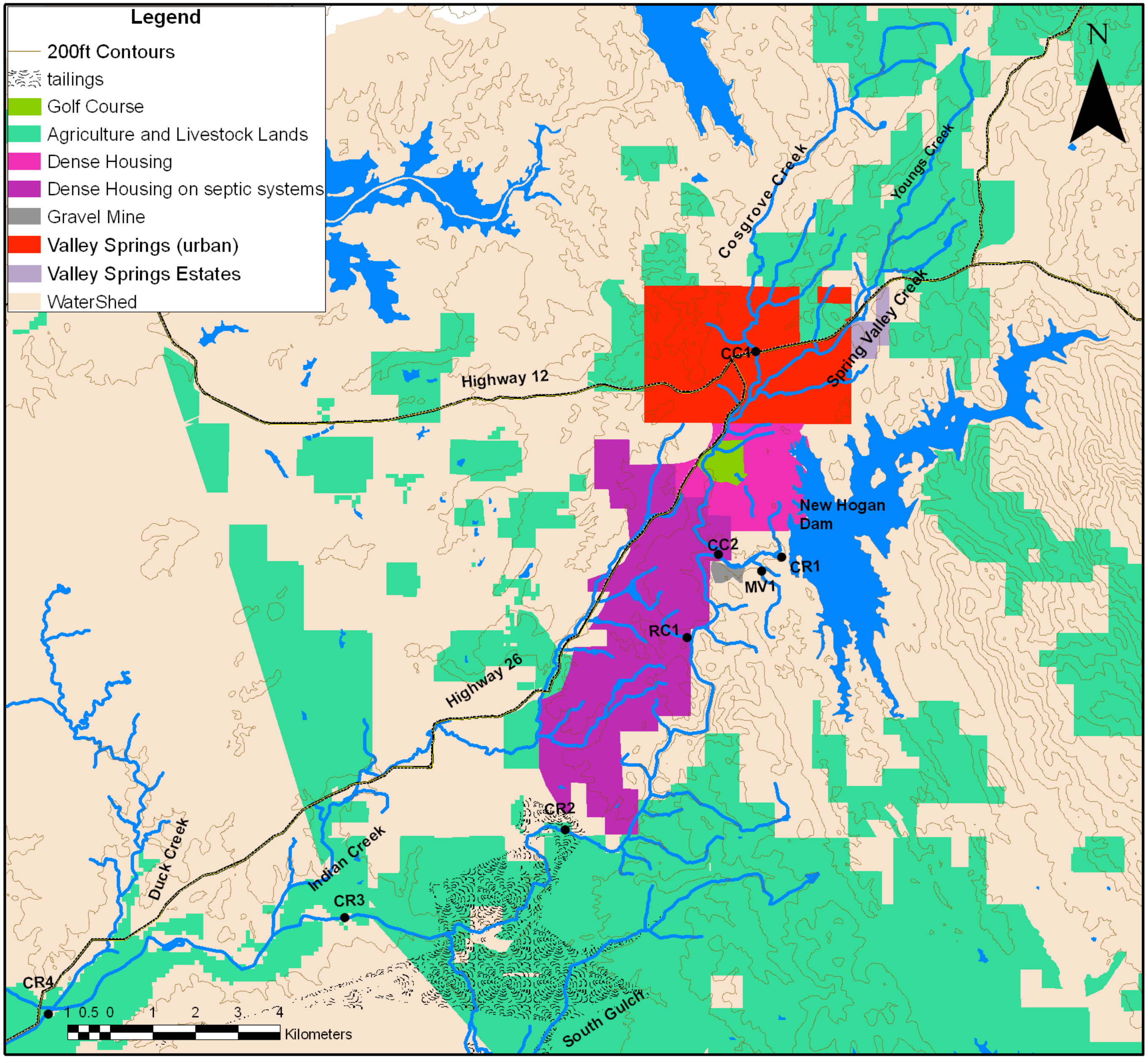


Figure 6. *Land use map of the upper reaches of the Lower Calaveras River Watershed.*

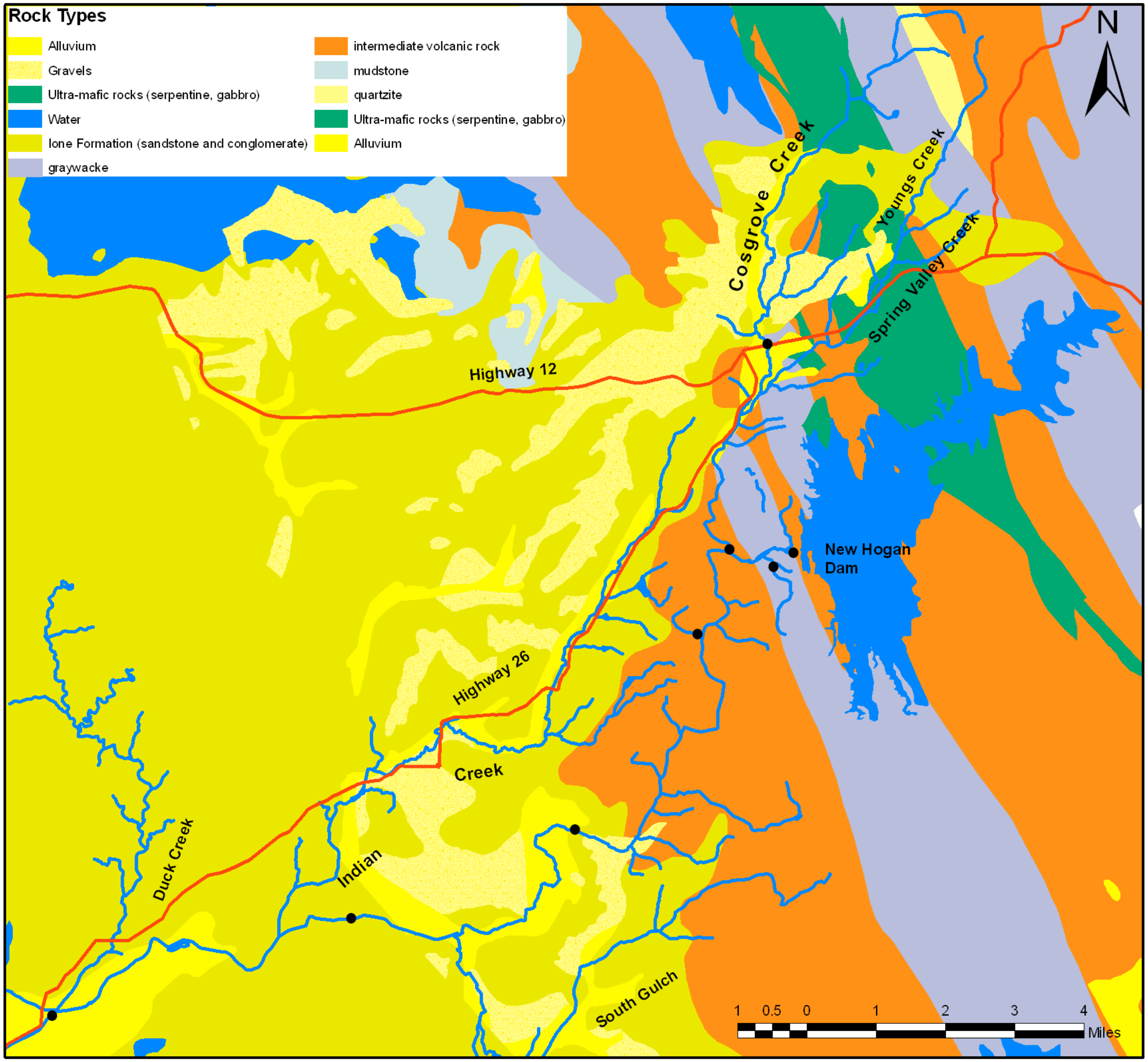


Figure 7. *Geologic map of the upper reaches of the Lower Calaveras River Watershed.*

The geology of the Calaveras River Basin from Stockton to the highest elevation is characterized by meta-sediments and meta-volcanic rock of Mesozoic age, overlain by tertiary sediment and volcanic rocks (Figure 7). (Brown and Caldwell 1995).

The Upper LCR can be divided into three reaches. The reach from NHD to Cosgrove is alluvial, the average channel gradient is approximately 0.005 (based on USGS topographic maps). Typical channel width is 26 meters and the channel bed is composed of gravel, cobble, and sand. The second reach starts downstream from Cosgrove Creek. The channel enters a steep, bedrock confined gorge. The average channel gradient is 0.013 (based on USGS topographic maps). The channel is confined with bed and banks composed of bedrock. The third reach starts at the end of the gorge near the town of Jenny Lind. The gradient returns to an average of 0.005 (based on USGS topographic maps). The channel bed is composed of gravel and cobble. The channel enters an abandoned gravel mine where it forms several large pools. Near the Shelton Road sampling site bedrock is exposed along the sides and in the bed of the channel with cobble and some gravel. Upstream of the Bellota Wier the channel enters a small abandoned gravel mine where it forms a pool. There is also a large pool formed behind the wier.

Potential sources of pollution in the LCR watershed include both point and non-point sources. Potential point sources include the Jenny Lind water treatment plant, the La Contenta sewer treatment plant, and Valley Springs storm water discharges, all of which contribute discharge to the LCR (Tetra Tech 2001). The treatment facilities dispose of effluent to ponds, to leach fields, and spray to fields (Tetra Tech 2001). Treatment plants can contribute fecal coliform and nutrient loading, which contribute to surface water quality impairments (EPA 2004). Non-point sources can be a source of bacteria, nutrient loading, and poor water quality. Examples of non-point sources include: septic systems, golf courses, agricultural runoff, urban storm water runoff, livestock, and wildlife (www.epa.gov/nps).

PREVIOUS STUDIES

Water quality monitoring along the LCR includes raw and treated water at the Jenny Lind, and Dr. Joe Waidhofer water treatment plants and intakes (Figure 7). The Jenny Lind water treatment plant is operated by the Calaveras County Water District (CCWD) and supplies drinking water to consumers in Calaveras County. SEWD operates the Dr. Joe Waidhofer water treatment plant and supplies drinking water to consumers in the Stockton metropolitan area of San Joaquin County. For the period between 1995 and 2000, the physical and chemical parameters of the LCR were monitored by CCWD and SEWD (Tetra Tech 2001).

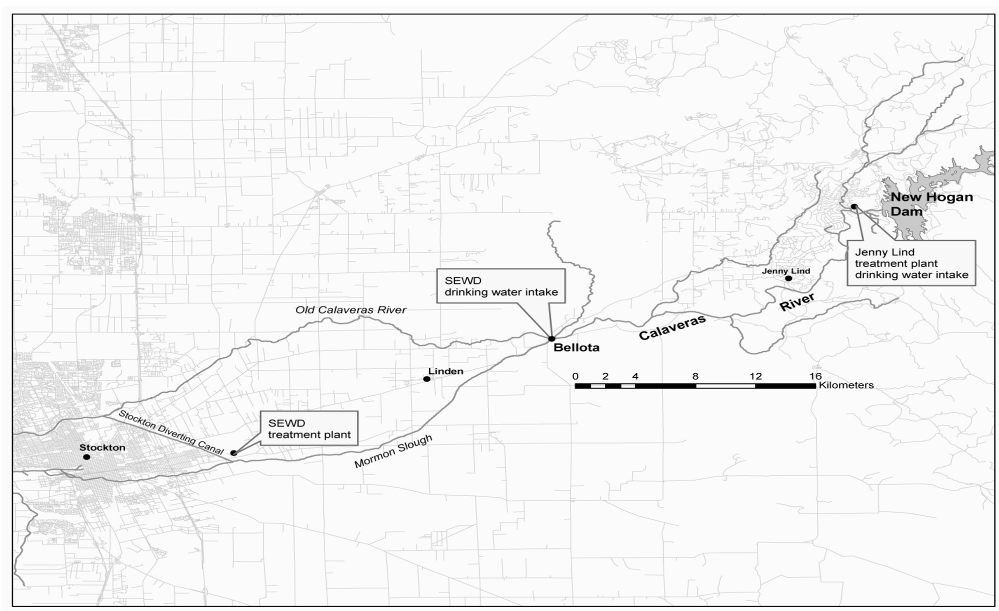


Figure 7. *Location of Stockton East Water District's drinking water intake and treatment plant and Calaveras County Water District drinking water intake and their Jenny Lind treatment plant.*

Based on these results, a clear correlation between turbidity and total coliform counts at both monitoring locations (Figures 8A and 8B) was identified. Currently, SEWD analyzes raw water samples for total and fecal coliform bacteria on a weekly basis and total organic carbon on a monthly basis. The Calaveras River Watershed Sanitary Survey (Brown and Caldwell, 1995), identifies contaminants from recreational activities, pesticide and nitrogen contamination, septic tank failures, and contaminants in storm water as the primary water quality concerns in the LCR.

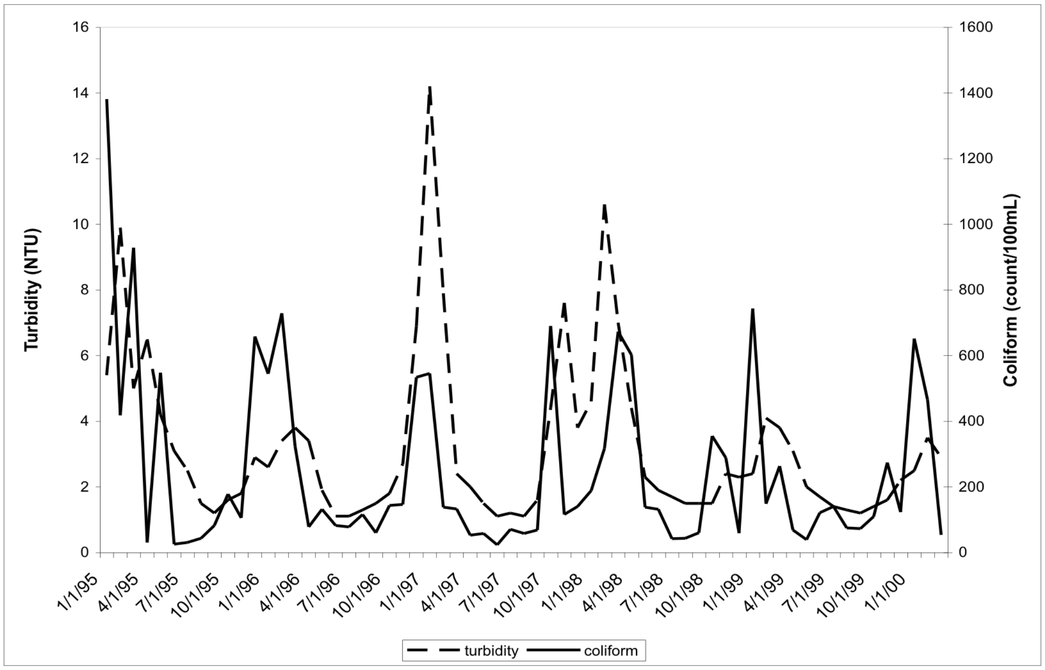


Figure 8A. *Coliform concentrations vs turbidity at Jenny Lind WWTP intake from 1995to 2000 (Tetra Tech. 2001).*

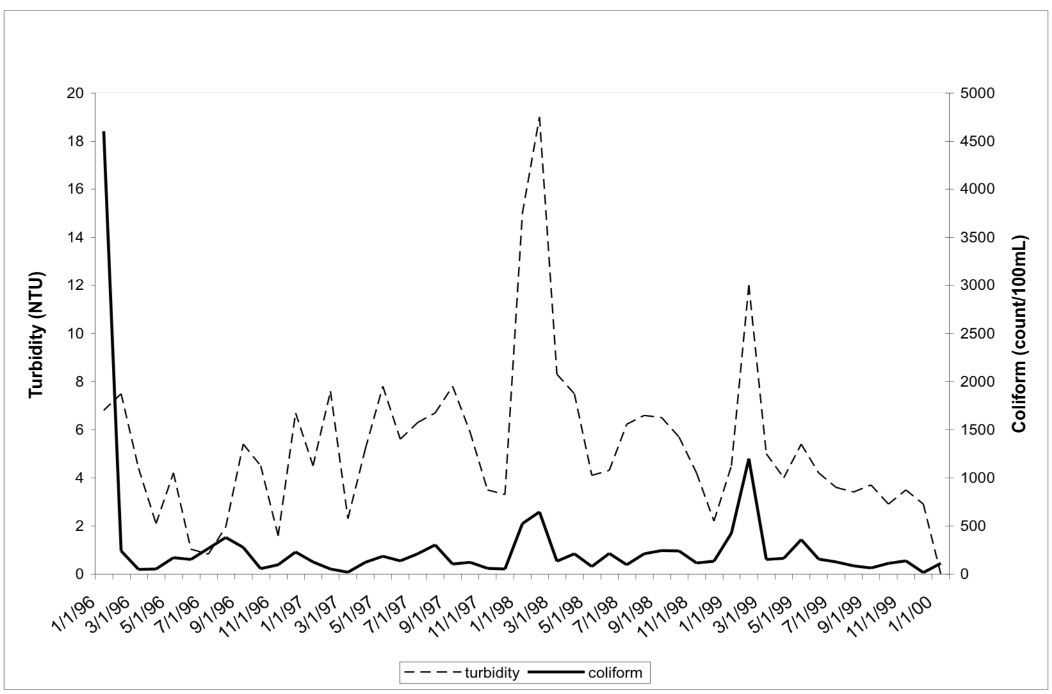


Figure 8b. *coliform vs turbidity at SEWD intake from 1996 to 2000 (Tetra Tech. 2001).*

METHODS AND MATERIALS

Data collection for this study included two sets of background (pre wet season, 12/8/06, 11/18/07) water quality data and two sets of post precipitation data. Sampled events were selected based on precipitation totals and observable increases in discharge along the tributaries. Data was not collected from tributaries during the initial sampling event due to no flow conditions. Data collected included conductivity, dissolved oxygen, pH, temperature, and turbidity. These parameters are indicators of overall water quality. Turbidity and bacteria often co-exist with other, more serious water quality impairments (epa.gov/nps), and thus, are used as a proxy of general water quality. Samples were collected for general coliform and E. coli determination. In addition samples were collected for total organic carbon (TOC) and anion analysis.

The monitoring sites for this study are located on the LCR and its tributaries

(Table 2 and Figure 9). The first step in choosing monitoring sites involved review of The Calaveras River Field Assessment Report (Tetra Tech, 2000). Careful consideration was made to ensure sites are evenly distributed across the LCR, in order to get a representative sample of water quality. Data collected from water year 2007 was used to add additional monitoring stations and remove un-necessary stations. Lastly sites were chosen based on accessibility from paved roads and are public access.

Station	ID	Latitude	Longitude
Calaveras at New Hogan	CR01	N 38 08.995	W 120 48.997
Calaveras at Milton Road	CR02	N 38 05.501	W 120 52.373
Calaveras at Shelton Road	CR03	N 38 04.369	W 120 05.923
Calaveras at Bellota	CR04	N 38 03.132	W 121 00.682
Cosgrove Creek at Hwy 12	CC01	N 38 11.59	W 120 49.319
Cosgrove Creek at Calaveras River	CC02	N 38 9.018	W 120 49.940
Tributary at Monte Vista Recreation Area	MV01	N 38 08.933	W 120 49.389
Tributary along Clements Place	RC01	N 38 07.958	W 120 50.430

Table 2. *Lower Calaveras River Watershed monitoring stations.*

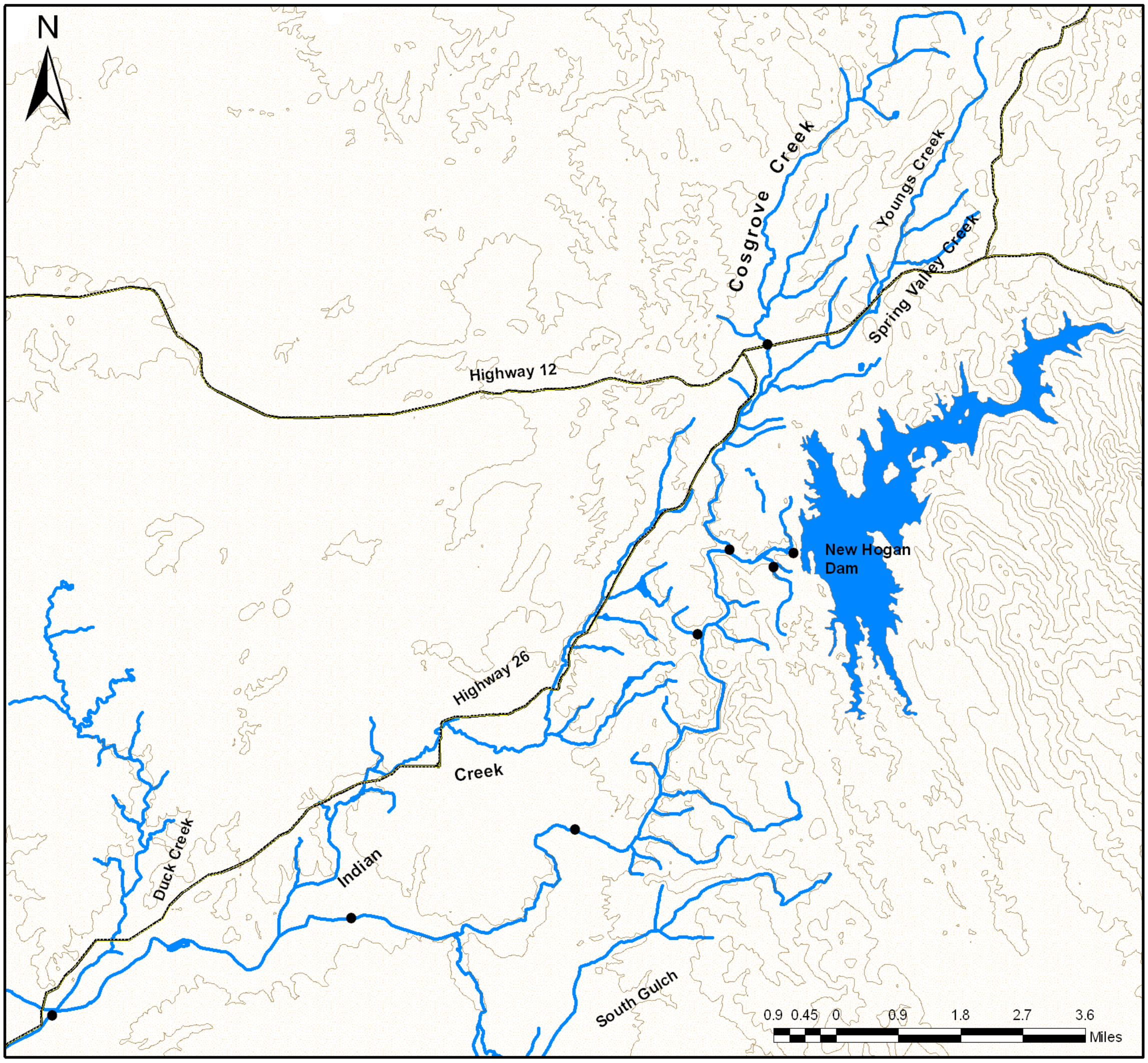
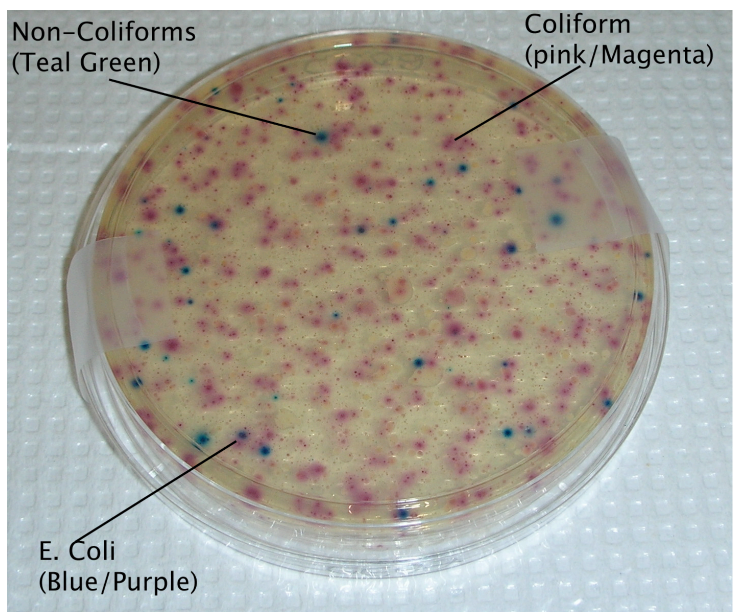


Figure 9. *Map of the LCR study area. Each of the monitoring locations are marked with a point and their station ID (see Appendix B for full size map).*

Surface water samples were collected for bacterial, TOC, and anion analysis and in situ water quality parameters were monitored at each actively flowing sampling location during a sampling campaign. Field personnel waded from the shore to the middle of the sampled channel with minimum disturbance to the channel sediment. The sampler's body was positioned downstream from the sample collection location. The sampler wore nitrile gloves while collecting and handling all samples and equipment. In situ water quality parameters include pH, conductivity, and water temperature and were measured using a YSI model #556 multiprobe. In addition, field analysis of turbidity was performed on collected samples using a Lamotte tubidimeter. Bacteria samples were collected in the sterilized bottles provided with the ColiQuant EZ kit using a sterilized plastic syringe to fill the bottle.

Collected samples were stored at 4°C for transport and until analysis in the laboratory at Pacific. Logistical constraints prevented sampling of sites at the same time during each campaign. However, all samples associated with a sampling event were collected on the same day, within 6 hours of one another. Unpredictable flow conditions and safety considerations require a minimum of two personnel for each sampling campaign. The PI notified the project advisor at the Department of Geosciences of the dates and times of sampling. Sampling was discontinued any time field personnel determined that driving conditions, site access, or sampling conditions were unsafe for that site and parameter.

Bacteria analysis was performed at the University of the Pacific. Samples were analyzed using the EPA approved Coliscan Easygel method. This method was achieved by using LaMotte's ColiQuant EZ kit. The kit provides everything necessary to analize water samples for general coliform and E. coli bacteria. Samples are collected in the provided bottle, using the provided dropper a desired amount of sample is added the Coliscan Easygel and then poured in a provided Petri dish for incubation at room tempreture (48 hrs). After 48 hours bacteria is ready to be counted. General coliform bacteria appear as pink and E. Coli bacteria appear as purple. This method is



limited to a maximum of 300 coliform units that can be counted per sample. LaMott recommends using 1 mL of sample when bacteria concentrations are unknown, for sampling events one and two this was the amount of sample used. During the counting for sample some of the sites had counts of at least 300, therefore an accurate count was unable to be determined. For those sites where counts were not able to be obtained during the second sampling event, 0.5 mL of sample was used during analysis of the third sampling samples. For subsequent sampling events 0.250 mL of sample was used for all sites with exception of New Hogan where 2.0 mL of sample was used. For water year 2007 1 bacteria sample was collected, for water year 2008 bacteria samples were collected in triplicate.

Anion analysis was performed at the University of the Pacific. Samples were analyzed using the US EPA 300.0 method using a Dionex ICS-1000 Chromatograph System. Each sample was ran a total of three times in order to get an average. The machine was calibrated with a 7 anion standard and samples were run for chloride, nitrate, phosphate, and sulfate.

RESULTS

All other parameters were within acceptable limits. pH was generally neutral to slightly basic and temperatures ranged from about 7.5 ^{o} - 12.5^{o} C in the Calaveras and 6.9 ^{o} - 10.5^{o} C in the tributaries.

Water discharging from New Hogan was typically of the best quality and was degraded downstream (Figure 9). Conductivity levels were highest in the tributaries tested and lowest at New Hogan (figure 10). Dissolved oxygen and pH were variable at each site, with no consistent pattern throughout the LCR watershed. The most common water quality impairment observed during the sampling campaign was high total coliform levels, which ranged from 66.5 to 112,000 CFU/100 mL. Cosgrove Creek (CC01/CC02) have the highest concentrations of bacteria (Figure 11). Sites with the highest conductivity and turbidity levels tend to have the highest total coliform concentrations (Figure 9 and Figure 11). The highest levels of both turbidity and bacteria in the LCR are in each of the three tributaries monitored (Cosgrove Creek, MV01 (un-named), and RC01 (un-named). Water quality improved downstream of the tributary inlets, as the LCR approaches Bellota. Water quality at Bellota is generally good, but coliform concentrations did exceed the guidelines set forth by the basin plan after the largest precipitation events. Total coliform concentrations correlate with turbidity, when turbidity increased so did coliform concentrations (Figure 12). Similar studies such as one by Mallin et al. have found the same correlation with both total coliform and fecal coliform.

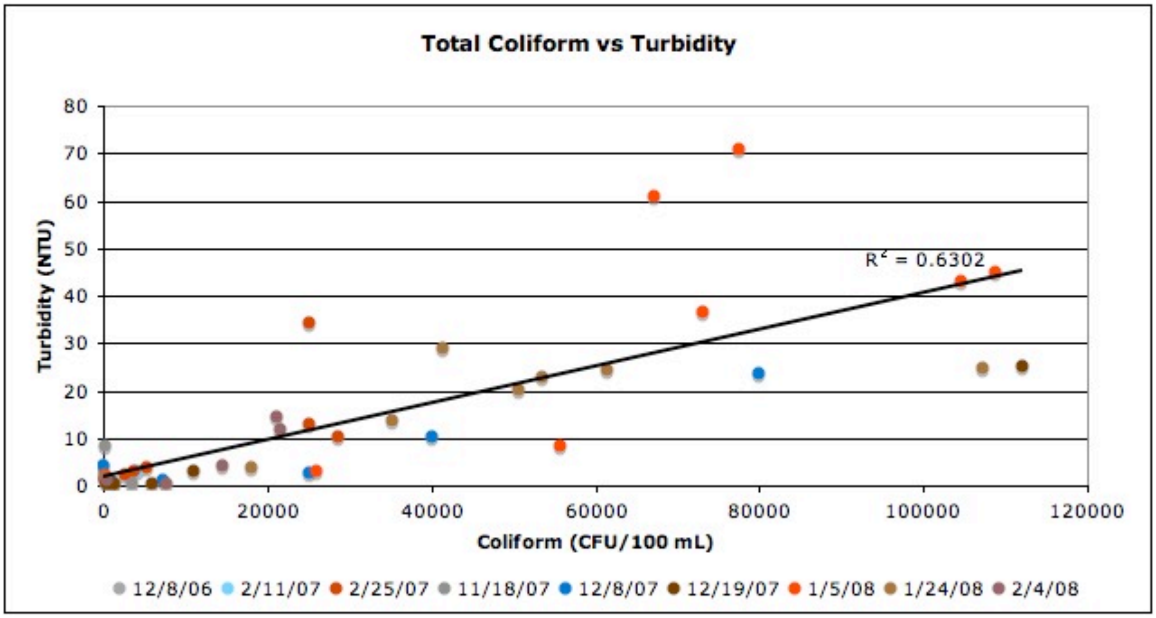


Figure 12. *Graph of general coliform vs turbidity in the Lower Calaveras River Watershed. The graph includes all sampling events, all of which were used to display trend lime and calculate R2*

Cosgrove Creek, the largest tributary in the LCR had the worst quality in the LCR. Cosgrove Creek is the first tributary in the LCR and is less than 1 kilometer downstream of New Hogan. Cosgrove Creek was determined to have the highest total coliform counts of all sites monitored as well as one of the highest concentrations of E. coli. Turbidity and conductivity measurements were also some of the highest recorded in the LCR. Cosgrove creek had discharge that was higher than New Hogan during post precipitation event sampling times (Figure 13). It is likely that Cosgrove is the source of pollution as far downstream as CR02 (Jenny Lind), and likely to be completely diluted by the time it passes this site.

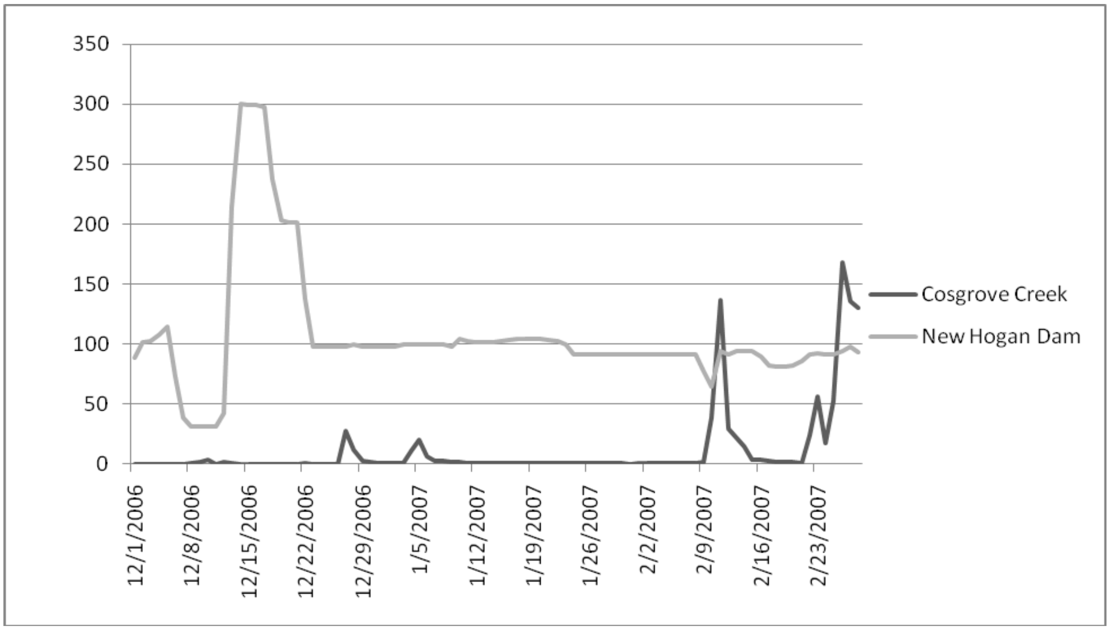


Figure 13. *Discharge at Cosgrove creek vs New Hogan during the 2006-2007 wet season (Oct-Apr).*

During the dry season E. coli concentrations were negative and at all monitoring sites with flow and general coliform concentrations were below guidelines. All of the tributaries in the LCR are either dry or water is stagnant until significant precipitation occurs. Conductivity and turbidity levels were at their lowest. During this time there were periods where discharge out of New Hogan was greater than during the wet season.

Consistent changes in pH and dissolved oxygen were not observed during the course of this study and all observations were within the basin plan guidelines for water quality. However, conductivity gradually increased at each site over the course of the study period with the biggest increases observed a Cosgrove Creek and Bellota.

Nitrate levels were minimal for the most part, with increases seen after precipitation events, especially after the largest events. The highest levels were found in Cosgrove Creek, the tributary at Monte Vista Recreation area (MV01) and the tributary flowing through Rancho Calaveras (RC01). The two un-named tributaries had the most significant levels of nitrate. The tributary flowing through Rancho Calaveras had levels of nitrate ranging from (15 – 34 ppm) after precipitation events and the tributary at Monte Vista Recreation area that had high levels between (10 - 44 ppm). (Figures 15-16)

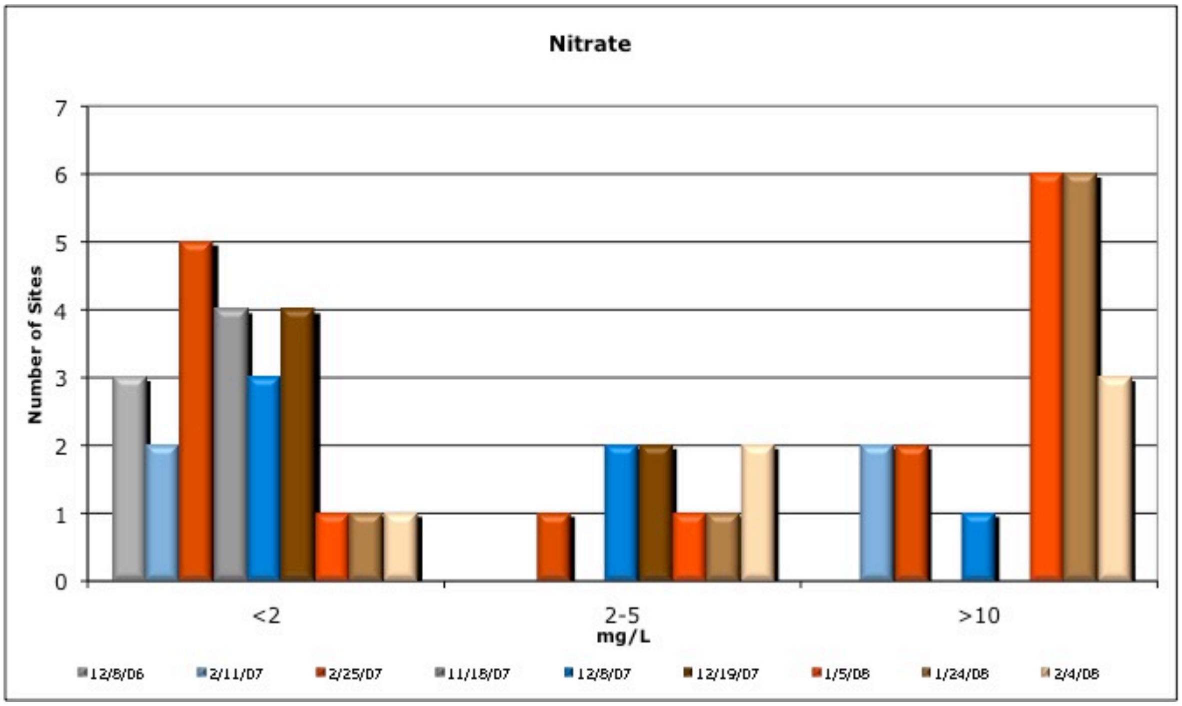
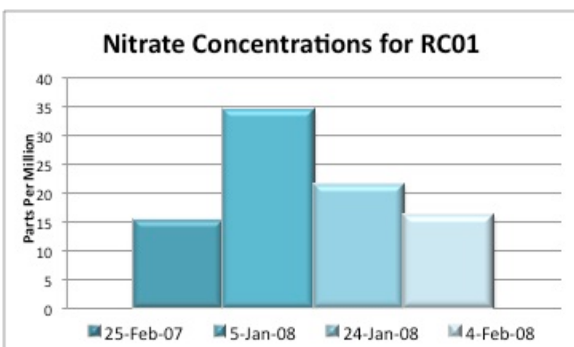
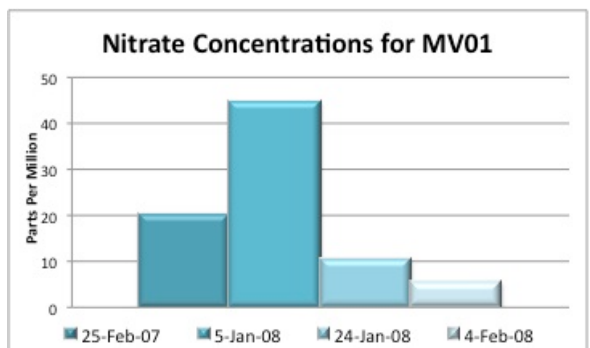


Figure 14. *Graph of nitrate concentrations for all monitoring station and sampling events. Pre wet season data are in grays, first precipitation event data are in blues, major precipitation events are in red, and all other precipitation events are in tans.*





Total coliform bacteria concentrations increased after each rain event, particularly after the first major rain event of the season (Figure 14). Bacteria levels were at their highest after major precipitation events and began to trail after subsequent events. E. coli was found in its highest concentrations in Cosgrove Creek and the tributaru in Rancho Calaveras, levels significantly exceeded environmental law standards in these tributaries and directly downstream of their confluence with the Calaveras.

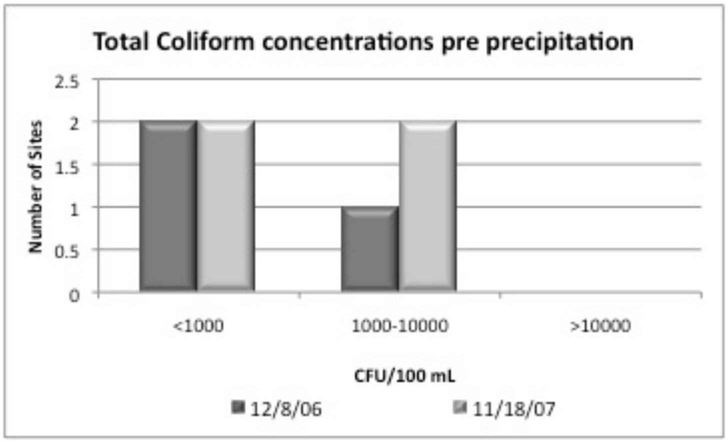


Figure 17. *Graph of E. coli concentrations for all monitoring station and before any precipitation events.*

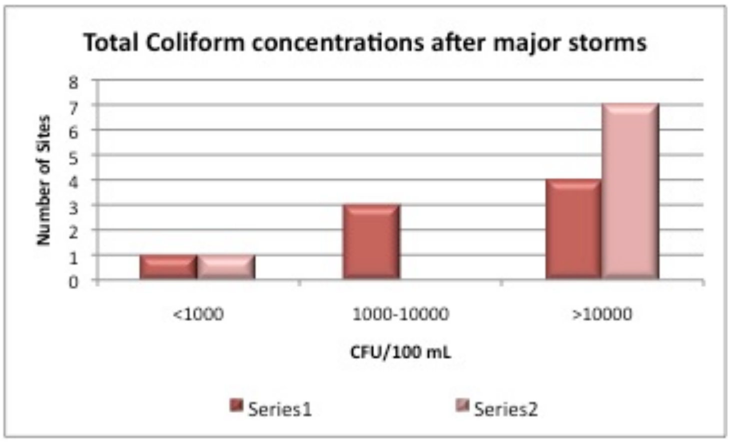


Figure 18. *Graph of E. coli concentrations for all monitoring station and before any precipitation events.*

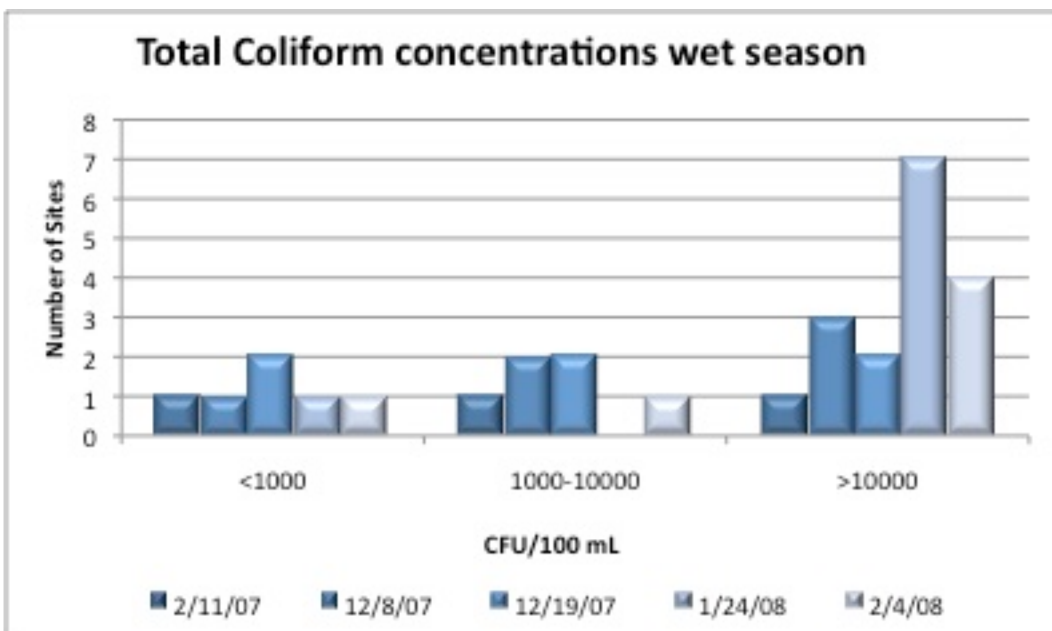


Figure 19. *Graph of E. coli concentrations for all monitoring station and before any precipitation events.*

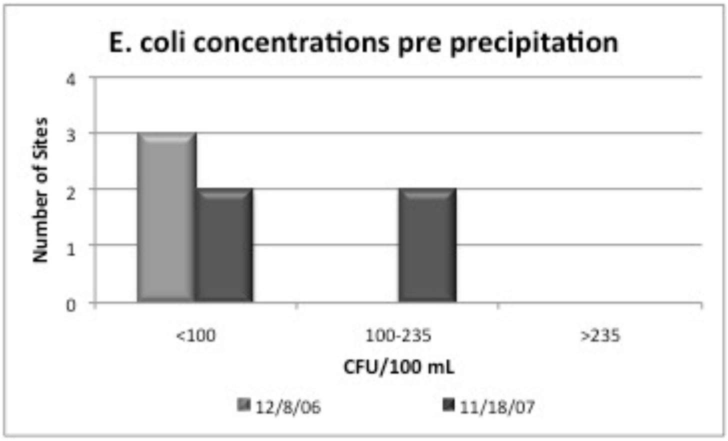


Figure 20. *Graph of E. coli concentrations for all monitoring station and before any precipitation events.*

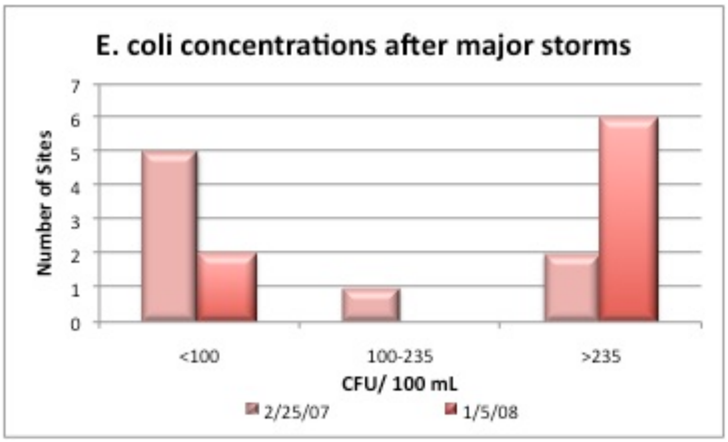


Figure 21. *Graph of E. coli concentrations for all monitoring station after major precipitation events.*

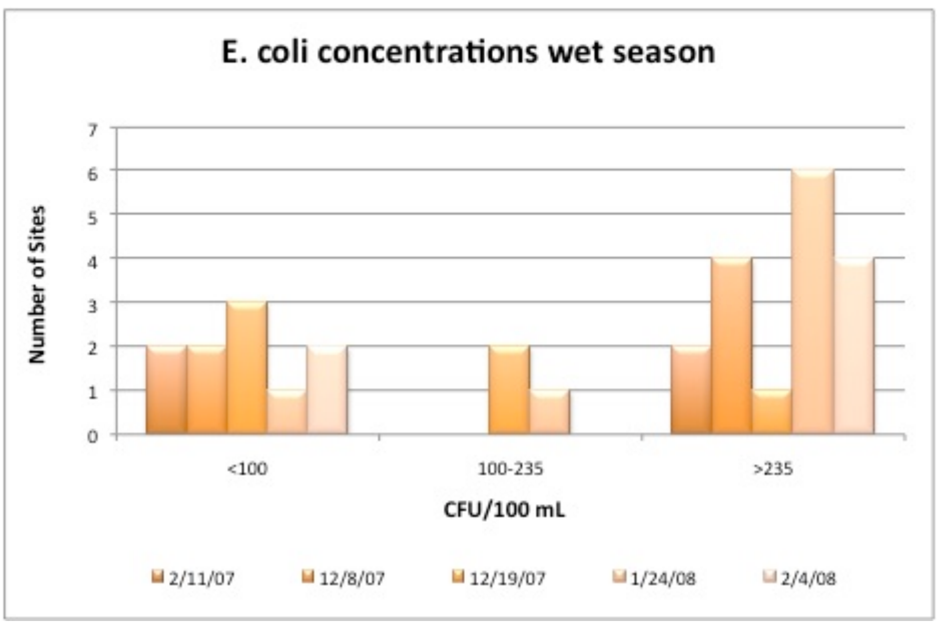


Figure 22. *Graph of E. coli concentrations for all monitoring station after precipitation events.*

Date	Longitude	Latitude	Site ID	Q (CFS)	pH	K (µs/cm)	DO (mg/L)	T (˚C)	Turbidity (NTU)	E. coli (CFU/100mL)	coliform (CFU/100mL)	Cl	Nitrate	PO_4	SO4	Na	K	Mg	Ca	TOC Concentration (ppm)
12/8/06	38.149752	-120.815232	CR01	31	7.3	106	10.5	12	1.68	0	400	2.77	0.7751		8.207					2.966
12/8/06	38.091548	-120.872707	CR02		7.4	104.5	12.18	10	1.59	0	500	3.084	0.3729		9.101					3.555
12/8/06	38.052173	-121.011417	CR04	40						0	1500	3.041	0.202		9.22					2.805
12/8/06	N 37 58.870	W 121 18.835	CR05		7.9	109	12.5	8.4	1.7	0	3000	5.448	1.0118		11.96					4.697
12/8/06	N 37 58.007	W 121 21.565	CR06		7.4	331	10.5	9.5	2.47	0	1300	91.42	7.4588		71					5.6
12/8/06	N 37 57.683	W 121 12.333	DC01		8	96	13.5	8.6	9.5	0	11800	3.038	0		8.882					3.365

Date	Longitude	Latitude	Site ID	Q (CFS)	pH	K (µs/cm)	DO (%)	T (˚C)	Turbidity (NTU)	E. coli (CFU/100mL)	coliform (CFU/100mL)	Cl	Nitrate	PO_4	SO4	Na	K	Mg	Ca	TOC Concentration (ppm)
2/11/07	38.149752	-120.815232	CR01	94	8	102	104.3	8.7	4.28	0	100	3.532	0.3992		9.63	6.6	6.8	8.715	20.39	2.784
2/11/07	38.091548	-120.872707	CR02		7.8	164	102.1	12	63.7333	500	N/A	10.42	5.8255		17.24	10	7.7	13.71	20.85	9.208
2/11/07	38.052173	-121.011417	CR04	111	7.8	113	100.8	11	2.96	0	4100	3.421	0.4146		7.645	7	6.8	8.963	20.38	2.629
2/11/07	N 37 58.867	W 121 18.834	CR05		7.3	76.5	73.65	14	22.85	200	N/A	3.034	3.1592		8.403					3.621
2/11/07	N 37 57.978	W 121 21.615	CR06		6.8	457	127.7	12	6.36	500	9300	109.8	13.226		89.85					4.818
2/11/07	N 37 57.683	W 121 12.334	DC01		8.1	82.333	114.1	14	9.90667	200	7400	3.134	0		7.785					2.598
2/11/07	N 38 09.015	W 120 49.935	CC02	125	7.8	140	103.5	12	53.5667	300	N/A	6.823	7.0133		10.58	9.5	7.5	11.91	19.01	12.538
2/25/07	38.149752	-120.815232	CR01	91	8.1	178.67	106.8	9	1.24	0	300	2.729	0.4279		6.849	6.8	7	8.902	21.21	2.922
2/25/07	38.091548	-120.872707	CR02		8.2	214	109.4	9.4	2.88333	0	3800	4.34	0.6826		8.274	8.5	6.9	11.26	22.51	3.483
2/25/07	38.072745	-120.932122	CR03		8.4	202.33	109.9	9.7	2.40333	0	2600	3.771	0.6178		7.605	8.1	7	10.42	22.23	5.34
2/25/07	38.052173	-121.011417	CR04	52	8.2	192.33	106	10	3.83	0	5300	3.746	0.63		7.222	8.4	7	11.5	22.85	5.336
2/25/07	N 37 57.978	W 121 21.615	CR06		8.1	496	75.3	12	5.91	200	9800	31.78	3.2647		29.4					6.571
2/25/07	N 37 57.683	W 121 12.333	DC01		8.4	193	115.4	11	3.6	100	4700	3.02	0		7.212					4.648
2/25/07	N 38 11.591	W 120 49.319	CC01		8	318.5	101.4	10	34.6667	500	25200	5.126	1.8806		13.21					9.786
2/25/07	N 38 09.018	W 120 49.940	CC02	53	8.2	375	110	10	10.3233	0	28600	13.9	2.9178		17.93					9.705
2/25/07	N 38 08.933	W 120 49.389	MV02		7.9	580	105.3	9.7	13.1	200	25200	29.37	20.212		123.7					10.704
2/25/07	N 38 07.958	W 120 50.430	RC02		8	268.33	102.9	11	30.7667	400	30000	21.13	15.364		18.4					12.682

Date	Longitude	Latitude	Site ID	Q (CFS)	pH	K (mS/cm)	DO (%)	T (˚C)	Turbidity (NTU)	E. coli (CFU/100mL)	coliform (CFU/100mL)	Cl	Nitrate	PO_4	SO4	Na	K	Mg	Ca	TOC Concentration (ppm)
11/18/07	38.149752	-120.815232	CR01	32	7.7	0.1903	102	11	8.56	0	215	4.174	0.6007	0.2	8.099	6.9	6.5	9.184	21.64	2.672
11/18/07	38.091548	-120.872707	CR02	1	8.1	0.188	111.1	12	0.43333	100	3466	4.169	0.1716	1	8.878	6.9	6.4	9.214	22.08	3.062
11/18/07	38.072745	-120.932122	CR03	2	7.5	0.198	103.8	12	0.09667	100	1333	4.193	0.1859	0.2	9.527	7.6	6.4	9.523	22.48	1.569
11/18/07	38.052173	-121.011417	CR04	4	7.2	0.197	99.73	14	1.44	0	633	4.711	0.0192	0	9.571	7.7	6.5	9.469	22	1.729
12/8/07	38.149737	-120.815152	CR01	42	7.5	0.185	99.6	12	4.34667	0	66.5	4.073	0.2756		8.305	7.1	6.5	9.488	22.07	23.93
12/8/07	38.091598	-120.87276	CR02	0.75	7.8	0.2967	108.6	11	2.76	866	25133	17.97	2.1107		21.54	15	7.2	10.93	26.46	38.951
12/8/07	38.072712	-120.932114	CR03	2	7.7	0.1957	107.3	10	1.28	300	7300	6.446	1.2347		11.5	7.7	6.6	9.98	22.55	42.478
12/8/07	38.052173	-121.011417	CR04	36	7.8	0.186	103.6	9.6	0.62333	0	1066	4.239			9.548	7.4	6.5	9.752	21.79	18.619
12/8/07	38.19317	-120.822004	CC01	0.1	7.3	0.2697	59	9.2	23.8	600	80000	16.52	8.6955		29.68	19	8.9	11.97	22.94	
12/8/07	38.150285	-120.832332	CC02	1	7.1	0.5083	92.81	8.8	10.1433	1000	40000	54.3	3.9334		49.99	33	8.6	34.07	31.23	
12/19/07	38.149737	-120.815152	CR01		8	0.195	103.6	11	1.5	0	167	4.297	0.1428		9.324	7.5	6.5	9.488	22.25	19.782
12/19/07	38.091598	-120.87276	CR02		8.3	0.2233	113.5	11	0.46333	200	5867	7.624	1.8785		13.43	8.7	6.6	10.93	23.94	26.205
12/19/07	38.072712	-120.932114	CR03		8.2	0.2063	110.7	10	0.08	200	1300	4.95	0.064		11.37	8.2	6.5	9.98	23.14	21.557
12/19/07	38.052173	-121.011417	CR04		8.1	0.199	104.9	9	0.21	0	467	4.253			10.3	7.6	6.5	9.752	21.62	20.91
12/19/07	38.19317	-120.822004	CC01	0.1	7.1	0.3047	60.13	9.1	25.1667	400	112000	14.86	4.7322		23.07	17	8	11.97	22.26	
12/19/07	38.150285	-120.832332	CC02		7.9	0.6303	96.2	8.4	2.97	0	11067	81.49	4.6738		59.48	45	7.8	34.07	40.91	
1/5/08	38.149737	-120.815152	CR01	46	8.1	0.1693	118.6	9.6	2.15333	0	316	4.963	0.8186		11.59	7.6	6.9	9.602	22.38	
1/5/08	38.091598	-120.87276	CR02		malf	0.221	110.3	9	60.8667	933	67,200	11.11	10.218		18.57	10	7.8	11.85	19.99	
1/5/08	38.072712	-120.932114	CR03		malf	0.191	106.8	9.2	70.7667	1,000	77,600	9.753	8.9551		16.24	8.9	7.7	10.27	19.1	
1/5/08	38.052173	-121.011417	CR04		malf	N/A	N/A	N/A	36.6333	900	73,200	8.648	4.4101		14.46	9.3	8	9.807	20.71	
1/5/08	38.193212	-120.821999	CC01		7.5	0.184	112.6	7.3	43.1667	2,133	104,533	8.285	18.837		12.88	7.8	8.2	15.01	18.57	
1/5/08	38.15029	-120.832333	CC02	60	7.7	0.268	116.1	7.8	45.1233	2,800	108,866	16.82	15.691		20.15	13	8.1	14.66	21.05	
1/5/08	38.148917	-120.823122	MV02		7.5	0.4813	106.4	8.3	2.86667	0	26,000	29.45	44.691		24.79	20	7	17.21	45.37	
1/5/08	38.132685	-120.840447	RC02		7.4	0.274	105.1	9.3	8.47667	400	55,800	26.74	25.748		115.7	15	8.2	19.01	24.25	
1/24/08	38.149737	-120.815152	CR01	38	8.2	0.183	122.4	8.9	1.82333	0	266		1.1285			7.5	7	9.545	22.22	
1/24/08	38.091598	-120.87276	CR02		8	0.185	118.8	7.5	24.6	2,000	107,200		5.3079			9.4	7.2	11.51	18.71	
1/24/08	8.0727116	-120.932114	CR03		7.7	0.193	116.3	8	22.8	1,200	53,600		6.7354			9.5	7.2	11.51	19.25	
1/24/08	38.052173	-121.011417	CR04	399	6.6	0.159	114.5	7.6	28.8	666	41,466		4.2872			8.5	7.8	8.835	17.82	
1/24/08	38.193212	-120.821999	CC01		8.2	0.178	121.3	6.9	20.2	533	50,666		6.2761			7.4	7.3	14.08	17.17	
1/24/08	38.15029	120.8323334	CC02	120	N/A	0.16	122.5	6.5	24.55	1,200	61,466		7.538			9.4	7.4	12.35	17.69	
1/24/08	38.148917	-120.823122	MV02		7.9	0.158	115.2	8.3	3.75667	266	18,133		10.34			15	6.5	12.23	32.07	
1/24/08	38.132685	-120.840447	RC02		7.8	0.247	109.7	8.6	13.75	133	35,333		21.358			13	7.9	14.49	19.76	
2/4/08	38.149737	120.8151516	CR01	60		malf			1.16	0	450		1.5631			7.6	7.1	9.532	18.16	
2/4/08	8.0727116	120.9321137	CR03			malf				800	14,800		3.218			9.3	6.9	10.58	N/A	
1/24/08	38.193212	-120.821999	CC01			malf			14.3	600	21,200		5.0107			7.9	7.3	14.62	N/A	
1/24/08	38.15029	120.8323334	CC02	34		malf			12	400	21,600		4.0251			11	7.2	13.91	14.35	
1/24/08	38.148917	-120.823122	MV02			malf			0.39	0	7,600		5.3893			13	6.3	11.8	26.5	
1/24/08	38.132685	-120.840447	RC02			malf			4.16	400	14,600		16.129			14	7.9	15.13	15.57	

Table 3. *Data*

DISCUSSION

The discussion below of this study's monitoring results reports quality controlled data. Data collected in this limited survey indicates that water quality in the LCR is acceptable, with the exception of E. coli bacteria, which was found in concentrations throughout the watershed that could potentially exceed Basin Plan objectives for contact recreation and lead to human health concerns. An additional concern of the water districts is whether the water quality in the Calaveras River Watershed is fully supportive of its designated beneficial uses. As mentioned previously, water quality parameters were compared to the Basin Plan Water Quality Objectives to assess whether there is the potential for impairment to the designated beneficial uses of the watershed, including aquatic life. This comparison indicated that there is the potential for water quality to be less than optimal with respect to E. coli bacteria levels, nutrient concentrations and subsequent eutrophication.

In general, turbidity and general coliforms are positively correlated throughout the LCR (Figure 11). The most turbid waters in the LCR also had the highest total coliform concentrations. Although coliform counts typically increase with increasing turbidity, several instances of moderate turbidity led to high total coliform concentrations.

Data collected in this limited survey indicates that overall water quality is within the basin plan guidelines, with exception of general coliform and E. coli bacteria. Bacteria levels throughout the LCR watershed exceed SWQCB standards. Conductivity, dissolved oxygen levels, turbidity, and temperature were all within acceptable limits.

Water originating from New Hogan Dam was nearly void of bacteria, whereas water originating from the monitored tributaries was impaired. However, water quality improved downstream, towards Bellota, and then decreased in quality downstream of Bellota. These downstream patterns of water quality suggest that factors contributing to water impairments below Bellota may not be the same as those affecting the LCR from New Hogan to Bellota.

Failure rates for septic systems typically range between one and five percent each year (De Walle, 1981) but can be much higher in some regions (Schueler, 2000). Improperly functioning septic systems are recognized as a significant contributor of pollutants (especially nitrogen) and microbiological pathogens and dispense more than one trillion gallons of waste each year to subsurface and surface waters (NSFC, 1995). According to the Calaveras County Environmental Health Department, the Rancho Calaveras area is particularly susceptible to septic system failure because the shallow, clayey soil is inadequate for proper leach field drainage (Tetra Tech 2000b).

The LCR experiences increases in conductivity immediately following rain events. Land use in the tributaries of the LCR where conductivities were the highest includes agriculture and cattle grazing which provide a potential source of salts. Results from this study cannot distinguish between these possible sources, and warrants further study. Increases in coliform bacteria are usually associated with runoff (epa.gov/nps). Runoff in the LCR occurs when precipitation washes into the river from agricultural and cattle grazing lands. Urban storm water runoff can carry a variety of pollutants, including coliform bacteria from urban areas including bacteria from pet wastes, surface wastewater from failing septic tank systems, excess nutrients from lawns and gardens, metals, oil and grease, and other pollutants associated with activities such as car washing and sidewalk cleaning (epa.gov/nps). Human waste has the potential to carry human pathogens; therefore, the relative risk of contamination of fecal coliform from human sources is much higher than the associated risks of contamination from cattle or other mammals.

Future research on water quality in the LCR should include a detailed study of each of the contributing tributaries, including analyzing water quality from their headwaters to their confluence with the Calaveras. Measurements of discharge at each tributary would also be beneficial in order to determine how long it takes for the discharge from the tributaries to be diluted or if they are having a significant impact. In addition, future-sampling plans should be developed in accordance with Basin

Plan guidelines to ensure transferability of results. Following the Basin Plan guidelines is an important step once the sources of bacteria and other impairments have been identified. Following the guidelines will ensure that when there is a violation the State and Local governments can take action to rectify the pollution sources. Supporting research that examines septic systems and other potential sources of water quality impairments near the Calaveras should also be a priority of future studies. Additional study should also include recently developed analytical methods that allow for source identification of fecal coliform to determine whether it originates from human, livestock, or wildlife sources. This would support a more focused program of septic tank mitigation.

CONCLUSION

The monitoring results indicate that there is no evidence to suggest there are serious threats to public health and safety, and that many of the indicators of watershed health are positive. Due to the limited nature of this study, additional monitoring is recommended before management actions are developed. Elevated E. coli bacteria and moderate nitrate concentrations are primary concerns. E. coli and total coliform levels are much higher than basin standards during a majority of the samplings. Livestock waste is a likely source based on land use observations upstream of sampling sites on Cosgrove Creek. A second potentially significant source is leaky or failing septic systems in the dense housing development of Rancho Calaveras, based on measurements of water quality on the tributary in the development. After significant precipitation events, coliform levels were elevated throughout the study area and the majority of sites exceeded both basin objectives and environmental laws for coliform and E. coli. The first major precipitation event of each water year had the largest negative impact on all parameters tested. Subsequent storms decreased some water quality parameters, but not to the same extent as the first major storm. Based on an analysis of land uses, agriculture, specifically cattle grazing is likely the primary source of elevated nitrate and impaired water quality in the watershed. This assessment is based on a small dataset, with no more than eight samples having been collected at any location and, as such, nothing definitive can be stated without additional study. Neither the number nor the frequency of samples collected during this study meet the requirements for the Basin Plan criterion for E. coli. However, the large percentage of elevated values does cause concern that the potential for bacterial impairment of surface waters in the watershed exists. All other parameters were within acceptable limits.

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