SWAMP
Surface Water Ambient Monitoring Program

Monitoring Plan	2009

Central Valley Bacteria Source Identification Study (Source ID Study)

April 2009

Water Boards

www.waterboards.ca.gov/swamp

Table of Contents

List of Figures

List of Tables

Introduction

This plan documents the key aspects of the Central Valley Bacteria Source Identification Study Project (Source ID Study). The Source ID Study is a coordinated monitoring effort between the University of California at Davis (UCD) and the Central Valley Regional Water Quality Control Board (Regional Board) Surface Water Ambient Monitoring Program (SWAMP). This program will monitor and assess ambient water quality of the Sacramento and San Joaquin River Watersheds at targeted locations during distinct seasons (snowmelt, irrigation, dry, and storm events) to further assess previously noted elevated levels of pathogen indicators and conduct a preliminary screening on potential sources (human, cow, dog, other).

Background

The Sacramento River and San Joaquin River Basins cover about one fourth of the total area of the State and over 30 percent of the State's irrigable land. The Sacramento River Watershed is approximately 27,000 square miles and covers 17 percent of California's land. The San Joaquin Watershed covers 17,720 square miles. These watersheds consist of two major valleys, the Sacramento Valley to the north and San Joaquin Valley to the south. These valleys are bounded by several mountain ranges: the Coast Range to the west, the Cascade and Klamath Ranges to the north, and the Sierra Nevada Mountains to the east. The Sacramento watershed drains from northern California from the Oregon border to the Delta, where it joins the San Joaquin River and San Francisco Bay. The San Joaquin watershed originates in Madera County,

The Sacramento River is the largest river in the watershed, with an annual average stream flow volume of 22 million acre-feet. The river is also the longest in the State, extending over 327 miles Major tributaries to the Sacramento River include the Feather, Yuba, American, and Pit Rivers. The main stem of the Sacramento River and most if its major tributaries have been developed for water storage, flood control, and power generation.

The San Joaquin River is the principal drainage artery of the San Joaquin Valley. Average annual surface runoff for the watershed is about 1.6 million acre-feet. Major tributaries to the San Joaquin River include the Cosumnes, Mokelumne, Calaveras, Stanislaus, Tuolumne and Merced Rivers, which primarily carry snowmelt. Flows from the west side of the river basin are dominated by agricultural return flows since west side streams are ephemeral and their downstream channels are used to transport agricultural return flows to the main channel.

Both basins provide a myriad of uses from their headwaters to discharge into the Sacramento-San Joaquin Delta, including timber production, grazing, recreation, fish habitat, drinking water supply and especially along the valley floor, agriculture. Combined, the two basins represent approximately 45% of the irrigated acreage in California.

Staff at the Central Valley Regional Board initiated a water quality monitoring program in October of 2000 as part of California Assembly Bill AB 982 (Chapter 495, Statutes of 1999). AB 982 focuses State Water Resources Control Board (SWRCB) efforts to develop a comprehensive ambient surface water quality monitoring program known as the Surface Water Ambient Monitoring Program (SWAMP).

At the Central Valley Regional Board, SWAMP is attempting to answer the following overarching question and related sub-questions.

Short Term:

- What is/are the status and trends of ambient water quality in streams and rivers in the Sacramento River, San Joaquin River, and Tulare Lake Basins?
- Are there spatial and temporal trends in water quality?
- What is the location and extent of various levels of water quality?
- Is there evidence of beneficial use impairment?

Long-term:

- Is water quality getting better or worse?
- Are Board programs (regulatory/non-regulatory) and management actions effective?

During initial monitoring surveys conducted both by SWAMP and also the Irrigated Lands Regulatory Program (ILRP), elevated concentrations of E. coli were detected at numerous locations throughout both basins. In many instances, E. coli concentrations exceeded USEPA guideline of 235 MPN/100-ml for full contact recreation (swimming). Some sites exceeded the guideline during every sampling event, other elevated concentrations appeared associated with flushing rainfall events. E. coli is an indicator of potential pathogen presence in a system.

Waterborne outbreaks of disease caused by microbial pathogen infection have been of increasing concern to public health. In 1997, the Legislature enacted AB 411 (Wayne, Chapter 765, Statues of 1997), which required the California Department of Public Health (CDPH) to adopt minimum standards for testing of waters adjacent to public beaches for total coliform, fecal coliform, and enterococci bacteria, or other microbiological indicators, specifically along California's beaches. However, much of California's inland rivers and streams are also used for contact recreation. Recent *E. coli* O157:H7 and *Salmonella* outbreaks between 1996 and 2006 brought attention to water supply systems and management practices used in raising crops. In 2007, a source identification study was conducted through the Central Valley Regional Board's Irrigated Lands Program in the lower San Joaquin River watershed, which utilized Bacteroides as the microbial source tracker. This study found that out of three categories (human, bovine, and chicken), the overwhelming majority of the bacteroides DNA found in their samples was of human origin.

Long-term reduction of pathogen pollution will require an integrated approach that combines pathogen monitoring, microbial source tracking, and monitoring protocols that can detect trends in recovery or degradation of microbial water quality. Sacramento River and San Joaquin River are major rivers in Central Valley as well as the State, and within their watershed boundaries resides approximately fifteen percent of the State's population and thirty two percent of the total state water use, mostly for agriculture and applied environmental water use. It is of great significance to monitor surface water quality including occurrence and source of pathogens in watersheds of the two rivers.

Study Design Overview

This Monitoring Plan (MP) and a separate document, Central Valley Bacteria Source Identification Study Quality Assurance Project Plan (Source ID QAPP), have been designed based on SWAMP's template. The following sections provide details of the plan, including constituents to be analyzed, sampling sites (stations), and frequency. Detailed information can be found in the Source ID QAPP.

Monitoring Design

This monitoring effort will provide water quality data within the Sacramento and San Joaquin River Watersheds to support SWAMP objectives. Specifically, this project will

investigate the occurrence and source of pathogenic bacteria in waters from Sacramento River and San Joaquin River. Major questions being asked by this study are:

1. What are the spatial and temporal trends in bacteria indicator and pathogen concentrations at selected tributaries with in the Sacramento and San Joaquin River Basins?
2. What are the potential sources of the identified bacteria (human, cow, dog, other)?
3. Is there any evidence that beneficial uses of recreation, drinking water, or irrigation water supply are being impacted?

The primary objectives of this project are:

- Evaluate seasonal bacteria concentrations and trends in selected water bodies within the Central Valley of California
- Determine whether *E. coli O157:H7* is present at any time at any of the sites being evaluated
- Evaluate potential sources of fecal contamination and at a minimum group potential sources to human, cattle, or other
- Document viable vs. non-viable impacts
- Compare reported concentrations to appropriate water quality objectives and guidelines including but not limited to the Central Valley Regional Board Basin Plan (Basin Plan, 2007) and USEPA Bacterial Water Quality Standards for Recreational Waters guidelines (USEPA Standards, 2003).

In order to answer these questions/objectives, monitoring work will be performed at designated stations to capture seasonal changes. The Source ID QAPP describes the protocols that will be used to ensure data quality will be sufficient to answer these questions.

A pilot sampling run may be conducted prior to final approval of this MP and the associated QAPP to verify ability to meet logistical constraints with holding time, water volume, laboratory capacities, and transport requirements as specified in the associated QAPP. Should this run occur, sampling protocols will comply with the 2008 SWAMP Quality Assurance Management Plan (QAMP) for the State of California's Surface Water Ambient Monitoring Program (http://www.waterboards.ca.gov/water_issues/programs/swamp/qapp.shtml).

Sampling Locations

Sampling sites selection is based on several factors, including the following:

- Sites that have historical monitoring conducted through either SWAMP, the Irrigated Lands Reporting Program (ILRP), Concentrated Animal Feeding Operations (CAFO), or Department of Water Resources (DWR)
- Sites which have demonstrated elevated E. coli concentrations continuously and/or seasonally in previous analyses
- Sites that are readily accessible and within transport holding time limitations
- Sites that represent distinct land use (agricultural, urban and/or rural)
- Even distribution between the Sacramento and San Joaquin Watersheds

Sixteen sites have been selected for sampling in Sacramento River and San Joaquin River watersheds (Table1). The map of the monitoring sites, (cross-referenced with Table 1), is located in the Appendix.

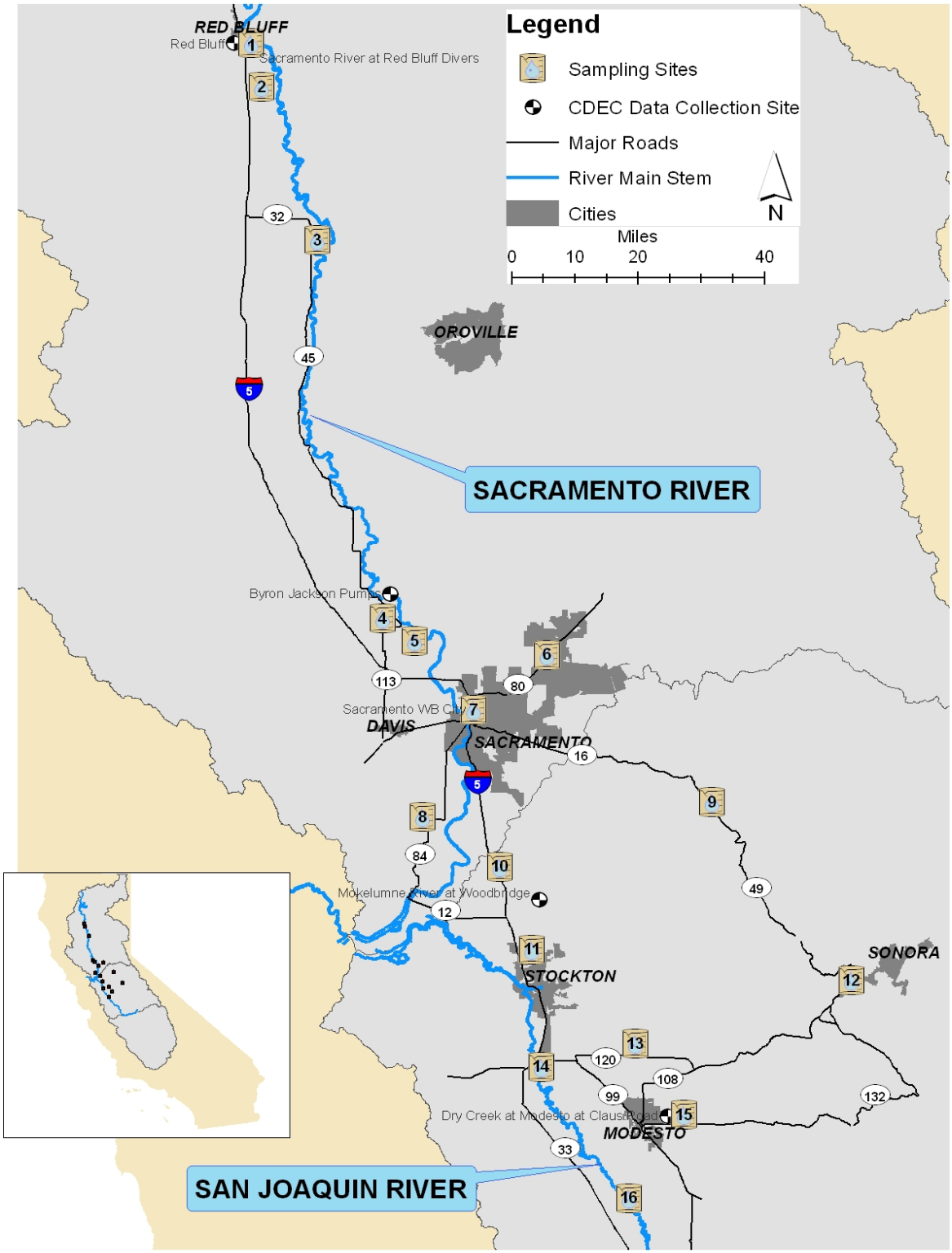
For all sites, safety and all-weather access are priorities for sampling activities. Based on field and weather conditions, the sampling plan may be modified by the project team during the sampling event to provide for field safety and make the collection accurate and thorough. Any changes made to the plan will be documented on the field sheet and added to this Monitoring Plan as Appendices. Changes will be reported as part of the final report to the Central Valley Water Board Contract Manager.

Table 1 Source ID Study Sampling Sites

Map ID	Station Number	Site Description	Land Use Representations	Historical Ranges (MPN/100 mL)	Latitude	Longitude
Sacramento Watershed						
1	A0275890 (DWR SWCMP)	Sacramento River below Red Bluff	A/E	980	40.1534	-122.1993
2	A0332000 (DWR SWCMP) 504ELD99W (SWAMP ID)	Elder Creek at Gerber	B/D	649	40.0509	-122.1666
3	A0290000 (DWR SWCMP) 504STNR24 (SWAMP ID)	Stony Creek at The Nature Conservancy (TNC)	E	>2420	39.6943	-121.9896
4	A0294710 (DWR SWCMP) 520CLSAKL (SWAMP ID)	Colusa Drain above Knights Landing	B	870	38.8121	-121.7741
5	A0219501 (DWR SWCMP) 519SACR16 (SWAMP ID)	Sacramento River below Knights Landing	A/D/E	548	38.7606	-121.6782
6	531PLA900 (SWAMP ID)	Dry Creek/ Cirby Confluence	D/E	210 - >2420	38.7335	-121.2885
7	544SAC007 (SWAMP ID)	American River at Discovery Park	D/E	187 - 1414	38.6017	-121.5027
Delta						
8	510TDNLHT (ILRP ID)	Toe Drain at Little Holland	B	170 - >2400	38.3491	-121.6450
San Joaquin Watershed						
9	532AMA002 (SWAMP ID)	Sutter Creek at Hwy 49	D/E	<1 - >2420	38.3926	-120.8013
10	544SAC002 (SWAMP ID)	Mokelumne River at New Hope Road	A/E	23 - >2420	38.2361	-121.4189
11	531SJC515 (SWAMP ID)	Bear Creek at Lower Sacramento Road*	B/D	15 - >2420	38.0428	-121.3214
12	536TUO208 (SWAMP ID)	Woods Creek at Mother Lode Fairgrounds*	D	84 - 1553	37.9778	-120.3903
13	535XLTABR (ILRP ID)	Lone Tree Creek at Bernnan Rd*	B/D	>1600	37.8255	-121.0159
14		Walthall Slough	C	NA	37.7692	-121.2891
15	535XDCAWR (ILRP ID)	Dry Creek at Wellsford Road*	C	8 - >1600	37.6602	-120.8743
16	535STC501 (SWAMP ID)	Harding Drain at Carpenter Road*	B/D	<1 - >2420	37.4644	-121.0303

A – Integrator Site
B – Irrigated Agriculture
C – Confined Animal Feeding Operation
D – Community Development
E – Recreation

Figure 1 Map of Sampling Sites



Indicators and Measurement Parameters

Parameters for this study were selected based on potential to address the primary objectives listed in section III.a. It is alos an opportunity to get a Region-wide assessment of ambient water quality conditions and preliminary review of beneficial use protection based on the indicators listed in Table 2. Study parameters include: field parameters, *E. coli, E. coli* O157:H7, and *Bacteroidales*. If resources allow, *Salmonella* will also be included.

All samples and field measurements will be collected in accordance with the Source ID QAPP. The Source ID QAPP will be submitted for review and approval by the SWAMP Quality Assurance Team with this Monitoring Plan. More specific information on field and laboratory procedures for each parameter follows.

Table 2 Parameters as Indicators for Beneficial Use Protection

Parameter	*Recreation*	*Drinking Water*	*Aquatic Life*	*Agriculture*
Temperature			X	
Dissolved Oxygen			X	
pH	X	X	X	X
Conductivity		X	X	X
Turbidity	X	X	X	
E. coli	X	X		
E. coli O157:H7				
Bacteriodales				
Salmonella				

The Regional Board will use a YSI multi-analyte probe to measure several basic parameters in the field, and collect grab samples to be analyzed by the Atwill Lab (Department of Population Health and Reproduction, University of California, Davis), Wuertz Lab (Department of Civil and Environmental Engineering, University of California, Davis), and Central Valley Regional Board Lab.

Field Parameters

Field parameters will include temperature, dissolved oxygen, pH, and specific conductivity. Turbidity may also be included, as resources permit. Collection of field parameters is cost effective and provides information on the protection of multiple beneficial uses (Table 2). Additionally, these field parameters link to large efforts including the Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS) and TMDL development and implementation.

A YSI 600XLM multiparameter water quality monitor will be used to collect data for dissolved oxygen, electrical conductivity, pH and temperature. In addition, a Hach 2100P turbidimeter will be used for field measurements of turbidity. All field equipment is calibrated using certified calibration standards and following the manufacturer specifications prior to and following each sampling event. Calibration records are maintained at the Regional Board office and are used to determine instrument accuracy.

E. coli

The Central Valley Water Board is able to analyze for total coliform and *E. coli* in-house using the IDEXX Colilert® QuantiTray system. *E. coli* is an important indicator for the protection of recreational beneficial uses, and may indicate when disease-causing agents are present at densities that could cause problems.

While *E. coli* analysis may indicate when disease-causing agents are present at densities that could cause problems, they also may not accurately represent the actual health risk. Additional analyses will be conducted in the laboratories, to include presence of *E. coli O157:H7* in the Atwill Laboratory, and presence and viability of Bacteroidales in the Wuertz Laboratory. Additionally, *Salmonella* samples may be analyzed by the Atwill Laboratory, dependant upon available resources. Protocols to be used in processing the samples are provided in the Source ID QAPP.

E. coli O157:H7

Water samples will be analyzed for the presence/absence of *E. coli* O157:H7 by the Atwill Laboratory. Water samples will be filtered at the laboratories within 24 hours after collection. At the Atwill Laboratory, A Qualitative Enrichment-IMS method will be used for detection of *E.coli* O157. Filtrations will be enriched in Tryptic Soy Broth followed by Immuno-magnetic separation (IMS). Rainbow agar plate and CT-SMAC II agar plate will be used for isolation of *E.coli* O157. Specific PCR will be performed on positive samples for group determination.

Bacteroidales

At the Wuertz Laboratory, using qualitative methods and quantitative models developed by the laboratory, sources of fecal contamination will be grouped to human, bovine, dog and universal (all warm blood animals) as determined by host-specific Bacteroidales qPCR assays.

Bacteroidales are anaerobic, intestinal bacteria and thus they represent an excellent alternative to current fecal indicators as their survival is quite unlikely outside of their hosts, and host-specific assays can distinguish between different sources of fecal contamination. The use of host specific molecular assays provides the additional advantage compared to culture based methods that nucleic acid extracts of samples can be safely stored over a longer period of time and reanalyzed using novel or improved assays.

Salmonella

Water samples will be analyzed for the presence/absence and concentration of *Salmonella* spp. by the Atwill Laboratory. An Enrichment-MPN (most probable number) method will be used for detection and estimation of concentrations of *Salmonella* in waters. A regime of 200ml × 4, 20ml × 4, and 2ml × 4 waters will be filtered at the laboratory within 24 hours after collection. Filtrations will be enriched in Buffered Peptone Water (BPW) and Rappaport-Vassiliadis (RV) buffer followed by isolation on

Xylose Lysine Deoxycholate (XLD) agar plates. *Salmonella* positive reactions on XLD agar will be confirmed by biochemical tests. Concentrations of *Salmonella* spp. in waters will be calculated as MPN/100ml of water using the MPN calculator of computer software.

Data Analysis

All data from this study will be assessed in the 2012 cycle of the Clean Water Act Section 305(b) and 303(d) Integrated Report. Data will be assessed based on the criteria in the Basin Plan, EPA Guidelines, and objectives of this project. A final project report will summarize these findings.

Where potential water quality problems are identified, this information will be provided to the appropriate Central Valley Water Board program for follow-up study. As funding permits, information from this study will also be used to direct expanded SWAMP monitoring that will rotate through each of the three Central Valley basins.

Data Collection and Frequency of Sampling

Four sampling events are planned for this study. All samples will be collected as grab samples. Sampling events will be timed as best as possible to represent spring snowmelt, irrigation, dry and winter runoff. Sampling events will be scheduled for each of the above season accordingly and with agreements among the laboratories at UC Davis and field crew of the Central Valley Water Board.

Table 3 Sample Frequency and Sites Sampled for Each Parameter

Parameter	***Sample Frequency***				***Sites Sampled***
	Spring Snowmelt	***Irrigation***	***Dry***	***Winter Runoff***	***All***
Field Parameters	X	X	X	X	X
Total coliform/*E. coli*	X	X	X	X	X
E. coli O157:H7	X	X	X	X	X
Bacteroidales	X	X	X	X	X
Salmonella (as resources permit)	X	X	X	X	X

Spatial and Temporal Scale

Sampling locations are distributed throughout the Sacramento and San Joaquin River Watersheds. Locations are targeted to represent different, sometimes multiple, land uses to include integrators (3 sites), irrigated agriculture (6 sites), concentrated animal feeding operations (2 sites), recreation (7 sites), and community development (9 sites) in upper and lower watershed areas.

Data from all 16 sites will be combined for a Region-wide assessment in the final project report. Table 4 summarizes the number of sites that represent each land use.

Sampling events are distributed to capture changes in water quality over four major seasons (spring snowmelt, irrigation, dry and winter runoff).

Data Management

All data from this study will be managed in accordance with the SWAMP data Management Plan (2009) and SWAMP Standard Operating Procedures (SOPs). Data will be entered and stored in the SWAMP v2.5 Database. The Central Valley Water Board will load field sheet, field parameter, and bacteria data into the database. The SWAMP contract laboratories will submit the remaining data in SWAMP-comparable format to the SWAMP data Management Team for entry to the database.

Data in the SWAMP Database will be made available to the public through the California Environmental Data Exchange Network (CEDEN). CEDEN is currently in development and is expected to be operational in 2009. Information on CEDEN is available at www.ceden.org.

Coordination and Review Strategy

UC Davis researchers prepared this MP and are responsible for coordinating the sampling events, including providing sample containers from the labs, insuring capacity at laboratory facilities, conducting laboratory analysis, data management, and report to the Regional Board. The Regional Board will be responsible for sampling, field measurements and observations, delivery of samples to analytical laboratories at UC Davis, and analysis of grab samples for E. coli.

The sites monitored for this study are a subset of the networks of sites selected for the Irrigated Lands Reporting Program, Department of Water Resources Integrator Seasonal Trend Monitoring Study, SWAMP Recreation Studies, and SWAMP historical monitoring. All programs which conduct monitoring at the sites included in this study will be provided data results and copies of the final project report.

In addition to review by program staff from both the Central Valley Regional Board and UC Davis, this document will be reviewed by two external reviewers, in accordance with SWAMP procedures.

Quality Assurance

Blind field replicates will be collected for 5% of samples collected. Water samples will be bottled as appropriate and held at 6°C, before being transferred to the laboratory for analysis. Chain-of-custody documentation will be maintained for all samples.

All aspects of this study will be conducted in accordance with the 2008 SWAMP Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program, and the Regional Board's San Joaquin River Procedures Manual,

Appendix F Bacteria Monitoring. Additionally, procedures will comply with the Source ID Study QAPP, which will be submitted for SWAMP review along with this Monitoring Plan.

Reporting

The Central Valley Water Board will prepare Fact Sheets highlighting analytical results and findings. All field sheet and bacteria data will also be posted at the end of this project. Both Fact Sheets and field and bacteria data will be made available to the public on the Central Valley Water board's SWAMP webpage at: http://www.waterboards.ca.gov/centralvalley/water_issues/water_quality_studies/surface_water_ambient_monitoring/index.shtml. Target completion dates are shown in Table 4.

Upon completion of the Study, UC Davis will submit draft and final reports to the Regional Board summarizing all analytical data collected.

Project Schedule

A timeline for project activities and target completion dates are provided in Table 4.

Table 4 Target Completion Dates for Products

Activity	Date (MM/DD/YY)		Deliverable	Deliverable Due Date
	Anticipated Date of Initiation	Anticipated Date of Completion		
Start project	3/1/2009	5/31/2010	none	none
Tentative logistical field run (Snowmelt event)	*4/1/2009*	*5/31/2009*	*None*	*none*
Tentative Sample Analysis (snowmelt event)	*5/1/2009*	*7/31/2009*	*Data set*	*7/31/09*
Sample Collection (irrigation event)	7/1/2009	9/30/2009	none	None
Sample Analysis (irrigation event)	7/1/2009	10/31/2009	Data set	10/31/09
Sample Collection (dry season)	10/1/2009	11/30/2009	none	None
Sample Analysis (dry season)	10/1/2009	12/30/2009	Data set	12/30/09
Sample Collection (storm season)	12/1/2009	1/31/2009	none	None
Sample Analysis (storm season)	12/1/2009	2/28/2010	Data set	2/28/10
Fact Sheets/Data Posted	5/1/2009	3/15/2009	Fact Sheets/Data Website Posting	3/15/2009
Draft report	2/28/2010	3/31/2010	Draft report to Water Board	3/31/2010
Final report	3/31/2010	5/31/2010	Final report to Water Board	5/31/2010

References

California Department of Public Health. Investigation of the Taco John's *Escherichia coli* O157:H7 Outbreak Associated with Iceberg Lettuce. 2008. (http://www.dhs.ca.gov/fdb/local/PDF/TJreport_FINAL_021508_Redacted_Compressed.pdf)

California Department of Public Health. Environmental Investigation of *Escherichia coli* O157:H7 Outbreak Associated with Taco Cell Restaurants in Northeastern States. 2007. (http://www.dhs.ca.gov/fdb/local/PDF/Taco_Bell_final_report_redacted_11_19_2007.pdf)

California Department of Public Health. Investigation of an *Escherichia coli* O157:H7 Outbreak Associated with Dole Pre-packaged Spinach. 2007. (http://www.dhs.ca.gov/fdb/local/PDF/2006%20Spinach%20Report%20Final%20redacted.PDF)

California Department of Public Health. *E. coli* O157:H7 Illnesses in Washington – July, 2002. 2002. (http://www.dhs.ca.gov/fdb/local/PDF/02_07reportweb.pdf)

California Department of Public Health. Environmental Investigation of Salmonella Enteritidis, Phage Type 30 Outbreak Associated with Consumption of Raw Almonds. 2001. (http://www.dhs.ca.gov/fdb/local/PDF/2001AlmondReportWebVersion.pdf)

California Department of Public Health. Report of Investigation of *E. coli* Outbreak at San Mateo County Retirement Facility in October 2003. 2004. (http://www.dhs.ca.gov/fdb/local/PDF/E%20coli%20Sequoias%20final%20redacted%20web.pdf)

California Department of Public Health. Investigation of an E. coli O157:H7 Outbreak Linked to Fancy Cutt Farms. 1996. (http://www.dhs.ca.gov/fdb/local/PDF/Fancy%20Cutt%20Farms%20Investigation%20Report%2008%201996.pdf)

California Department of Public Health. Investigation of Pre-washed Mixed Bagged Salad Following an Outbreak of *E. coli* O157:H7 in San Diego and Orange County. 2004. (http://www.dhs.ca.gov/fdb/local/PDF/PO%20Report%20Web%20Version%202.PDF)

California Department of Public Health. Environmental Investigation of *Salmonella* Enteritidis Phage Type 9c Outbreak Associated wit Consumption of Raw Almonds. 2004. (http://www.dhs.ca.gov/fdb/local/PDF/SEAlmond2004Redacted.PDF)

California Regional Water Quality Control Board, Central Valley Region. Procedures Manual for the San Joaquin River Water Quality Monitoring Program. 2008 (Draft).

California Regional Water Quality Control Board, Central Valley Region. San Joaquin River Basin bacteria Monitoring Program. 2007.

California Regional Water Quality Control Board, Central Valley Region. Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin. Fourth Edition. 2007. (http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr.pdf)

Department of Water Resources, DWR. Annual Land and Water Use Data. 2001. (http://www.landwateruse.water.ca.gov/annualdata/datalevels.cfm)

Department of Water Resources, DWR. California Water Plan Update Bulletin 160-98. 1998. (http://rubicon.water.ca.gov/pdfs/es/esch4.pdf)

State Water Resources Control Board, The Water Board. Source Investigations of Storm Drain Discharges Causing Exceedances of Bacteriological Standards. 2001. (http://www.waterboards.ca.gov/water_issues/programs/beaches/beach_surveys/docs/ab538rpt_finalfinal.pdf)

United States Environmental Protection Agency, USEPA. Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report. EPA-823-R-03-008. 2003. (http://www.epa.gov/waterscience/beaches/local/statrept.pdf)