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San Joaquin River
Up-Stream DO TMDL Project

Task 4
Monitoring and Associated Studies
Interim Report No. 1
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William Stringfellow[1,3]
Sharon Borglin[1,3]
Jeremy Hanlon[1]
Randy Dahlgren[2]
Solomon Henson[2]
Arlene Granadosin[1]
Jesse Merkel[1]

[1]Environmental Engineering Research Program
School of Engineering & Computer Science
University of the Pacific
3601 Pacific Ave., Sears Hall
Stockton CA 95211

[2]Department of Land, Air and Water Resources
University of California, Davis

[3]Ecology Department
Berkeley National Laboratory

Introduction

For many years, the Deep Water Ship Channel (DWSC) on the San Joaquin River (SJR) has had intermittent low dissolved oxygen (DO) conditions. The DO sag is most acute during the late summer and early fall, but low DO incidences occur year-round (Foe et al. 2002, Lehman 2001). The low DO conditions are impacting critical fish habitat and a total maximum daily load (TMDL) Implementation Plan for oxygen-demanding substances is currently being developed by the Central Valley Regional Water Quality Control Board (CVRWQCB).

In support of the development of a scientific DO TMDL allocation, 13 research and monitoring projects examining various aspects of DO demand in the SJR were conducted in the summers of 1999, 2000, and 2001. Additionally, the CVRWQCB generated a "strawman" allocation of responsibility report (Strawman Report). The Strawman Report represents a process by which responsibility for the low DO conditions can be assigned and a plan for remediation of the DO sag in the SJR can be implemented (Foe et al. 2002). The final reports for these projects can be found on the SJR DO TMDL website (www.sjrdotmdl.org).

Studies conducted in the summers of 1999, 2000 and 2001 identified four major factors contributing the formation of a DO sag in the DWSC: the deepening of the ship channel, ammonia discharges from the Stockton Wastewater Treatment Plant (WWTP), transport of oxygen-consuming materials from the upper SJR into the DWSC, and production of oxygen-consuming organic matter in the channel. The actual impact of these factors is dependent on flow and temperature, where lower flows and higher temperatures allow a DO deficit to accumulate if the other factors are present.

The Up-Stream DO TMDL Project (ERP-02D-P63) is an inter-organizational research program focused on understanding the sources of oxygen-consuming materials in the SJR upstream of the DWSC. The purpose of this study is to provide a comprehensive understanding of the sources and fate of oxygen-consuming materials, particularly algae biomass, in the SJR watershed between Channel Point (lat long) and Lander Avenue (lat long). The study objectives are to understand current (baseline) conditions of the basin, determine the sources and sinks of oxygen demanding materials, and provide scientific tools for measuring the impact of water quality management programs being implemented in the SJR basin.

Previous studies have identified algal biomass as the most significant oxygen-demanding substance in the SJR upstream of the DWSC (Kratzer et al. 2004, Lehman 2001). Algal biomass is not a conserved substance, but grows and decays in the SJR; hence, characterization of oxygen-demanding substances in the SJR is inherently complicated and requires an integrated effort of extensive monitoring, scientific study, and modeling. The Up-Stream DO TMDL Project includes a coherent and comprehensive study of algal growth dynamics in the SJR and will identify sources of algal nutrients to the SJR.

Other oxygen-demanding substances found in the SJR above the DWSC include ammonia and organic carbon from sources other than algae (Kratzer et al. 2004). The SJR watershed contains municipalities, dairies, wetlands, and agricultural industries that may potentially contribute biochemical oxygen demand (BOD) to the SJR. This study is designed to discriminate between algal BOD and other sources of BOD throughout the entire SJR watershed.

This interim report concerns activities conducted under Task 4 (Monitoring and Scientific Studies) of the Up-Stream DO TMDL Project. The specific objectives of Task 4 are to:

1) Collect sufficient hydrologic and water quality data to characterize the loading of algae, other oxygen-demanding materials, and nutrients from individual tributaries and sub-watersheds of the upstream SJR between Channel Point and Lander Avenue.
2) Identify and characterize sub-watersheds that are the most significant sources of algal biomass, nutrients, and BOD to the river, providing basic scientific information to support a water quality management program.
3) Characterize the transformation and fate of nutrients and algae in the watershed and the impact of nutrients on algal growth.
4) Characterize the temporal variability of water quality parameters on a daily and seasonal basis.
5) The data collected in Task 4 will also be used in Task 6 to model and predict the transformation and fate of algae in the river.

Scientific activities for Task 4 commenced in the early spring of 2005 and this project in currently in seventh month of research. The initial focus of Task 4 was the development and execution of a bi-monthly (twice-monthly) grab sampling program for the collection of water-quality data. This program began in March 2005 and this report includes a description of that program and water-quality data collected between March and July 2005. Research to characterize individual sub-watersheds has been started. This research is in it's preliminary stages and results from those efforts are not included in this report, but will be described in the second Interim Report scheduled for March 2006. In cooperation with activities conducted under Task 5 (Installation of Flow Monitoring Stations), scientists under Task 4 have been compiling and evaluating flow and electrical conductivity data generated by watershed groups. That work under Task 4 has consisted largely of compiling raw data and training technical personnel on station calibration and quality control procedures. Scientific effort on characterization of temporal and seasonal variability are initiated, but results are too premature to warrant inclusion in this report. A characterization of algal and nutrient interactions premature until more data is collected.

Methods

Grab samples and field measurements were executed in accordance with guidelines from the SWRCB (Puckett 2002). Grab samples from each site are collected in a minimum of 3, one liter glass, acid washed Wheaton bottles, as well as a minimum of 3 250 mL plastic bottles (VWR trace-clean). The 1 liter Wheaton bottles are filled by attaching one open bottle to a custom-built cradle attached to a 14 foot telescoping pole. The bottle is then slowly dipped into the site waters to effect the collection of a depth-integrated sample. This process is then repeated for the remaining 1 L Wheaton bottles. The 250 mL bottle samples are collected via a custom-build cradle attached to a similar 14 foot telescoping pole. All three bottles are held in the cradle contemporaneously and dipped into the site waters to effect the collection of a depth-integrated sample. For sampling sites inaccessible with the telescoping pole, a 2 L bucket attached to a rope is dropped into the site waters and retrieved. The bucket's contents are then poured into the sample bottles by swirling the water in the bucket while pouring into a funnel that is randomly rotated from sample bottle to sample bottle. This alternative process is used to fill both the 1 L Wheaton and the 250 mL bottles. All sample bottles are capped immediately after a sample has been collected, placed in an ice cooler, and kept at a temperature of 4° Celsius (C) until delivered to the laboratory.

Light is measured using both a VWR LUX light-meter and a custom-built PAR platform incorporating a Li-Cor spherical quantum detector. The LUX light-meter measures light in the visible spectrum the way photographer would for exposing film. The PAR platform measures sunlight as photosynthetically-active radiation in micro-Moles per second per square meter of photons. Each device is placed in open ground, under direct sunlight, in as flat a position as possible. The PAR meter has an incorporated bubble site level to better achieve this latter criterion.

Sample site velocity is recorded using a Marsh-McBirney Flo-mate 2000 (measured in feet/second). The sensor head of this device is attached in a perpendicular position to the end of a six-foot pole, which is then dipped into the site waters to a depth of 40% total stream depth or at least two feet from the surface in deeper water. The sensor head, with the help of a visual guide, is then positioned to face upstream and collect data.

A multi-parameter YSI 6600 SONDE is used to collect temperature (°C), specific conductivity (mS/cm), total dissolved solids (g/L), dissolved oxygen (sat %, mg/L, charge), pH, depth (feet), oxidation-reduction potential (mV), turbidity (NTU), chlorophyll-a (ug/L), Fluorescence (%FS), and barometric pressure (mm HG) data. The sonde is held vertically in the site waters, deep enough to submerge the device, but shallow enough to prevent it from resting on the bottom. The data is then collected via a cable connection to a YSI MDS-650 handset and recorded internally. Each sonde undergoes a pre- and post-operation calibration in the laboratory to ensure consistent and accurate data collection.

All samples were processed and/or preserved within 24 hours of sampling. Processing consisted of filtering the samples using a vacuum filter apparatus with a Whatman GF/F filter, preservation of TOC samples, and setting up the BOD analyses. Loading of sample onto the filter was dependent on the amount of solids in the sample and ranged from 250 to 1000 ml of water per filtration. Filters were prepared for chlorophyll analysis, USGS analysis, and TSS/VSS determination. Filtrate was collected for DOC and USGS analysis, as wells as for internal archive. For all analyses, standard curves and other quality control parameters were followed as outlined in the QAPP for this project.

Biochemical oxygen demand (BOD) was analyzed by Standard Method (SM) 52101 B with a modification for measurement of oxygen demand at 10 days rather than 5 days (APHA 1998). Previous studies in the SJR have used 10-day BOD analysis (BOD_{10}) as a standard procedure and it is necessary to continue this protocol order to be consistent with prior studies. The BOD_{10} tests were initiated within 24 hours of sampling. Samples were kept at $4^{o}C$ until incubation, but were stabilized at 20oC before the initial oxygen reading. The samples were shaken prior to incubation to assure initial dissolved oxygen (DO) levels between 7 and 9 mg/L. BOD_{10} was measured on all samples without seed, also as in previous studies. Carbonaceous BOD ($CBOD_{10}$), was determined by inhibiting nitrogenous demand with N-Serve Nitrification Inhibitor (HACH, Loveland, Colorado). Nitrogenous BOD ($NBOD_{10}$) was then determined by subtracting $CBOD_{10}$ from BOD_{10}. Initial and final dissolved oxygen was measured using a calibrated YSI 5100 DO meter (Yellow Springs, Ohio). One duplicate measurement and three blank measurements (trip blank, buffer solution, and deionized water) were prepared for a minimum of every sample set or every 20 samples. Samples were run both full strength and diluted 1:3 to assure that a valid BOD_{10} measurement was achieved for all samples, with a residual greater DO than 1 mg/L and at least 1 mg/L consumed. Standards were prepared with each standard set consisting of buffer solution spiked with a known amount of 300mg/l glucose/300mg/l glutamic acid (HACH, Loveland, CO) and 5 ml sample seed.

Total organic carbon (TOC) was measured by high temperature combustion using a Teledyne Tekmar Apollo 9000 (Mason, Ohio) according to SM 5310 B (APHA 1998). Dissolved organic concentration (DOC) phosphoric acid and stored in the dark at $4^{o}C$. Deionized water rinses were run between all samples to reduce occurrence of sample carryover. Samples were run within 28 days of collection and preservation.

Total suspended solids (TSS) and volatile suspended solids (VSS) were analyzed by SM 2540 D and E, respectively (APHA 1998). The filters were pre-rinsed with deionized water, placed in aluminum dishes, and pre-combusted at $550^{o}C$ for 1 hour prior to use. After combustion the filters and aluminum dishes were stored in a dessicator until use. Sample loading was dependent on the amount of solids in the sample and generally ranged from 250 to 1000 ml of sample per filter. After filtration, samples were dried in a vacuum oven at $105^{o}C$ until a constant weight was achieved, then combusted at $550^{o}C$ for 1 hour.

Chlorophyll-a (chl-a) and pheophytin-a (pha-a) was extracted and analyzed using UV absorption (SM 10200H). Filtration of the samples was done under low light conditions and sample loaded onto the filter was preserved with a saturated $MgCO_3$ solution and storing at $-20^{o}C$. Filters were ground in a 90% acetone/10% $MgCO_3$ solution using a Teflon tissue grinder while maintaining the samples below $4^{o}C$ at all times. The ground filters were extracted in the acetone mixture at $4^{o}C$ for 4 to 24 hours. The extract was analyzed on a Perkin Elmer Lambda 33 Spectrophotometer (Boston, MA). After measurement of the extract, 33microliters of 0.1N HCl/ml of sample were added for determination of pheophytin. Analysis of sample was performed within 14 days of sampling.

Nitrate and ammonium concentrations are determined on samples filtered through a 0.45 mm Nuclepore membrane filter (filters are pre-rinsed with sample). Nitrate and ammonium are quantified simultaneously using an automated membrane diffusion/conductivity detection method (Carlson, 1978, 1986; Carlson et al., 1990).

Total nitrogen was determined on non-filtered samples. Total nitrogen is determined conductimetrically (as described above) following persulfate oxidation (Yu et al., 1994) using a 1% persulfate oxidant concentration, a sample:oxidant ratio of 1:1 (V/V), and heating in an autoclave. Recovery of total nitrogen is statistical identical to the Kjeldahl total nitrogen method in a comparison study conducted by UC Davis utilizing several reagent grade, organic nitrogen compounds. Quantification of nitrogen is by the automated membrane diffusion/conductivity detection method (Carlson, 1978, 1986; Carlson et al., 1990).

Ortho-phosphate is determined on samples filtered through a 0.45 mm Nuclepore membrane filter (filters are pre-rinsed with sample). We use method SM 4500-P.D, the “stannous chloride” method for this analysis (APHA 1998). We have the ability to utilize a 5 cm cell to lower the limit of detection; however, we find that the 1 cm cell in sufficient for most Central Valley river waters. Alternatively, ortho-phosphate and total phosphorous will be quantified by the Ascorbic Acid Method (adapted from SM 4500-P-E).

Total phosphorus is determined on non-filtered samples. Total P is measured by the “stannous chloride” method following persulfate digestion as described above for the total N procedure. The limit of detection for this method is about 5 ppb P using a 1 cm cell for measurement.

Results

A major effort of Task 4 has been the collection of water quality data from 20 sites that are believed to represent the San Joaquin River and its major tributaries. The location of these twenty "core" grab sampling sites and a brief description are provided in Table 1. An overall map of the Core Sites is provided in Figure 1. In Figures 2 through 20, aerial pictures of the site locations are shown. In addition to these Core Sites, grab samples were collected at Fremont Ford on the SJR and Modesto Irrigation District Lateral 4 during the period included in this report (March to July 2005). Water quality results for these sites are summarized in Table 2. Photographs documenting some of the sampling activities conducted under Task 4 are shown in Figures 21 through 27.

Station installation activities have begun under Task 5 and raw data has been provided to the Task 4 team by water districts on the Westside of the SJR. East-side flow stations are being up-graded and stage and electrical conductivity (EC) will become available in the next few months. Flow and EC data from stations managed by the USGS and DWR will be compiled as it becomes available in the fall. Table 3 provides a summary of flow stations identified for potential inclusion in this study.

An example of some of the raw data being provided by the new West-side stations is shown in Figure 28 and 29. Calculation of flow for each station is dependent on the calibration of the stage-flow relationship, which is in progress, so quality assured flow data can not be provided in this report. A quality control program for continuous EC measurement is being implemented and raw EC data will be processed using statistical methods developed for other projects.

Discussion

The SJR basin is located in a Mediterranean climate characterized by a dry season (typically May through November) and a wet season (November through May). During the dry period, the water quality in the river is heavily influenced by return flows from irrigated lands. With the exception of the Tuolumne, Stanislaus, and Merced Rivers, which convey water from the Sierra reservoirs, the tributaries included in this study consist largely of irrigated runoff during the dry season.

The results collected between March and July largely support previous studies that indicate algal biomass, as measured by chlorophyll-a (chl-a), is a major contributing factor to BOD in the basin (r^2 = 0.523), however the poor relationship between total organic carbon (TOC) and chl-a (r^2 = 0.229) and the strong relationship between BOD and TOC (r^2 = 0.513) suggest that other sources may also contribute to BOD in the river. Results from individual tributaries (Table 2) also indicate that algae are not the only source of BOD in the system. The relationship between BOD, TOC, and chl-a is being further investigated.

Results presented in Table 2 indicate that variability in water quality within a tributary is low enough that significant and consistent differences between tributaries can be measured with a bi-monthly grab sampling program. These results suggest that the concept of developing a predictive model for the basin has a significant probability for success. Future research will investigate inter-year variability and differences between wet and dry season water quality.

Further investigation of additional tributaries will be designed to allow statistical comparison to the Core Sites, with the intention of determining if water quality results from the Core Sites can be used to characterize tributaries that are sampled less frequently. Currently, models of the SJR are using data from a few sites to estimate water quality at uncharacterized tributaries without clear evidence that this approach is valid. The validity of this approach should be resolved as the result of research carried out under Task 4.

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Table 1: Location and common name of the Core Sample Sites for the DO TMDL Project. These sites are scheduled for bi-monthly summer sampling for the duration of the project. Sample locations that were also included in prior water quality studies (Kratzer et al. 2004) are indicated in the right column.

DO Site Number	Sample Station Name	Latitude	Longitude	Included in UC Davis & USGS Study
4	**SJR at Mossdale**	37.7871	-121.3076	X
5	**SJR at Vernalis**	37.6758	-121.2653	X
6	**SJR at Maze**	37.6400	-121.2292	X
7	**SJR at Patterson**	37.4937	-121.0808	X
8	**SJR at Crows Landing**	37.4320	-121.0117	X
10	**SJR at Lander Avenue**	37.2942	-120.8513	
12	**Stanislaus River at Caswell Park**	37.7016	-121.1772	X
14	**Tuolumne River at Shiloh Bridge**	37.6035	-121.1313	X
16	**Merced River at River Road**	37.3504	-120.9620	X
18	**Mud Slough near Gustine**	37.2625	-120.9056	X
19	**Salt Slough at Lander Avenue**	37.2480	-120.8519	
20	**Los Banos Creek at Highway 140**	37.2763	-120.9557	X
21	**Orestimba Creek at River Road**	37.4140	-121.0149	X
23	**Modesto ID Lateral 5**	37.6145	-121.1434	
25	**Modesto ID Miller Lake**	37.6702	-121.2193	
28	**Turlock ID Westport Drain**	37.5420	-121.0941	
29	**Turlock ID Harding Drain**	37.4643	-121.0309	
36	**Del Puerto Creek Flow Station**	37.5395	-121.1221	
44	**San Luis Drain End**	37.2609	-120.9052	X
59	**SJR Laird Park**	37.5573	-121.1501	X

Table 2: Summary of water quality sampling results from March to July, 2005.

DO Site Number	Site		Temp. C	Spec Cond, mS/cm	TDS g/L	DO%	DO mg/L	pH	Turbidity NTU	Chl-a by Sonde ug/L	BOD mg/L	CBOD mg/L	NBOD mg/L	Chl-a by SM ug/L	Total Organic Carbon mg/L	Dissolved Organic Carbon mg/L	VSS mg/L	TSS mg/L	NH4-N mg/L	NO3-N mg/L	PO4-P mg/L
4	SJR at Mossdale	mean	18.68	0.28	0.18	102.77	9.57	7.75	22.29	22.90	3.63	2.60	1.03	20.10	3.44	2.67	6.19	56.63	0.04	0.74	0.09
		SD	3.87	0.15	0.10	16.78	1.21	0.33	5.36	15.89	1.98	1.22	1.16	16.95	0.54	0.90	1.48	16.78	0.02	0.43	0.02
		CV (%)	20.7	55.4	55.4	16.3	12.6	4.2	24.0	69.4	54.4	47.1	112.5	84.3	15.7	33.6	23.8	29.6	47.3	58.0	20.6
		n	9	9	9	9	9	9	9	9	9	9	9	9	8	9	9	9	9	9	9
5	SJR at Vernais	mean	17.99	0.29	0.19	102.27	9.68	7.78	20.94	19.68	4.85	3.13	1.71	17.21	3.75	3.06	5.68	44.27	0.04	0.64	0.08
		SD	3.54	0.16	0.10	13.58	1.14	0.23	5.98	11.79	3.09	1.49	2.96	14.76	0.86	0.78	2.20	8.20	0.03	0.44	0.02
		CV (%)	19.7	54.9	54.8	13.3	11.8	3.0	28.6	59.9	63.9	47.8	172.8	85.8	22.8	25.4	38.7	18.5	76.0	69.4	27.6
		n	10	10	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10
6	SJR at Maze	mean	17.93	0.32	0.21	103.80	9.85	7.83	25.36	19.66	2.98	2.21	0.77	14.33	3.43	2.92	5.63	53.33	0.05	0.73	0.08
		SD	3.72	0.17	0.11	12.26	1.12	0.18	7.81	12.09	1.37	1.06	0.79	15.43	0.52	0.66	1.29	19.72	0.02	0.53	0.03
		CV (%)	20.8	53.1	53.0	11.8	11.4	2.3	30.8	61.5	45.9	47.7	102.9	107.7	15.2	22.6	23.0	37.0	39.1	72.5	36.1
		n	8	8	8	8	8	8	8	8	8	8	8	8	7	8	8	8	8	8	8
7	SJR at Patterson	mean	20.10	0.58	0.38	105.96	9.54	7.87	28.04	28.42	4.25	3.43	0.82	26.42	5.12	4.17	1.19	49.89	0.04	1.29	0.15
		SD	3.89	0.40	0.26	29.38	2.15	0.23	13.97	13.62	1.96	1.78	0.72	23.91	1.18	1.29	20.32	23.38	0.01	1.04	0.06
		CV (%)	19.3	68.6	68.6	27.7	22.6	3.0	49.8	47.9	46.0	51.9	88.0	90.5	23.1	31.0	1702.4	46.9	32.6	80.4	37.0
		n	10	10	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10
8	SJR at Crows Landing	mean	18.81	0.51	0.33	101.92	9.45	7.84	23.00	22.90	4.54	2.73	1.81	26.22	4.95	4.07	7.20	47.21	0.04	1.12	0.10
		SD	3.83	0.44	0.28	24.24	1.91	0.26	10.33	12.12	3.28	0.79	3.23	16.55	1.58	1.42	3.57	23.04	0.02	1.01	0.05
		CV (%)	20.4	86.2	86.2	23.8	20.2	3.3	44.9	52.9	72.3	28.9	178.7	63.1	32.0	34.8	49.5	48.8	41.9	90.5	45.7
		n	10	10	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10
9	SJR at Fremont Ford	mean	18.45	1.39	0.90	102.95	9.62	7.93	12.94	34.64	12.15	2.67	9.48	39.68	7.83	7.54	5.24	23.59	0.03	1.82	0.19
		SD																			
		CV (%)																			
		n	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	SJR at Lander Avenue	mean	21.59	0.54	0.35	125.41	10.90	8.21	37.80	50.07	8.10	5.83	2.27	54.07	8.16	5.84	9.18	37.14	0.10	0.91	0.11
		SD	4.21	0.46	0.30	57.89	4.62	0.50	54.18	46.55	4.79	3.55	1.99	57.00	3.64	2.08	7.04	16.67	0.12	0.85	0.04
		CV (%)	19.5	83.9	83.9	46.2	42.4	6.1	143.4	93.0	59.2	60.9	87.6	105.4	44.7	35.7	76.7	44.9	121.1	93.4	39.3
		n	10	10	10	10	10	10	10	10	10	10	10	10	8	10	10	10	10	10	10
12	Stanislaus River at Caswell Park	mean	18.49	0.11	0.07	101.95	9.60	7.87	6.56	4.12	1.70	1.29	0.56	1.89	2.55	2.33	1.83	6.10	0.09	0.29	0.06
		SD	4.15	0.04	0.02	6.98	0.98	0.24	7.75	1.57	1.31	0.58	1.24	1.29	0.71	0.60	1.25	14.60	0.12	0.19	0.04
		CV (%)	22.4	33.8	34.1	6.8	10.2	3.0	118.3	38.1	76.9	44.6	221.6	68.4	28.0	25.8	68.3	239.4	134.0	66.4	67.1
		n	10	10	10	10	10	10	10	10	10	9	10	10	8	10	10	10	10	10	10
14	Tuolumne River at Shiloh Bridge	mean	15.25	0.05	0.04	107.11	10.76	8.31	4.70	2.78	1.59	1.10	0.49	1.40	2.01	1.78	1.81	16.09	0.04	0.18	0.02
		SD	2.57	0.01	0.01	4.50	0.55	0.34	1.41	0.87	0.97	0.35	0.65	0.70	0.36	0.31	0.94	4.07	0.02	0.16	0.01
		CV (%)	16.9	24.6	24.7	4.2	5.1	4.1	30.0	31.4	61.0	31.6	132.7	50.3	17.7	17.6	52.2	25.3	50.9	86.3	54.2
		n	10	10	10	10	10	10	10	10	10	10	10	10	7	10	10	10	10	10	10
16	Merced River at River Road	mean	16.52	0.08	0.05	103.41	10.09	7.75	11.08	11.07	1.63	1.50	0.18	2.19	2.85	2.23	5.53	30.46	0.04	0.42	0.02
		SD	3.69	0.05	0.03	12.24	0.76	0.27	4.38	23.87	0.65	0.51	0.21	1.12	0.48	0.52	4.68	18.09	0.01	0.52	0.01
		CV (%)	22.3	59.3	59.4	11.8	7.5	3.5	39.5	215.5	40.1	34.3	112.3	51.3	16.8	23.5	84.8	59.4	27.1	123.7	57.0
		n	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
18	Mud Slough near Gustine	mean	21.49	3.28	2.13	111.54	9.68	8.40	40.47	96.16	11.94	9.55	2.39	104.81	10.00	7.94	16.84	87.46	0.07	7.55	0.07
		SD	4.05	0.62	0.40	26.78	1.68	0.16	11.57	55.12	3.35	3.74	1.36	69.10	2.34	2.64	4.05	29.48	0.04	1.76	0.11
		CV (%)	18.9	18.9	18.9	24.0	17.4	2.0	28.6	57.3	28.1	39.1	56.9	65.9	23.4	33.2	24.1	33.7	63.3	23.3	171.7
		n	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	9

Table 2: Summary of water quality sampling results from March to July, 2005 (continued).

DO Site Number	Site		Temp. C	Spec Cond, mS/cm	TDS g/L	DO%	DO mg/L	pH	Turbidity NTU	Chl-a by Sonde ug/L	BOD mg/L	CBOD mg/L	NBOD mg/L	Chl-a by SM ug/L	Total Organic Carbon mg/L	Dissolved Organic Carbon mg/L	VSS mg/L	TSS mg/L	NH4-N mg/L	NO3-N mg/L	PO4-P mg/L
19	Salt Slough at Lander Avenue	mean	21.20	1.25	0.81	80.99	7.14	7.74	59.34	16.56	3.70	2.17	1.54	8.73	7.19	5.84	10.19	92.82	0.11	1.87	0.23
		SD	3.78	0.44	0.29	18.51	1.35	0.07	36.71	5.64	1.23	0.49	1.32	6.92	1.47	1.34	6.30	60.57	0.07	0.92	0.06
		CV (%)	17.8	35.4	35.4	22.9	18.9	0.9	61.9	34.0	33.1	22.6	85.6	79.2	20.4	23.0	61.9	65.3	58.4	49.3	25.9
		n	10	10	10	10	10	10	10	10	10	10	10	10	9	10	10	10	10	10	10
20	Los Banos Creek at Highway 141	mean	20.97	1.55	1.01	78.55	6.95	7.94	140.18	56.48	12.22	8.01	4.22	50.13	12.63	10.38	24.08	218.19	0.23	1.04	0.34
		SD	3.94	0.74	0.48	15.85	1.14	0.28	51.81	29.52	4.36	3.96	1.93	44.28	4.63	4.40	13.90	160.53	0.21	0.62	0.25
		CV (%)	18.8	47.6	47.6	20.2	16.4	3.5	37.0	52.3	35.7	49.5	45.9	88.3	36.7	42.3	57.7	73.6	92.8	59.9	72.6
		n	9	9	9	9	9	9	9	9	9	9	9	8	9	9	9	9	9	9	9
21	Orestimba Creek at River Road	mean	21.01	0.63	0.41	97.30	8.68	8.07	181.89	15.89	3.22	1.68	1.55	5.63	4.66	5.32	14.87	189.88	0.18	4.25	0.15
		SD	3.51	0.11	0.07	13.77	1.23	0.24	110.88	5.32	1.58	0.50	1.55	3.03	1.19	6.34	11.24	149.60	0.29	2.27	0.07
		CV (%)	16.7	17.7	17.7	14.1	14.2	2.9	61.0	33.5	49.0	30.1	100.3	53.8	25.5	119.0	75.6	78.8	159.7	53.4	47.1
		n	9	9	9	9	9	9	9	9	9	9	9	9	8	9	9	9	9	9	9
22	Modesto ID Lateral 4	mean	22.24	0.19	0.12	121.60	10.58	8.68	1.90	7.41	2.34	1.82	0.52	3.43	2.72	2.35	1.72	5.95	0.06	2.15	0.03
		SD	1.39	0.12	0.08	9.73	0.76	0.23	1.04	2.50	0.66	0.78	0.28	1.43	0.17	0.38	0.97	3.05	0.02	2.30	0.01
		CV (%)	6.2	61.7	61.7	8.0	7.1	2.6	54.8	33.7	28.2	42.9	53.9	41.8	6.4	16.1	56.4	51.3	39.1	106.8	36.3
		n	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	3	5
23	Modesto ID Lateral 5	mean	23.23	0.15	0.10	149.06	12.69	9.12	1.88	4.81	1.72	1.36	0.34	6.65	3.30	2.10	1.87	5.09	0.04	0.75	0.03
		SD	2.79	0.12	0.08	35.49	2.84	0.43	2.47	2.56	0.40	0.44	0.12	12.99	1.72	0.45	1.63	4.17	0.02	1.48	0.01
		CV (%)	12.0	76.7	76.8	23.8	22.4	4.7	131.3	53.2	23.3	32.5	34.6	195.2	52.2	21.2	87.0	81.8	56.4	198.8	52.8
		n	7	7	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7
25	MID Miller Lake	mean	25.73	0.31	0.20	49.55	4.01	7.49	5.00	12.83	11.02	3.13	7.89	1.46	13.00	10.70	1.26	4.97	1.59	0.68	0.88
		SD																			
		CV (%)																			
		n	2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2
28	Turlock ID Westport	mean	22.84	0.76	0.49	147.60	12.59	8.25	4.63	7.35	2.27	1.74	0.55	4.35	3.63	3.46	3.30	15.78	0.30	14.40	0.24
		SD	3.41	0.26	0.17	31.34	1.95	0.18	3.56	4.78	1.17	0.66	0.78	5.21	0.89	0.83	2.31	21.91	0.52	4.61	0.13
		CV (%)	14.9	34.0	34.0	21.2	15.5	2.2	77.0	65.0	51.5	38.1	141.1	119.8	24.7	24.0	70.0	138.8	174.5	32.0	57.1
		n	7	7	7	7	7	7	7	7	7	7	7	6	6	7	7	7	7	7	7
29	Turlock ID Harding Drain	mean	22.40	0.63	0.41	126.66	10.93	7.79	21.85	9.12	5.92	3.38	2.54	3.52	6.57	4.90	7.19	61.89	0.36	8.06	2.29
		SD	3.40	0.20	0.13	23.74	1.62	0.13	13.89	4.32	4.33	2.20	2.32	1.89	4.85	2.22	4.79	57.66	0.45	2.62	1.41
		CV (%)	15.2	31.2	31.2	18.7	14.8	1.7	63.6	47.4	73.2	64.9	91.2	53.7	73.8	45.3	66.6	93.2	124.8	32.5	61.5
		n	9	9	9	9	9	9	9	9	9	9	9	9	8	9	9	8	9	9	9
36	Del Puerto Creek Flow Station	mean	21.81	0.64	0.42	102.73	9.01	8.43	72.25	22.07	5.93	3.42	2.51	18.64	5.14	4.22	13.36	101.08	0.20	2.71	0.19
		SD	4.28	0.25	0.16	8.39	0.57	0.18	37.48	11.53	2.92	1.03	3.15	10.89	1.48	0.94	7.93	67.54	0.35	1.30	0.07
		CV (%)	19.6	39.3	39.3	8.2	6.3	2.1	51.9	52.2	49.3	30.2	125.5	58.4	28.8	22.3	59.3	66.8	171.8	47.8	35.3
		n	9	9	9	9	9	9	9	9	9	9	9	9	8	9	9	9	9	9	9
44	San Luis Drain End	mean	22.06	4.87	3.16	159.16	13.64	8.69	29.25	201.61	15.21	13.73	2.07	171.88	9.80	6.26	17.13	57.52	0.04	16.10	0.00
		SD	4.25	0.59	0.38	27.12	1.56	0.15	5.15	124.58	4.86	4.80	1.84	107.14	2.32	0.90	5.48	24.44	0.01	6.01	0.00
		CV (%)	19.3	12.0	12.0	17.0	11.4	1.8	17.6	61.8	32.0	35.0	88.9	62.3	23.7	14.4	32.0	42.5	33.4	37.3	104.7
		n	9	9	9	9	9	9	9	8	9	9	9	9	8	9	9	9	9	9	6
59	SJR Laird Park	mean	22.66	0.46	0.30	103.73	8.86	7.90	30.07	28.00	4.87	3.70	1.17	41.89	4.79	3.63	9.03	69.03	0.03	1.13	0.13
		SD	3.18	0.36	0.23	30.28	2.08	0.20	19.30	19.68	2.12	1.88	0.28	28.98	1.08	0.48	8.10	64.17	0.01	0.83	0.04
		CV (%)	14.0	77.7	77.7	29.2	23.5	2.6	64.2	70.3	43.7	50.8	24.0	69.2	22.5	13.1	89.6	93.0	32.5	73.4	27.9
		n	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6	6	5

Table 3: Current information on flow measurements and flow data availability for the San Joaquin River watershed. Table includes flow & grab sample stations originally included in the March 2003 proposal as well as additional stations or tributaries identified in field surveys and meetings with watershed groups conducted between February and July, 2005. Stations designated “NA” have not yet been assigned site numbers for the DO TMDL Project.

DO Site Number	Sample Station Name	Latitude	Longitude	Organization Responsible for Flow Station	Suggested Contact for Flow Data
1	**SJR at Channel Point**	37.95027	-121.33715	No station	None
2	**SJR at Lathrop**	37.86488	-121.32267	DWR	Joe Tapia
3	**SJR at Old River**	37.81082	-121.32392	DWR	Joe Tapia
4	**SJR at Mossdale**	37.78710	-121.30757	DWR	Joe Tapia
5	**SJR at Vernalis-McCune Station (River Club)**	37.67936	-121.26504	DWR (use Vernalis)	USGS Sacramento
6	**SJR at Maze**	37.64142	-121.22902	USGS	USGS Sacramento
7	**SJR at Patterson**	37.49373	-121.08081	DWR	Joe Tapia
8	**SJR at Crows Landing**	37.43197	-121.01165	USGS	SFEI
9	**SJR at Fremont Ford**	37.30985	-120.93055	DWR	SFEI
10	**SJR at Lander Avenue**	37.29424	-120.85125	DWR	Joe Tapia
11	**French Camp Slough-Van Buskirk**	37.91613	-121.30447	No Station	None
12	**Stanislaus River at Caswell Park**	37.70160	-121.17719	No Station (use Ripon)	USGS Sacramento
13	**Stanislaus River at Ripon**	37.73113	-121.10811	USGS	USGS Sacramento
14	**Tuolumne River at Shiloh Bridge**	37.60350	-121.13125	No Station (use Modesto)	USGS Sacramento
15	**Tuolumne River at Modesto**	37.62722	-120.98742	USGS	USGS Sacramento
16	**Merced River at River Road**	37.35043	-120.96196	No Station (use Stevinson)	DWR/Joe Tapia
17	**Merced River near Stevinson**	37.38730	-120.79366	DWR	Joe Tapia
18	**Mud Slough near Gustine**	37.26250	-120.90555	USGS	SFEI
19	**Salt Slough at Lander Avenue**	37.24795	-120.85194	USGS	SFEI
20	**Los Banos Creek Flow Station**	37.27546	-120.95532	Grassland WD	Lara Sparks
21	**Orestimba Creek at River Road**	37.41396	-121.01488	Del Puerto WD	Liz Vonckx
22	**Modesto ID Lateral 4**	37.63057	-121.15888	Modesto ID	Michael Niemi
23	**Modesto ID Lateral 5**	37.61452	-121.14339	Modesto ID	Michael Niemi

Table 3: (continued) Flow measurement information.

DO Site Number	Sample Station Name	Latitude	Longitude	Organization Responsible for Flow Station	Suggested Contact for Flow Data
24	**Modesto ID Lateral 6 to Stanislaus River**	37.70383	-121.14143	Modesto ID	Michael Niemi
25	**Modesto ID Miller Lake**	37.66792	-121.21520	Modesto ID	Michael Niemi
26	**Turlock ID Highline Spill**	37.38921	-120.80568	Turlock ID	Keith Larson
27	**Turlock ID Lateral 2**	37.56522	-121.13836	Turlock ID	Keith Larson
28	**Turlock ID Westport Drain**	37.54196	-121.09408	No Station	TID/Keith Larson
29	**Turlock ID Harding Drain**	37.46427	-121.03093	Turlock ID	Keith Larson
30	**Turlock ID Lateral 6 & 7 at Levee**	37.39782	-120.97225	No Station	TID/Keith Larson
31	**BCID – New Jerusalem Drain**	37.72669	-121.29963	SJVDA	Liz Vonckx
32	**El Solyo WD – Grayson Drain**	37.58563	-121.17699	No Station	None
33	**Hospital Creek**	37.61029	-121.23082	SJVDA	Liz Vonckx
34	**Ingram Creek**	37.60026	-121.22506	SJVDA	Liz Vonckx
35	**Westley Wasteway Flow Station**	37.55818	-121.16375	SJVDA	Liz Vonckx
36	**Del Puerto Creek Flow Station**	37.53947	-121.12206	SJVDA	Liz Vonckx
37	**Newman Wasteway**	37.33768	-120.97207	No Station	None
38	**Marshall Road Drain**	37.43605	-121.03600	SJVDA	Liz Vonckx
39	**Salado Creek at River Rd**	37.49960	-121.10539	No Station	None
40	**Patterson Irrigation District Diversion**	37.49716	-121.08280	PID	John Sweigart
41	**West Stanislaus Irrigation District Diversion**	37.58438	-121.20053	WSID	Ron Roos
42	**Banta Carbona Irrigation District Diversion**	37.71266	-121.31146	BCID	David Wisenberger
43	**El Solyo Water District Diversion**	37.64011	-121.22949	ESWD	John Hanson (DPWD)
44	**San Luis Drain End**	37.26090	-120.90520	No Station (Use Station B)	SFEI
45	**Volta Wasteway at Ingomar Grade**	37.10528	-120.93643	Grassland WD	Lara Sparks
45	**Volta Wasteway Flow Station**	37.12903	-120.91937	Grassland WD	Lara Sparks

Table 3: (continued) Flow measurement information.

DO Site Number	Sample Station Name	Latitude	Longitude	Organization Responsible for Flow Station	Suggested Contact for Flow Data
46	**Mud Slough at Gun Club Road**	37.23145	-120.89923	Grassland WD	Lara Sparks
47	**Delta-Mendota Canal inlet to the Mendota Pool**	36.78070	-120.37221	Exchange Contractors Authority	Nigel Quinn
48	**FC-5 – Grassland Area Farmers**	36.92428	-120.65411	SJVDA	Joe McGahan, Mike Gardener
49	**PE-14 – Grasslands Area Farmers**	36.93884	-120.63555	SJVDA	Joe McGahan, Mike Gardener
50	**San Luis Drain Site A**	36.96660	-120.67060	GBP	SFEI
51	**Arroyo Canal**	37.08526	-120.81582	Exchange Contractors Authority	Nigel Quinn
52	**Salt Slough at Sand Dam**	37.12415	-120.73735	No Station	None
53	**Salt Slough at Wolfsen Road**	37.15937	-120.81292	LBNL	Nigel Quinn
54	**Los Banos Creek at Ingomar Grade**	37.07780	-120.88046	No Station	None
55	**Modesto WWTP**	37.53584	-121.09311	City of Modesto	NPDES
56	**Turlock WWTP**	37.48421	-120.87039	City of Turlock	NPDES
59	**SJR Laird Park**	37.55731	-121.15011	No Station	None
NA	**DP-25 – Grasslands Area Farmers**	36.86626	-120.63584	SJVDA	Joe McGahan, Mike Gardener
NA	**San Luis Drain Site B**	37.24082	-120.88190	USGS	SFEI
NA	**Tartar Plant**	37.32000	-120.98000	Unknown	NPDES
NA	**Newman WWTP**	37.32304	-120.98233	City of Newman	NPDES
NA	**SJR Hills Ferry**	37.34944	-120.97520	USGS	USGS Sacramento
NA	**Turlock ID Stevinsen Spill Flow Station**	37.37129	-120.93070	Turlock ID	Keith Larson
NA	**Moran Drain**	37.43547	-121.03551	SJVDA	Liz Vonckx
NA	**Spanish Grant Drain**	37.43576	-121.03581	SJVDA	Liz Vonckx
NA	**Ramona Lake**	37.47881	-121.06850	SJVDA	Liz Vonckx
NA	**Patterson WWTP**	37.49989	-121.09140	City of Patterson	NPDES

Table 3: (continued) Flow measurement information.

DO Site Number	Sample Station Name	Latitude	Longitude	Organization Responsible for Flow Station	Suggested Contact for Flow Data
NA	**Modesto ID Jacobsen Drain**	37.61657	-121.15910	Modesto ID	Michael Niemi
NA	**El Solyo Water District Drain**	37.64060	-121.22925	No station	None
NA	**Modesto ID Main Drain to Miller Lake**	37.66619	-121.19553	Modesto ID	Michael Niemi
NA	**SJR at Vernalis (Flow Station)**	37.67578	-121.26527	USGS	USGS Sacramento
NA	**Banta WWTP**	37.75313	-121.32589	City of Banta	NPDES
NA	**Manteca WWTP**	37.79540	-121.30905	City of Manteca	NPDES
NA	**Manteca Storm Drain**	37.80308	-121.31260	City of Manteca	NPDES
NA	**Old River USGS Flow Station**	37.80782	-121.33149	USGS	USGS Sacramento
NA	**French Camp Slough-Airport Way**	37.88154	-121.24914	DWR	Joe Tapia
NA	**SJR Brickyard Site**	37.89723	-121.32736	University of Pacific	Gary Litton
NA	**SJR at Stockton (Garwood Bridge)**	37.93495	-121.32940	USGS	USGS Sacramento
NA	**Stockton WWTP**	37.93810	-121.33580	City of Stockton	NPDES
NA	**SJR at Rough and Ready Island**	37.96257	-121.36600	DWR	Joe Tapia

Figure 1: Map of DO TMDL Project Core Sites for water quality sampling. See Table 1 for site names.

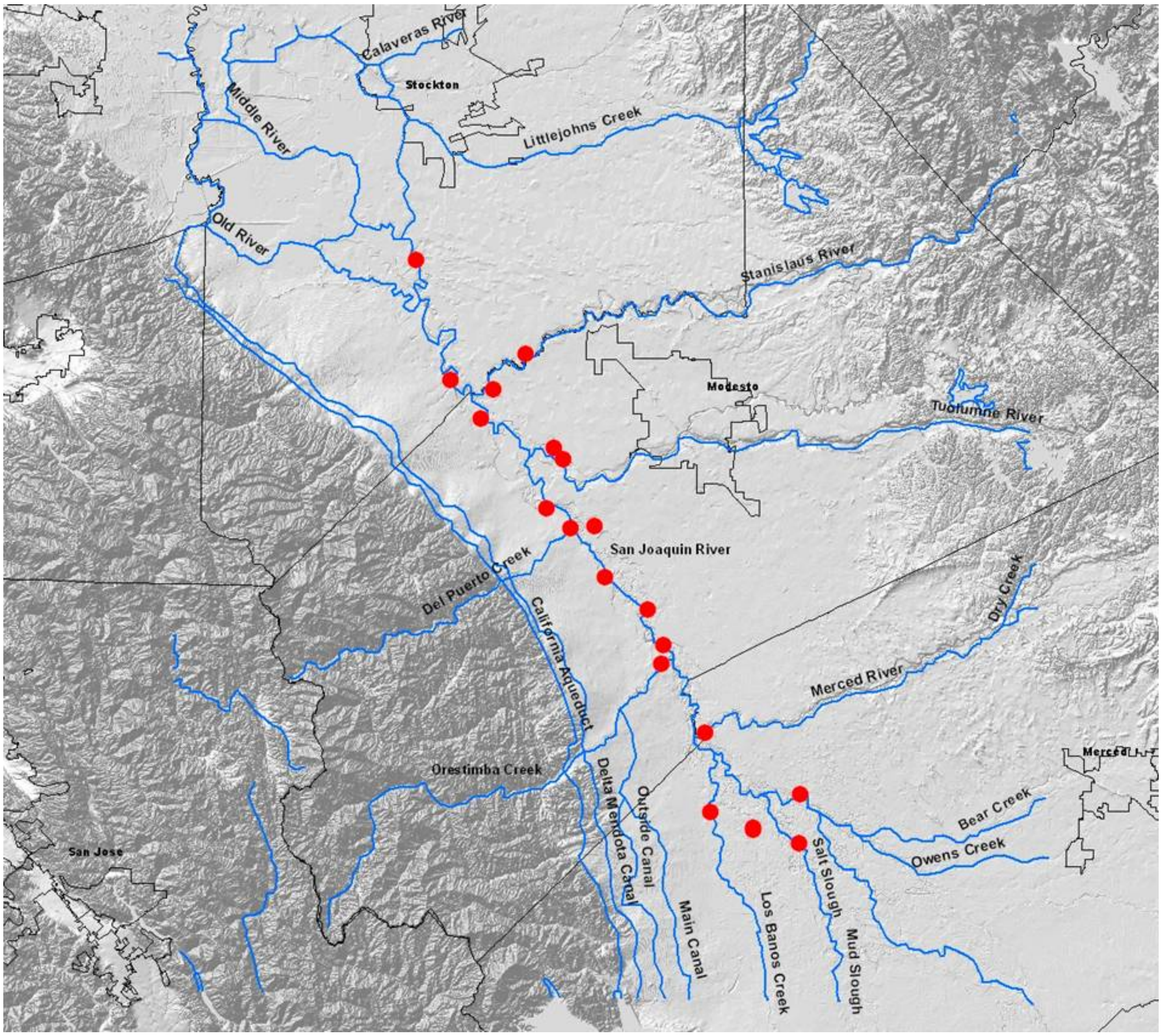

Figure 2: Aerial view of DO TMDL Project water quality sampling station DO-4 San Joaquin River at Mossdale.

Figure 3: Aerial view of DO TMDL Project water quality sampling station DO-5 San Joaquin River at Vernalis.

Figure 4: Aerial view of DO TMDL Project water quality sampling station DO-6 San Joaquin River at Maze Boulevard.

Figure 5: Aerial view of DO TMDL Project water quality sampling station DO-7 San Joaquin River at Patterson.

Figure 6: Aerial view of DO TMDL Project water quality sampling station DO-8 San Joaquin River at Crows Landing.

Figure 7: Aerial view of DO TMDL Project water quality sampling station DO-10 San Joaquin River at Lander Avenue.

Figure 8: Aerial view of DO TMDL Project water quality sampling station DO-12 Stanislaus River at Caswell Park.

Figure 9: Aerial view of DO TMDL Project water quality sampling station DO-14 Tuolumne river at Shiloh Bridge.

Figure 10: Aerial view of DO TMDL Project water quality sampling station DO-16 Merced River at River Road.

Figure 11: Aerial view of DO TMDL Project water quality sampling station DO-18 Mud Slough near Gustine and DO-44 San Luis Drain End.

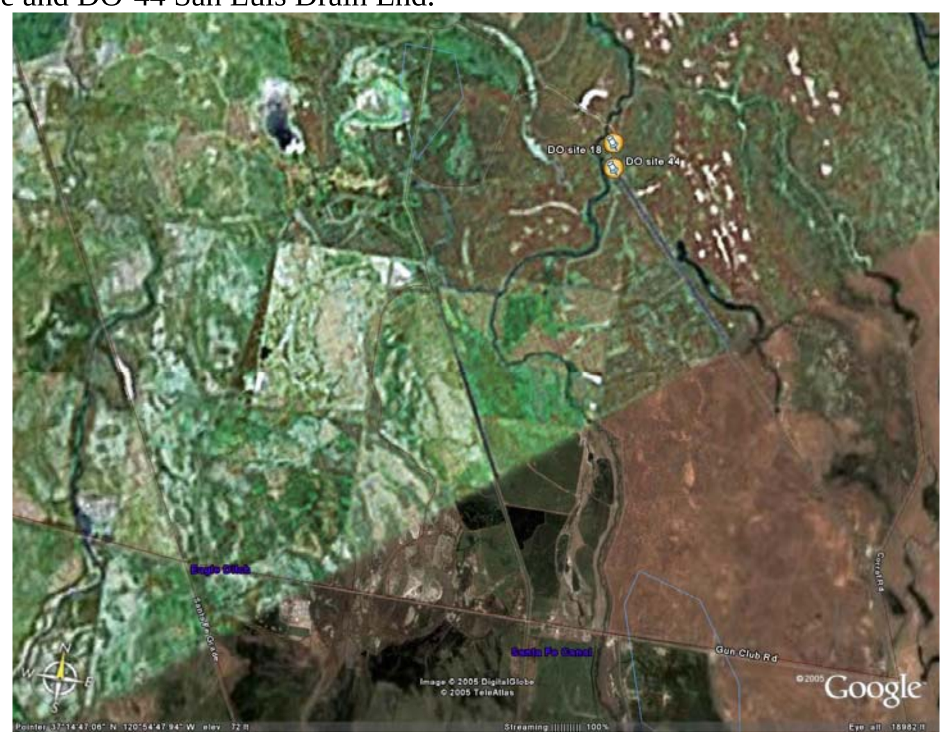

Figure 12: Aerial view of DO TMDL Project water quality sampling station DO-19 Salt Slough at Lander Avenue.

Figure 13: Aerial view of DO TMDL Project water quality sampling station DO-20 Los Banos Creek at Highway 140.

Figure 14: Aerial view of DO TMDL Project water quality sampling station DO-21 Orestimba Creek at River Road

Figure 15: Aerial view of DO TMDL Project water quality sampling station DO-23 Modesto Irrigation District Lateral 5 at Paradise Road.

Figure 16: Aerial view of DO TMDL Project water quality sampling station DO-25 Modesto Irrigation District Miller Lake.

Figure 17: Aerial view of DO TMDL Project water quality sampling station DO-28 Turlock Irrigation District Westport Drain Flow Station.

Figure 18: Aerial view of DO TMDL Project water quality sampling station DO-29 Turlock Irrigation District Harding Drain at Carpenter Road.

Figure 19: Aerial view of DO TMDL Project water quality sampling station DO-36 Del Puerto Creek Flow Station

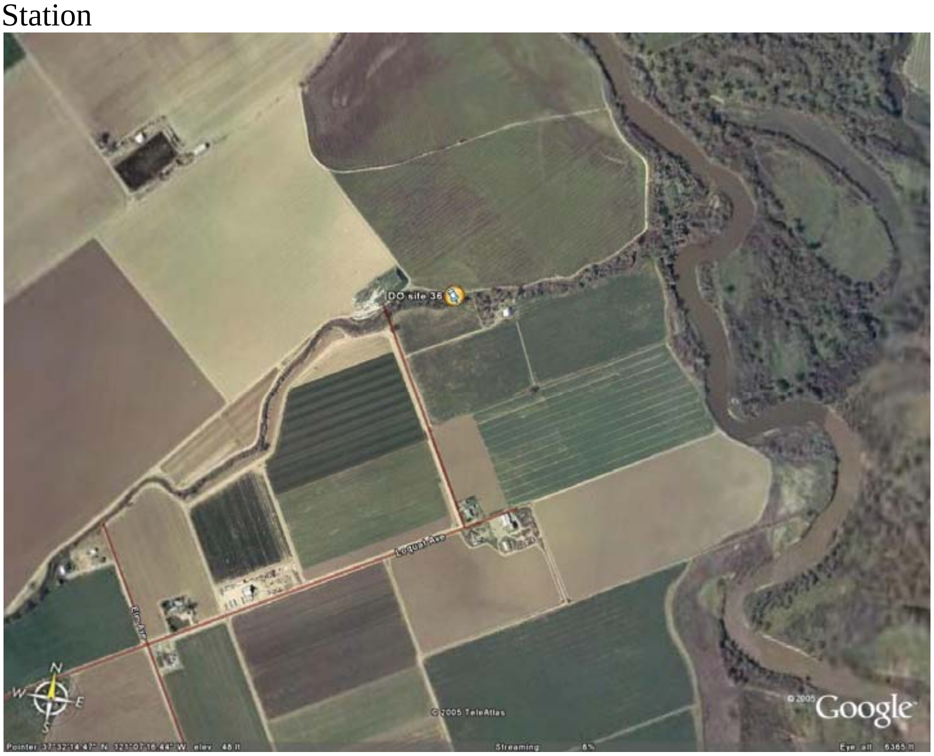

Figure 20: Aerial view of DO TMDL Project water quality sampling station DO-59 San Joaquin River at Laird Park.

Figure 21: Sampling at DO-5, the McCune (Vernalis) sample station, built and operated by the DWR.

Figure 22: Sampling with bucket at DO-16, Merced River at River Road.

Figure 23: Sample station DO-8, Crows Landing, is located in the Turlock Sportsman Club. In the spring, water levels were to the edge of the upper road shown in picture.

Figure 24: Depth integrated sampling at DO-44, San Luis Drain End. The pole and bottle holder are designed to fill bottles slowly as they decent through the water column.

Figure 25: In-situ measurement of chlorophyll-a and other water quality parameters using a YSI 6600 sonde at DO-21, Orestimba Creek. The tripod allows the sonde to be placed further into the middle of the flow without wading.

Figure 26: University of the Pacific van, equipped for sampling.

Figure 27: Measurement of incident light with spherical and flat quantum light detectors. Light is measured to provide reference for interpretation of chlorophyll-a results.

Figure 28: Example of raw stage data. Stage data will be used to calculate flow data as quality control and calibration data becomes available.

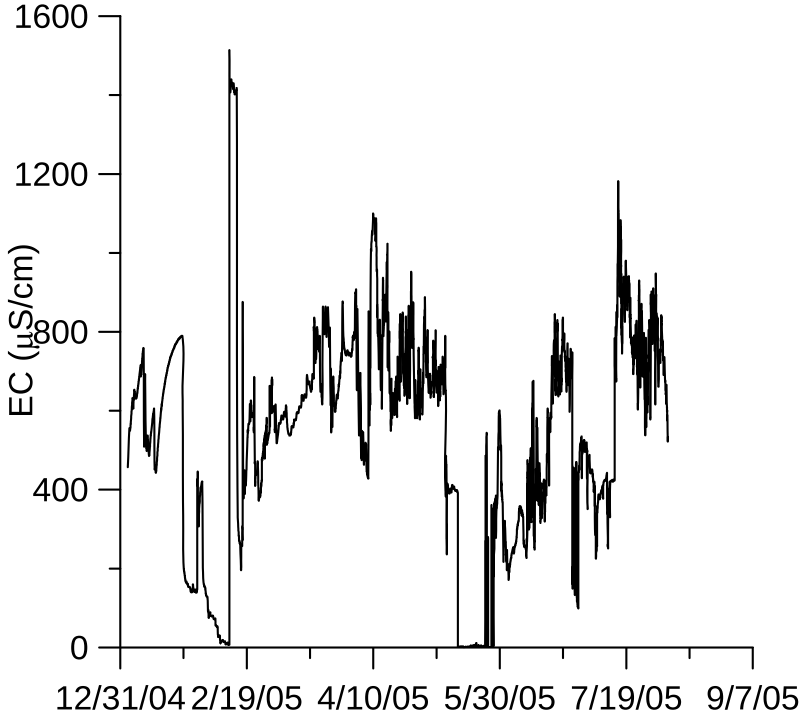

Figure 29: Example of raw electrical conductivity (EC) data being provided by water districts. EC raw data is will be processed into final data when quality control and calibration data becomes available.