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Sacramento River Watershed Program

Final Proposition 50 Grant Monitoring Report 2005 – 2007

Prepared by:

Larry Walker Associates

for

the Sacramento River Watershed Program

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EXECUTIVE SUMMARY

Introduction and Report Overview

This is the final monitoring report for the Sacramento River Watershed Program (SRWP) Prop 50 Grant project. This document provides a review of the Sacramento River Watershed Program (SRWP) monitoring effort and data generated. This report describes data collected from 2006-2007 by the SRWP and by programs coordinating with the SRWP. These water chemistry, aquatic toxicity, and fish tissue data are used to evaluate the attainment of beneficial uses and potential impairment of surface waters of the Sacramento River Watershed (watershed) and to assess spatial and temporal distributions of a variety of important water quality characteristics.

The three categories of water quality data considered in this review of SRWP 2006-2007 monitoring data are (1) parameters of concern related to drinking water, (2) aquatic toxicity and pesticides, and (3) bioaccumulative pollutants in water and fish tissue. The findings from SRWP monitoring are summarized in relation to the major uses and activities in the watershed – drinking water, recreation, aquatic life, and fishing are evaluated for each category of monitoring because they are considered the most sensitive to water quality. The beneficial uses of navigation and water supply for agriculture and industry are not as sensitive to water quality and are also generally supported throughout the watershed.

Locations discussed in this report are illustrated in **Figure 2** in the review of monitoring results beginning on page **16**. SRWP monitoring has found that most sites monitored in 2006-2007 continued to meet current water quality objectives most of the time, and that the mainstem river and major tributaries are high quality sources for water for municipal and agricultural uses. With the exception of mercury, the legacy of metals contaminants from the mining era has been largely addressed, and trace metals are no longer a problem in the watershed. Methylmercury and polychlorinated biphenyl (PCBs) continue to be a concern for human health and wildlife, and should continue to be monitored (especially in fish) in the watershed.

Drinking Water and Recreational Uses

Dissolved and suspended solids, turbidity, nitrogen and phosphorus compounds, organic carbon, and bacteria were monitored by the SRWP for their relevance to the evaluation of the attainment of a variety of uses, including drinking water supply, recreation, aesthetics, aquatic habitat, and agricultural supply. The mainstem Sacramento River, and major tributaries (the Yuba, Feather, and American rivers) consistently meet water quality goals and objectives for drinking water-related parameters. Based on these indicators, SRWP monitoring results suggest that designated beneficial uses of the Sacramento River and tributaries as sources of municipal and agricultural supply water and recreational uses are generally attained within the watershed.

There was a general trend for concentrations of TDS, organic carbon, and nutrients to increase in the mainstem Sacramento River from the upper watershed to the lower watershed. This trend can be attributed to a combination of natural and anthropogenic sources, and is moderated by high-quality Sierra tributary inflows. It generally follows a similar trend in land uses of increasing urban development and agricultural uses, and commensurately decreasing open space, as water moves from the upper to the lower watershed. The highest concentrations of most parameters of concern for drinking water were generally observed in agricultural drains (Sacramento Slough and Colusa Basin Drain). These findings were consistent with results of SRWP monitoring conducted prior to 2006. However, the urban drainage monitored in 2006-2007 (Churn Creek) was not elevated for most of these drinking water related parameters, and did not fit the pattern observed for urban drainages and creeks monitored prior to 2006 (Natomas East Main Drain, Arcade Creek) which were elevated for most parameters.

The results of SRWP monitoring indicate that salinity, and nutrient concentrations are not impairing beneficial uses within the watershed. However, concerns remain that nutrients in the Sacramento River may contribute to excessive and nuisance algae growth in the Delta and in drinking water transport and storage systems outside of the watershed.

For the purpose of evaluating achievement and potential impairment of contact recreational uses, data for the pathogen indicator *E. coli* were compared to adopted Basin Plan objectives. The single-sample Basin Plan limit for *E. coli* was exceeded occasionally at most locations monitored (except at mainstem sites upstream from Veterans Bridge) and more frequently at lower mainstem sites, tributary sites, and agricultural drain sites. The highest concentrations of bacteria were observed at the sites with the greatest urban land use percentages (lower Sacramento River sites, lower American River sites, Churn Creek). The single-sample objective was exceeded most frequently in Churn Creek (~33% of samples), but median bacteria concentrations for 2006-2007 did not exceed the 126 MPN/100 mL objective (implemented as a five-sample geometric mean) at any site. *E. coli* exceeded the Basin Plan objectives more frequently in wet season (~32% of samples), and rarely exceeded the objectives in dry season (~7% of samples). This seasonal pattern was seen for most sites, except the agriculture drainage sites, which did not exhibit higher concentrations of bacteria during the drier than normal 2006-2007 wet season. Overall, these findings were similar to those of past SRWP monitoring efforts.

Aquatic Toxicity and Pesticides

The results of the 2006-2007 monitoring and previous SRWP aquatic toxicity monitoring efforts have confirmed that significant toxicity to test organisms continues to occur sporadically in surface waters throughout the watershed and throughout the monitoring period. There were no substantial differences in the frequency of toxicity observed at the different types of sites (mainstem, tributary, agricultural drainage, and urban creeks). Organophosphorus pesticide toxicity to *Ceriodaphnia dubia* in agricultural runoff and urban runoff has been definitively shown previously by SRWP monitoring and other studies (de Vlaming *et al.,* 2000; Larsen *et al*., 1998; Bailey *et al.,* 1996). This specific cause of toxicity appears to have declined substantially in recent years due to changes in practices and decreases in the applications of the most commonly used organophosphates – there were no cases of toxicity attributed to diazinon or chlorpyrifos in the 2006-2007 monitoring period.

Toxicity tests with the green alga *Selenastrum capricornutum* indicated that ambient toxicity to algae was infrequent. Because of the infrequently observed toxicity, there were no consistent spatial or temporal trends observed in algal toxicity. Toxicity that was observed was not attributable to any detected pesticides or other toxicants. Most samples exhibited a significant increase in growth compared to the control, and the increasing growth response in the mainstem Sacramento River was consistent with increasing percentages of agriculture and urban development land uses that contribute nutrients to the river.

The frequency and magnitude of toxicity to *Ceriodaphnia dubia* was markedly greater than was observed for algae – approximately 10% of the samples exhibited significant reductions in *Ceriodaphnia* survival, with an additional 13% of the samples exhibiting a significant reduction in reproduction. Nearly every sample that caused a significant reduction in survival resulted in ≤50% survival, and most of those caused complete mortality of the test organisms. There were no consistent spatial trends in the *Ceriodaphnia* responses, and there were no discernible trends in toxicity for different types of water bodies. This finding differs somewhat from past SRWP findings that observed more frequent toxicity in the urban creek sites monitored in previous years.

In the 20 Toxicity Identification Evaluations (TIEs) performed with *Ceriodaphnia*, the most common result was a lack of persistence of the toxicity, a significant decrease in toxicity, or a delay in onset of toxicity. TIE tests were initiated between three and eight days after sampling for all samples, and there was no relationship between this elapsed time period and the persistence of toxicity (i.e., persistence was not more common in samples with a shorter elapsed period between sampling and test initiation). In the 11 samples with persistent toxicity, metabolically-activated non-polar organic substances were most frequently indicated as the cause of toxicity.

The lack of persistent toxicity in many of the samples, coupled with the delayed onset and decreased magnitude of toxicity for many samples, indicates that persistent toxicants (e.g., metals) were not likely to have caused the observed toxicity in most of the samples. Because pesticides have a history of causing toxicity in the watershed, the analytical results for the toxic samples were also evaluated to determine if there were any contaminants that could have been responsible for the observed toxicity. The consistent result of this evaluation was that monitored organophosphorus, triazine, carbamate, and organochlorine pesticides were not detected or were well below concentrations toxic to *Ceriodaphnia* in toxic samples. In no cases were pesticides detected at concentrations that would explain the observed toxicity to *Ceriodaphnia*, either individually or due to know synergistic or additive combinations.

Approximately 7% of the samples exhibited significant reductions in larval stage fathead minnow (*Pimephales promelas*) survival, with an additional 9% of the samples exhibiting a significant reduction in growth. There was an indication of a spatial trend in the fathead minnow responses in the mainstem Sacramento River, with more frequent mortality and lower growth in the two most upstream sites. There were no other discernible trends in toxicity for different types of water bodies.

Six TIEs were performed with fathead minnows with results similar to those for *Ceriodaphnia*. Toxicity was persistent for five of the six samples and was delayed or decreased in four of these five samples, a pattern consistent with contaminants that were degrading or becoming less bioavailable over time. Of these five samples with persistent toxicity, the patterns in TIE results were similar to those for *Ceriodaphnia*, with metabolically-activated, non-polar organic substances being indicated most frequently. As was found with the *Ceriodaphnia* results, there were no pesticides or other toxicants detected in the samples that were consistent with the TIE results, and the specific probable responsible toxicant(s) were not identified.

There were seasonal trends in *Ceriodaphnia* and fathead minnow toxicity, with significantly higher percentages of toxic samples observed in wet season samples (36%) than in dry season samples (10%). This result is consistent with previous SRWP reports and many other studies that indicate that stormwater runoff is frequently a source of toxicity in many aquatic systems.

Monitoring conducted from 1998–2007 has been valuable in evaluating the overall frequency and distribution of observed water column toxicity, and for identifying and confirming the causes of some of the observed toxicity. SRWP monitoring has been successfully conducted over a wide range of environmental conditions and events. However, spatial coverage of the watershed by SRWP (and other programs) is far from comprehensive, and significant questions remain regarding the sources, severity, persistence, and ecological significance of periodic toxicity in surface waters of the watershed. Definitively addressing these questions will require monitoring and studies of different scope (and greater cost) than the recent efforts by SRWP and other programs.

Bioaccumulative Pollutants in Water and Fish

Mercury and certain organic contaminants [including legacy organochlorine pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs)] are readily accumulated directly from water or through the food web from low levels in water, resulting in concentrations in fish tissue that may be of concern to humans and wildlife. Monitoring these pollutants in fish provides an effective way to assess potential human health risks in the watershed. Although the primary concern is over these contaminants in fish tissue, mercury species were also measured in water to allow continued tracking of longer-term trends in water column concentrations. Because fish accumulate contaminants throughout their life span, measurements of contaminant concentrations in fish tissue provide an indication of average conditions over space and time. Fish tissue data are useful for the determination of longer-term average concentrations and trends of bioaccumulative contaminants (such as mercury, DDT and PCBs) in the watershed. This long-term dataset can also be used to measure the effectiveness of activities to control these pollutants.

The results of the analyses of mercury, organochlorine pesticides, and PCBs in fish tissue were similar to those from past SRWP monitoring years. However, some of the conclusions based on these results have changed, primarily due to updates of the California Office of Environmental Health Hazard Assessment’s (OEHHA) fish tissue screening values for some trace organics. Because of the changes in screening values, the risks from consuming fish contaminated with organic compounds appears lower than was concluded in previous SRWP reports. However, there are still significant risks, particularly from mercury and PCBs.

None of the composite fish samples exceeded OEHHA’s screening values for “Group-A” organochlorine pesticides (aldrin, chlordanes, endrin, heptachlor, PBDEs, endosulfan, and toxaphene). In previous SRWP monitoring, dieldrin and DDT were found to exceed the 1999 screening values at many locations. No fish were found to exceed the updated (higher) 2006 screening values for dieldrin and DDT. There appears to be little risk to human consumers from contamination of fish tissue with these pesticides. These results also continue to support SRWP's previous recommendations to consider "delisting" the lower Feather River for impairment due to Group A pesticides. PBDEs were detected in all samples tested, but did not approach an estimated screening value of 1786 parts per billion (ppb or ng/g) calculated using USEPA and OEHHA methodology. Based on these results, there also appears to be little risk to human consumers from contamination of fish tissue with these common flame retardants.

The results and risks associated with mercury and PCBs were little changed from previous evaluations by SRWP. PCBs (total aroclors) exceeded the OEHHA 2006 screening in approximately 25% of tissue samples in a variety of species from eight different sites. Screening values were exceeded in fish from the lower Sacramento River (Veterans Bridge to Rio Vista), the lower American River, Sacramento Slough, and in one composite from Clear Creek. The highest PCB concentration (213 ppb) was observed in a catfish composite from Sacramento River at Colusa. This overall rate of exceedance of the PCB screening value (39%) was essentially the same as observed in previous SRWP monitoring conducted prior to 2005 (38%). Based on preliminary data from the CALFED Fish Mercury Project (FMP), there is no apparent change in patterns of mercury contamination in the Sacramento River watershed.

Recommendations for Future Monitoring

Monitoring in the Sacramento River watershed should be continued, expanded, and integrated with other regional monitoring efforts. SRWP has recently launched an effort to develop a long-term, sustainable regional monitoring program for the watershed. A number of ecological and regulatory factors drive a continued need for expanded and integrated regional monitoring in the watershed, including the Pelagic Organism Decline (POD) in the Delta, Central Valley Drinking Water Quality Policy development, sediment quality objectives, 303(d) listings of impaired waters and a number of ongoing and upcoming TMDLs, expanding NPDES permit ambient monitoring requirements, and the Irrigated Lands Regulatory Program. Implementation of the State Board's Strategic Plan and POD Resolution are recent regulatory responses to these issues and also recognize the need for additional and more focused monitoring. It is anticipated that a major portion of the funding for the program envisioned by the SRWP will come from the program's many stakeholders. This regional program will be consistent with the SRWP's existing goals and objectives, but could be expanded to establish baseline conditions for sediment quality, biodiversity and ecological health. Additional focus will be placed on understanding pollutant fate and transport, linking water quality to beneficial uses and sources to impairment, evaluating emerging contaminants, and evaluating longer term trends in conditions.

Additional recommendations for specific changes in future monitoring strategies for drinking water, toxicity, pesticides, and bioaccumulative pollutants in the watershed are provided for consideration in the main body of the report.

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SRWP AND MONITORING PROGRAM OVERVIEW

The Sacramento River Watershed Program (SRWP) was founded in 1996. The SRWP is a collaborative, consensus-based group of stakeholders with long-term interests in sustaining and enhancing a 27,000-square-mile watershed that covers 17 percent of California's total land mass. Stakeholders of the program are represented by a 21-member board of trustees, which holds open meetings and oversees program activities. Activities include monitoring for contaminants, providing watershed education and networking with and supporting other northern California watershed groups. More broadly, the program aims to promote the long-term social and economic health of the watershed and its many users. In addition to monitoring watershed conditions, the SRWP forms alliances and partnerships with stakeholders in the watershed, seeks private and public funding for specific projects and conducts public outreach to increase awareness of the watershed, its uses and issues.

Monitoring Program

The goal statement developed by the participating stakeholders for the SRWP in 1996 is:

> *"To ensure that current and potential uses of the watershed's resources are sustained, restored and, where possible, enhanced while promoting the long-term social and economic vitality of the region."*

The Monitoring Committee has established the following long-term goal for the SRWP monitoring program:

> *"In coordination with other subcommittees and the larger stakeholder group, develop a cost-efficient and well-coordinated long term monitoring program within the watershed to identify the causes, effects and extent of constituents of concern that affect the beneficial uses of water and to measure progress as control strategies are implemented."*

The SRWP monitoring program was envisioned by the committee to be a long-term (e.g., 20 year) effort that will provide information to promote the understanding of conditions in the watershed and to assess the relative health of the watershed. The monitoring program has been a dynamic activity that is expected to change over time as information is accumulated and new information needs are identified.

The Monitoring Committee established the following goal for the first year of the monitoring program, and retained this goal for subsequent years of monitoring:

> *"To assess conditions in the main stem of the Sacramento River through the collection of baseline information, with an emphasis on examining the degree to which beneficial uses are attained."*

Consistent with these objectives, the SRWP monitoring program has collected ambient monitoring data for several purposes. These data have been (and continue to be) used to examine the degree to which beneficial uses are attained or potentially impaired. The existing and potential beneficial uses for the Sacramento River watershed are outlined in the water quality control plan (Basin Plan) for the Central Valley Region. The following beneficial uses of the Sacramento River watershed are defined in the Central Valley Region Basin Plan (CVRWQCB 2007):

Municipal water supply	Navigation
Industry (process, service supply, power)	Agriculture water supply
Non-contact recreation	Contact recreation
Migration	Freshwater habitat
Wildlife habitat	Spawning

Another purpose of the SRWP monitoring program is the comparison of observed ambient concentrations with adopted water quality objectives and criteria[1]. Numeric and narrative objectives have also been adopted in the Basin Plan (CVRWQCB 2007) for surface waters of the Sacramento River watershed for selected toxic pollutants in California. Basin Plan objectives are analogous to national water quality criteria[2]. Water quality criteria for toxic pollutants are also included in the California Toxics Rule (CTR) (USEPA 2000). The CTR criteria are largely the same as the USEPA recommended national ambient water quality criteria (USEPA 2005).

These evaluations are in turn used to support management decisions by public agencies and stakeholders, and for public education efforts. No other more specific decisions or outcomes are dictated based on the monitoring data collected by SRWP.

Funding Source Proposition 50 Grant

Funding for the SRWP monitoring for this project was provided directly to SRWP as a Proposition 50 Grant administered by the Central Valley Regional Water Quality Control Board. Prior to 2006, funding for SRWP monitoring was provided primarily by the Sacramento River Toxic Pollutant Control Program (SRTPCP) through federal grants totaling over $10 million since 1996 from USEPA and administered by USEPA Region IX. Matching funds have been provided by the Sacramento Regional County Sanitation District, and in-kind services were provided by many stakeholders. Additionally, significant public and private support of the program has been provided through the active and generous participation of numerous representatives on the SRWP committees.

Coordination with Other Programs

The monitoring program has augmented and coordinated with a number of other monitoring efforts in the watershed, including the USGS National Water Quality Assessment Program, the Sacramento Coordinated Water Quality Monitoring Program, the Central Valley Irrigated Lands Regulatory Program, and monitoring efforts by the California Department of Water Resources, California Department of Pesticide Regulation, US Bureau of Reclamation, City of Sacramento, and City of Redding. Monitoring in 2006-2007 was actively coordinated with the Sacramento Valley Water Quality Coalition, the City of Sacramento, the Sacramento Coordinated Monitoring Program, and the CALFED Fish Mercury Project.

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[1] The SRWP's review and evaluation of designated uses and the criteria developed to protect these uses is consistent with the Water Quality Standards program mandated by the Clean Water Act (33 U.S.C. §§ 1251 *et seq*.), wherein a Standard for a water body is defined by four elements: designated uses of the water body, water quality criteria to protect the designated uses, an antidegradation policy, and general policies addressing implementation issues.

[2] http://www.epa.gov/waterscience/criteria/wqcriteria.html

MONITORING METHODS

The SRWP monitoring program includes chemical, physical, biological and toxicological monitoring elements. Surface water and fish tissue samples were collected and analyzed for the constituents summarized with related beneficial uses in **Table 1**. All samples were collected in a manner appropriate for the specific analytical methods used. Water samples were typically collected as mid-depth mid-channel grab samples. Fish tissue samples were collected through coordination with the CALFED Fish Mercury Project. Standard operating procedures for collection of surface water and fish tissue samples are provided in the SRWP QAPP (Appendix A).

Table 1. Parameters Measured for SRWP Monitoring and Relevant Beneficial Uses

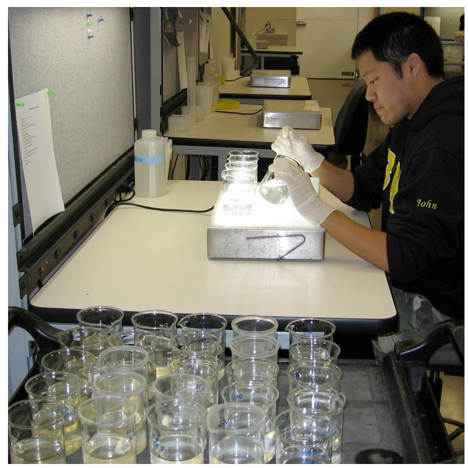
	Beneficial Uses									
Parameters Monitored	**Municipal and Domestic Water Supply**	**Industrial Water Supply**	**Agricultural Water Supply**	**Non-Contact Recreation (Aesthetic)**	**Contact Recreation**	**Sport and Subsistence Fishing**	**Freshwater Habitat and Aquatic Life**	**Spawning**	**Fish Migration**	**wildlife Habitat and Uses**
Physical and Chemical Parameters in Water										
Conductivity	X	X	X							
Dissolved Oxygen							X	X	X	
Hardness	X	X	X							
Mercury, Filtered and Unfiltered						X				X
Methylmercury, Filtered and Unfiltered						X				X
Nitrogen and Phosphorus Compounds	X	X	X				X			
Organic Carbon	X									
pH							X			
Temperature							X	X	X	
Total Dissolved Solids (TDS)	X	X	X							
Total Suspended Solids (TSS)							X	X		
Turbidity	X			X			X	X		
Ultraviolet Absorbance at 254 nm	X									
OP Pesticides, triazines, carbamates, pyrethroids							X			
Molinate and Thiobencarb	X						X			
Microbiological Characteristics in Water										
Escherischia coli Bacteria	X				X					
Total and Fecal Coliform Bacteria	X				X					
Aquatic Toxicity										
Ceriodaphnia dubia (Mortality and Reproduction)							X			
Pimephales promelas (Mortality and Growth)							X			
Selenastrum capricornutum (Cell Density)							X			
Fish Tissue										
Mercury						X				X
Organochlorine pesticides, PCBs, PBDEs						X				X

Water Column Samples

Water quality samples were collected using clean techniques that minimize sample contamination. These methods generally conformed to USEPA "clean" sampling methodology described in *Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels* (USEPA 1996). Grab samples were generally collected by wading or boating to mid-stream and filling bottles by direct submersion of the sample bottle or by pumping water from approximately mid-depth.

Analyses of water column samples for 2006-2007 included pesticides, pathogen indicators, nitrogen and phosphorus compounds, and conventional and physical measures of water quality. These analyses were performed in filtered (dissolved) or unfiltered (total) samples, as appropriate for the analyte of concern. All pesticide analyses were conducted on unfiltered samples.

Toxicity Testing and Toxicity Identification Evaluations



Water quality samples were analyzed for chronic toxicity to *Ceriodaphnia dubia* (Water Flea), larval stage *Pimephales promelas* (fathead minnow), and *Selenastrum capricornutum*. Determination of chronic toxicity was performed using *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, 4th Edition* (USEPA 2002). Toxicity tests with *Ceriodaphnia* and *Pimephales* were conducted as six- to eight-day static renewal tests with daily renewals of test solutions after test initiation. Toxicity tests with *Selenastrum* were conducted as a 96-hour static non-renewal test. Because it has been found to be necessary to control pathogen-related mortality in tests with *Pimephales*, these test procedures were modified as described in Geis *et al*. (2003), using smaller test containers, including only two fish per container, and increasing the number of replicates to ten.

If initial testing indicated the presence of significant and consistent toxicity, Toxicity Identification Evaluation (TIE) procedures were initiated. Because factors responsible for chronic toxicity are often not stable for extended periods, TIE procedures were sometimes initiated prior to completion of initial chronic toxicity testing if warranted based on early responses of test organisms and a history of toxicity at the site. The decision to initiate TIE procedures was typically made by the Toxicity Focus Group (comprised of members of the SRWP Monitoring Committee). When deciding whether to initiate TIE procedures for a specific site and sample event, the Focus Group considered the history of toxicity at the site, the magnitude of toxicity, and the species and endpoints exhibiting toxic effects. The rationale for initiating TIE procedures for a specific sample was documented in toxicity data reports. TIE methods generally adhered to EPA procedures documented in conducting TIEs (USEPA 1991, 1992, 1993a-b). For samples exhibiting toxic effects consistent with carbofuran, diazinon, or chlorpyrifos, TIE procedures will follow those documented in Bailey *et al*. (1996).

Toxicity samples for the Sacramento Slough and Colusa Basin Drain sites were coordinated with the Sacramento Valley Water Quality Coalition (SVWQC). For the samples from these two sites, if 100% mortality to a test species was observed in the initial screening toxicity test, a multiple dilution test using a minimum of five sample dilutions was conducted with the same water sample to determine the magnitude of toxicity. Pesticide-focused TIEs were also initiated if 96-hour survival of *Pimephales* or *Ceriodaphnia*, or *Selenastrum* cell growth was less than 50% of control. In addition to dilution series tests and TIEs, sites exhibiting a statistically significant mortality in the initial tests were resampled to estimate the persistence of the toxicant in the water body. Additional samples were also collected upstream of the original site to evaluate potential sources(s) of the toxicity in the subwatershed.

Fish Tissue Samples

Tissue monitoring included analysis of fish tissue for mercury and trace organic compounds. Fish tissue samples were collected by the California Department of Fish and Game Moss Landing Marine Lab for analysis of mercury, PCBs, chlorinated pesticides, and Polybrominated Diphenyl Ethers (PBDEs) in tissue. Samples were collected by a variety of methods, including hook and line, seines, gill nets, and electroshocking. Target species were generally non-migratory species that are most representative of a given location, but also included some migratory species such as striped bass and Chinook salmon. In many cases, individual fish were collected in a range of sizes to allow development of species-specific size-concentration relationships with mercury at each location. Trace organic analyses were typically conducted on composite samples. Individual fish were analyzed for mercury in a range of legal catch sizes. Composite samples analyzed for trace organics or mercury consisted of equal-weight tissue samples from up to five fish of a similar size combined into a single 200-gram composite sample.

Largemouth bass and Sacramento pikeminnow were the primary target species for mercury analyses, but other species were targeted at sites where these species are less abundant or unavailable. Species analyzed for trace organics were selected from the available target species and by-catch (i.e., non-target species). Collection, handling and storage of tissue samples were performed in a manner designed to assure the collection of representative, uncontaminated tissue chemistry samples. Details of tissue sampling and processing are provided in **Appendix A**.

WATERSHED LEVEL INFORMATION

Monitoring Sites

Monitoring was conducted regularly at 13 sites considered to be the "backbone" of the monitoring program. Seven of the sites were located on the mainstem of the Sacramento River, from below Keswick Reservoir to River Mile 44. Three sites were located on major tributaries near their confluence with the Sacramento River, two sites were located on major agricultural drains in the Sacramento valley, and one site was located on a creek in a rapidly developing urbanized area near Redding. All of these locations were monitored during previous years, with the exception of the urban creek site near Redding (Churn Creek), which was initiated in 2006.

Of the 13 sites monitored in 2006-2007, aquatic toxicity testing was conducted regularly at 12 sites. River Mile 44 is monitored for toxicity by the Sacramento Regional County Sanitation District for their NPDES permit and was therefore not monitored by the SRWP. Chemical characteristics and pathogen indicators in water were monitored at 13 sites. Overall, the monitored sites represent over 300 miles of the Sacramento River system and a drainage area of over 15 million acres (nearly 24,000 square miles). **Table 2** lists the sampling sites for the SWRP 2006-2007 monitoring program with a description of the location, type of site, and contributing land use percentages. Land use percentages are also illustrated in **Figure 1**.

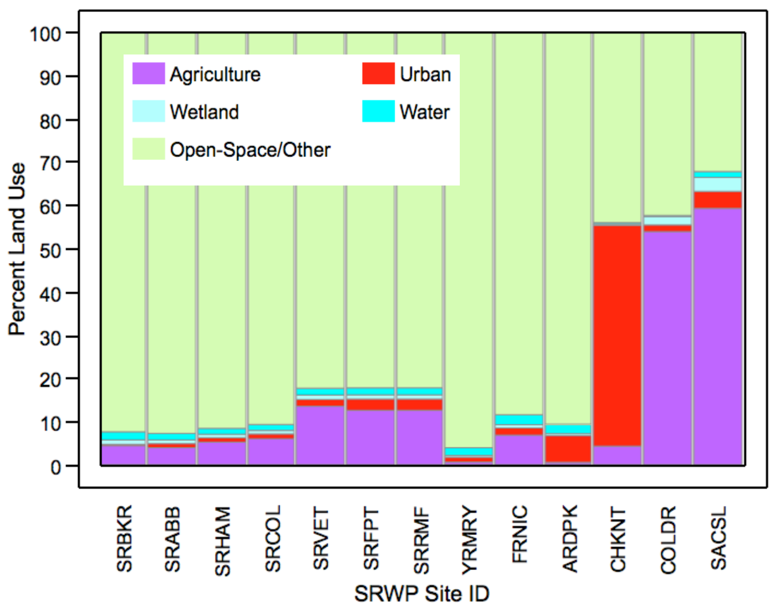


Figure 1. Land Use Percentages for SRWP Monitoring Sites

Mainstem sites are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are YRMRY=Yuba River; FRNIC=Feather River; and ARDPK= American River. Agricultural drain sites are COLDR=Colusa Drain; SACSL=Sacramento Slough; The urban creek site is CHKNT (Churn Creek).

SRWP monitoring site locations are illustrated in **Figure 2**, and the distribution of land uses in the watershed is illustrated for the entire watershed in **Figure 3**. Detailed maps and the distribution of land uses for individual monitoring sites are provided in **Appendix B**. SRWP sites are located mainly on the valley floor in agricultural and urban areas. The contributing drainages for mainstem sites and major tributaries are predominantly (>90%) open and undeveloped land, with agricultural uses being the next largest land use type. Contributing drainages in the two agriculturally dominated sites (Sacramento Slough and

Colusa Drain) are greater than 50% agricultural, and also had the greatest percentage of wetland acreage (~2-3%). The Churn Creek site near Redding is the smallest and most intensely developed drainage and includes approximately 50% urban land use acres.

Table 2. SRWP 2006-2007 Monitoring Sites

				Percent Contributing Land Use				
Site Description	**Site ID[1]**	**Type**	**Total acres**	**Agriculture**	**Urban**	**Open/Undeveloped[2]**	**Wetland**	**Water**
Sacramento River below Keswick	SRBKR	Mainstem	4,272,145	4.4	0.33	92.4	1.01	1.9
Sacramento River above Bend Bridge	SRABB	Mainstem	5,836,681	3.9	0.95	92.8	0.84	1.5
Sacramento River near Hamilton City	SRHAM	Mainstem	7,084,048	5.2	1.00	91.6	0.80	1.3
Sacramento River at Colusa	SRCOL	Mainstem	7,889,303	6.0	1.09	90.7	0.80	1.4
Sacramento River at Veterans Bridge	SRVET	Mainstem	13,781,358	13.5	1.58	82.4	1.03	1.6
Sacramento River at Freeport	SRFPT	Mainstem	15,264,599	12.6	2.59	82.3	0.97	1.6
Sacramento River at River Mile 44	SRRMF	Mainstem	15,264,919	12.6	2.59	82.3	0.97	1.6
Yuba River at Marysville	YRMRY	Major Trib	813,604	0.60	1.15	96.1	0.38	1.8
Feather River near Nicolaus	FRNIC	Major Trib	3,841,496	6.8	1.65	88.5	0.75	2.3
American River at Discovery Park	ARDPK	Major Trib	1,268,342	0.53	6.14	90.7	0.48	2.2
Colusa Basin Drain above KL	COLDR	Ag Drain	1,016,180	53.8	1.55	42.5	1.94	0.26
Sacramento Slough	SACSL	Ag Drain	787,781	59.1	3.94	32.3	3.23	1.4
Churn Creek at Knighton Road	CHKNT	Urban Creek	23,287	4.3	51.0	44.1	0.29	0.30

(1) SRWP Site identification Code.
(2) Includes snowfields, shrub and brush tundra, and transitional areas.

The distribution of development, land uses and precipitation in the watershed is an important factor affecting water quality. The open space that comprises the great majority of the watershed acreage for mainstem and major tributary sites also contributes a proportionally greater percentage of the flows to these streams. The precipitation that provides the flows to these waters in the form of rain and snow falls in much greater amounts in the higher elevations on the east side of the watershed, in the northern Sierra and southern Cascade ranges. The areas of the watershed that are most developed for urban uses and agriculture (**Figure 3**) are primarily on the valley floor and receive relatively little of the total rainfall in the watershed (**Figure 4**). More than 80% of this precipitation occurs from December through March and is released as snowmelt and from managed reservoirs through the dryer months of the year.

Figure 2. SRWP Monitoring Sites, 2006-2007

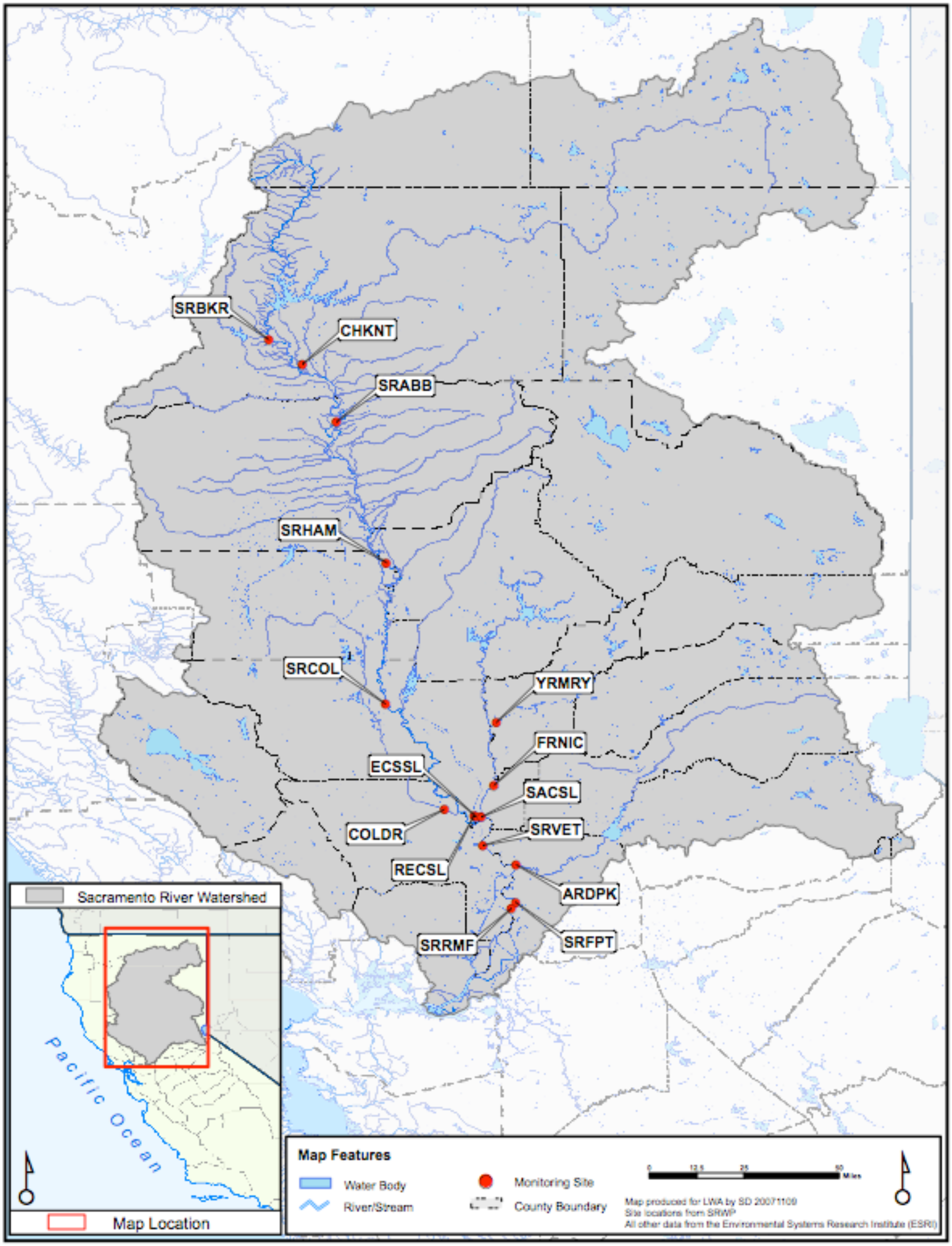


Figure 3. Major land uses in the Sacramento River watershed

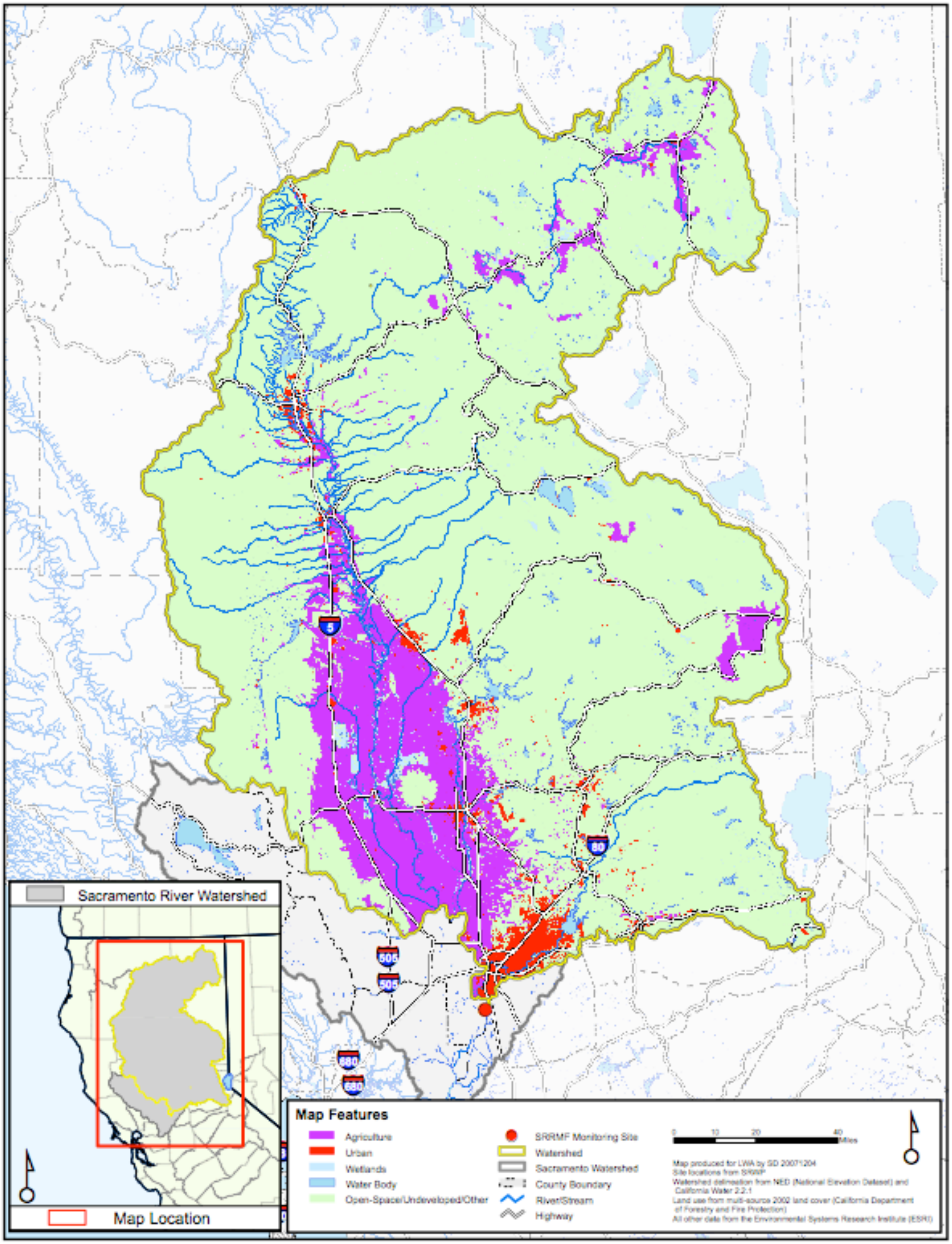
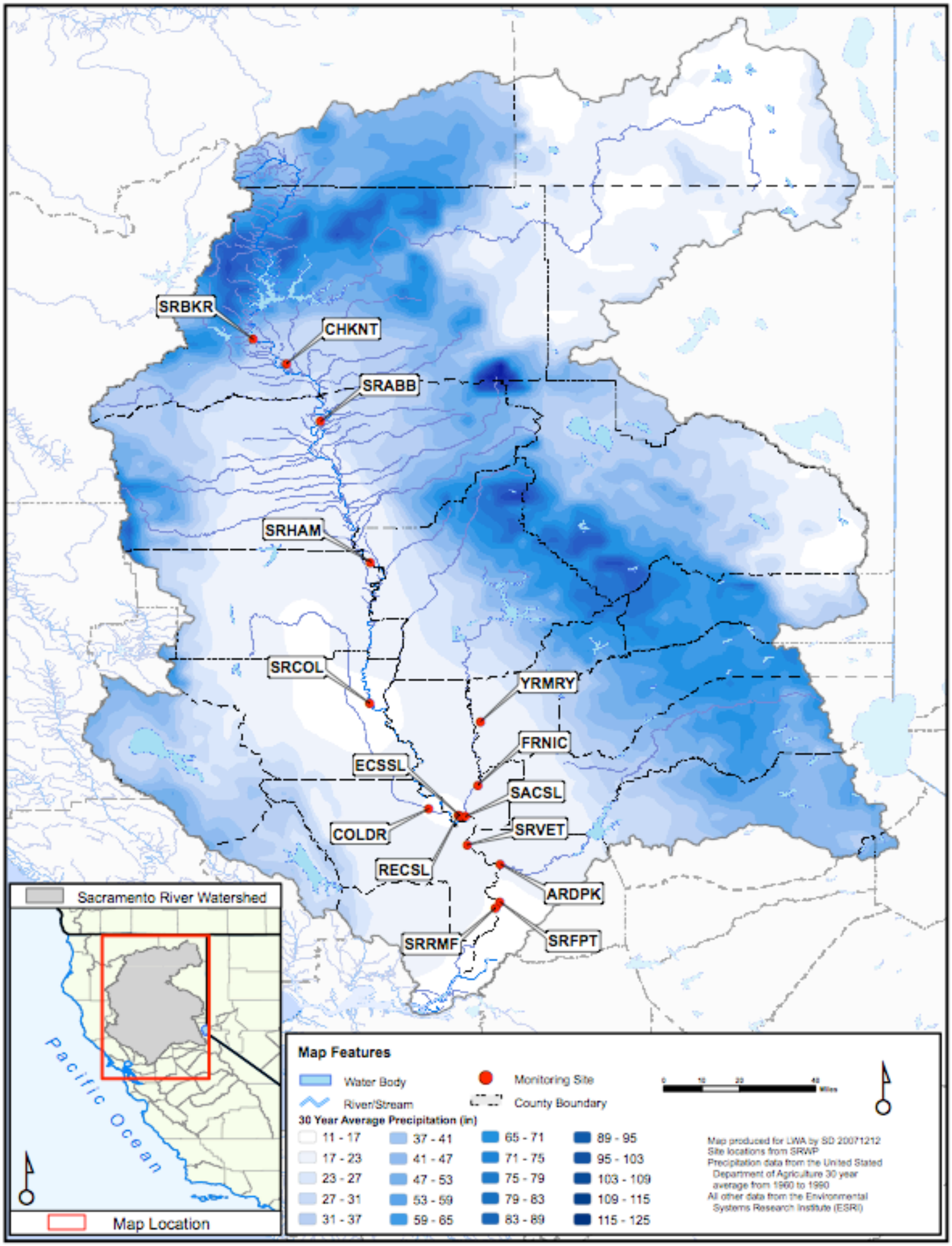


Figure 4. Average Annual Precipitation in Sacramento River Watershed



SAMPLING EVENTS, RAINFALL, RIVER FLOWS, AND OTHER EVENTS

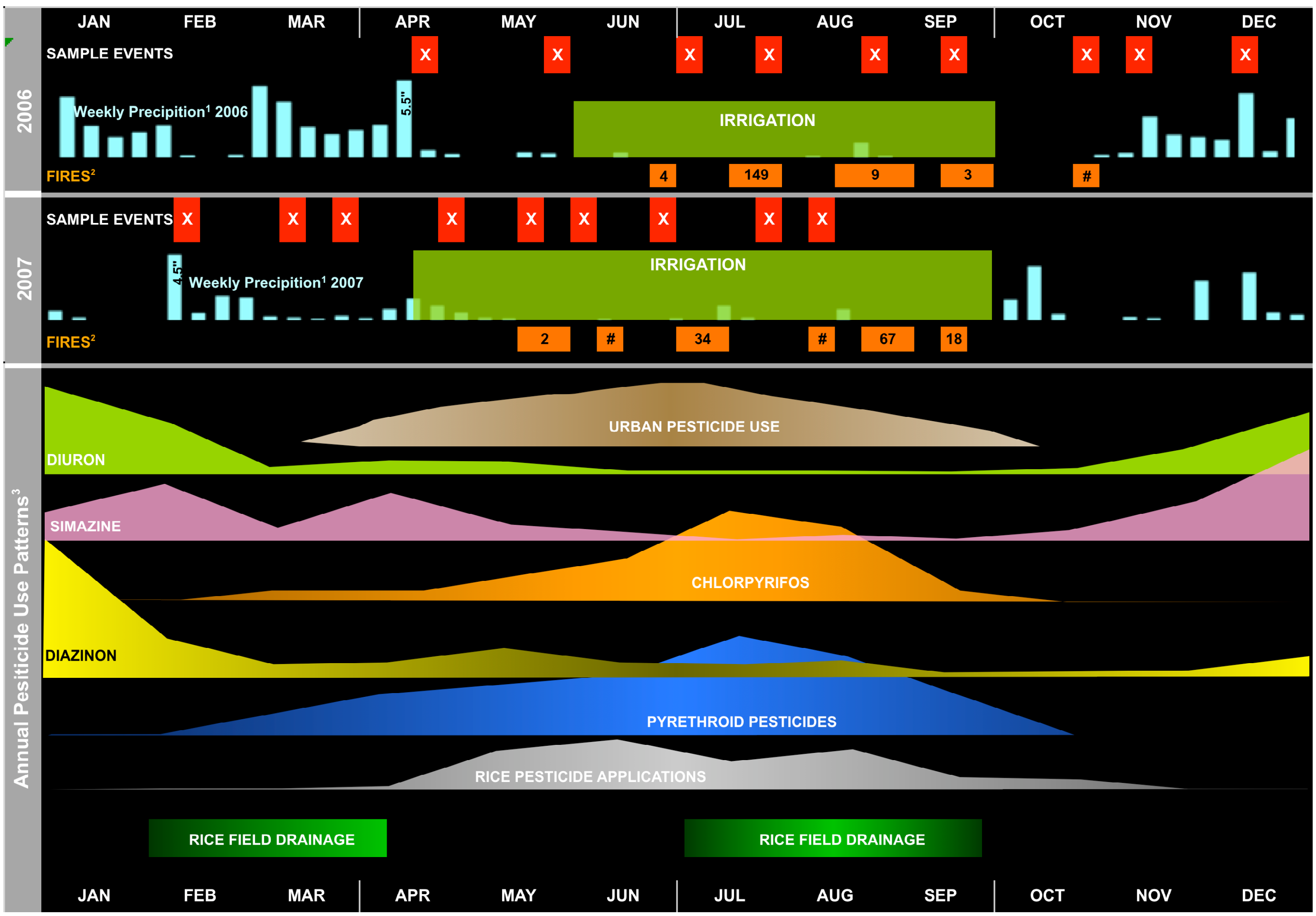
SRWP sampling events were planned and conducted to characterize a wide range of conditions in the watershed, including seasonal precipitation and flows, agricultural activities, and the effects that these factors have on water quality. **Table 3** summarizes the events that were characterized by SRWP monitoring in 2006-2007.

Table 3. Summary of SRWP Sampling Events Conducted April 2006 - August 2007

Calendar Period	Event Characterization	2006 Events	2007 Events	Description
JAN – FEB	Dormant spray, OP Application period, mid-wet season runoff	—	1	Represents quality potentially affected by runoff containing dormant spray pesticide applications. Primary factors expected to potentially affect water quality are agricultural runoff and urban storm runoff.
MAR	Late wet season storms and runoff (2 events, early and late March)	—	2	Represents quality during high flow conditions dominated by seasonal precipitation and runoff. Primary factors expected to affect water quality are reservoir storage control releases, flood management actions, watershed sediment loads and associated pollutants, and wet weather urban runoff.
APR	Snow melt and late season runoff, early irrigation return flows	1	1	Represents quality during declining seasonal hydrograph conditions. Primary factors expected to affect water quality are reservoir releases, watershed sediment loads and associated pollutants, and wet weather urban runoff.
MAY	Snow melt and late season runoff, early irrigation return flows	1	1	
Early JUNE	Dry season, early irrigation season	1	1	Continuing early dry season declining hydrograph and moderate flows. Primary factors expected to potentially affect water quality are water supply management activities, irrigation return flows, and instream sources and processes.
mid- to late JUNE (typically)	Rice field drainage and early irrigation return flows	1	1	Represents quality during early dry season hydrograph and moderate flows. Primary factors expected to potentially affect water quality are water supply management activities, irrigation return flows, and instream sources and processes.
JUL-SEP	Dry weather flows, mid irrigation season	3	2	Represents quality during stable flow conditions unaffected by precipitation and runoff events. Primary factors expected to affect water quality are reservoir releases, irrigation return flows, POTW discharges, dry weather urban runoff, and instream sources and processes.
OCT-DEC	Early wet season storms and runoff	3	—	Represents quality changes during stable flow conditions affected by early season precipitation and runoff events ("first flush") with relatively low dilution. Primary factors expected to potentially affect water quality are agricultural runoff and urban storm runoff.
Totals		**9**	**9**	

The timing of SRWP sample events and a variety of seasonal factors and watershed events with the potential to affect water quality are illustrated in **Figure 5**. These factors include precipitation, irrigation and pesticide application patterns, and major fires within and in the vicinity of the watershed. Agricultural application patterns are represented by the insecticides diazinon, chlorpyrifos, and pyrethroids. Herbicide application patterns are illustrated by diuron and simazine, and rice-specific pesticides. Pesticide graphics are based on acres treated in the watershed in 2006 (CDPR Pesticide Use Reporting data, 2007), with the exception of seasonal urban pesticide use, which is illustrated qualitatively based on typical use patterns.

Figure 5. SRWP Sample and Watershed Events



(1) Sum of weekly rainfall at Redding Fire Station
(2) Fires in counties within Sacramento River watershed, plus major fires in Trinity County proximate to watershed. Numbers represent thousands of acres burned.
(3) Pesticide applications illustrate patterns and timing of applications and are not to scale. Graphics are based on acres treated in 2006, with the exception of urban pesticide use, which is qualitatively based on typical use patterns.

Characterization of 2006 Wet and Dry Seasons

The 2005-2006 water year (defined as October through September) was the fifth wettest since 1920, with a total of 80.1 inches of precipitation measured for the 8-Station Index[3] in the Northern Sierra (**Figure 6**). The 2006 wet season was characterized by record-breaking daily precipitation at the beginning of January, a predominantly dry February with regional records set for both low and high temperatures, and a cold and wet March with a record-breaking 19 days of measurable rainfall in the lower Sacramento Valley (as measured at Sacramento Executive Airport).[4] Significant rainfall events occurred throughout the watershed at the beginning of January and during the month of March. Precipitation was generally greater in the northern part of the watershed and at higher elevations.

Sampling for SRWP began in April of 2006. In 2006, the irrigation season began in June (later than normal) due to late season precipitation occurring in May. The summer months were dominated by the dry weather and above-average temperatures typical for the Sacramento valley. Based on climatic data available for the Sacramento Executive Airport weather station, a record total of 0.3 inches of precipitation fell during the month of May; 0.23 inches of this total occurred during a 24-hour period spanning May 21-22. A trace amount of precipitation occurred on July 19, and no precipitation occurred in August or September. The maximum temperature exceeded 90˚F on five days in May, 22 days in July, 17 days in August, and 11 days in September. Record-setting high temperatures occurred throughout the Sacramento Valley in July; the average daily maximum temperature at the Sacramento Executive Airport during this month was 95.7˚F. No climatic data were available from the National Weather Service for the month of June.

Characterization of 2007 Storm and Irrigation Seasons

The 2006-2007 Water Year was the 24th driest year since 1920, with a total of 37.2 inches of precipitation measured at the 8-Station Index in the Northern Sierra (**Figure 6**). The 2007 wet season was characterized by slightly below-average precipitation in December 2006, record-breaking dry weather throughout the month of January, above-average precipitation in February, and above-average temperatures accompanying below-average precipitation in March. Significant rainfall events occurred throughout the watershed during the months of December 2006 and February 2007.

In 2007, the dry season was characterized by typically dry weather with above average temperatures (mean temperature, April through August; September and October had

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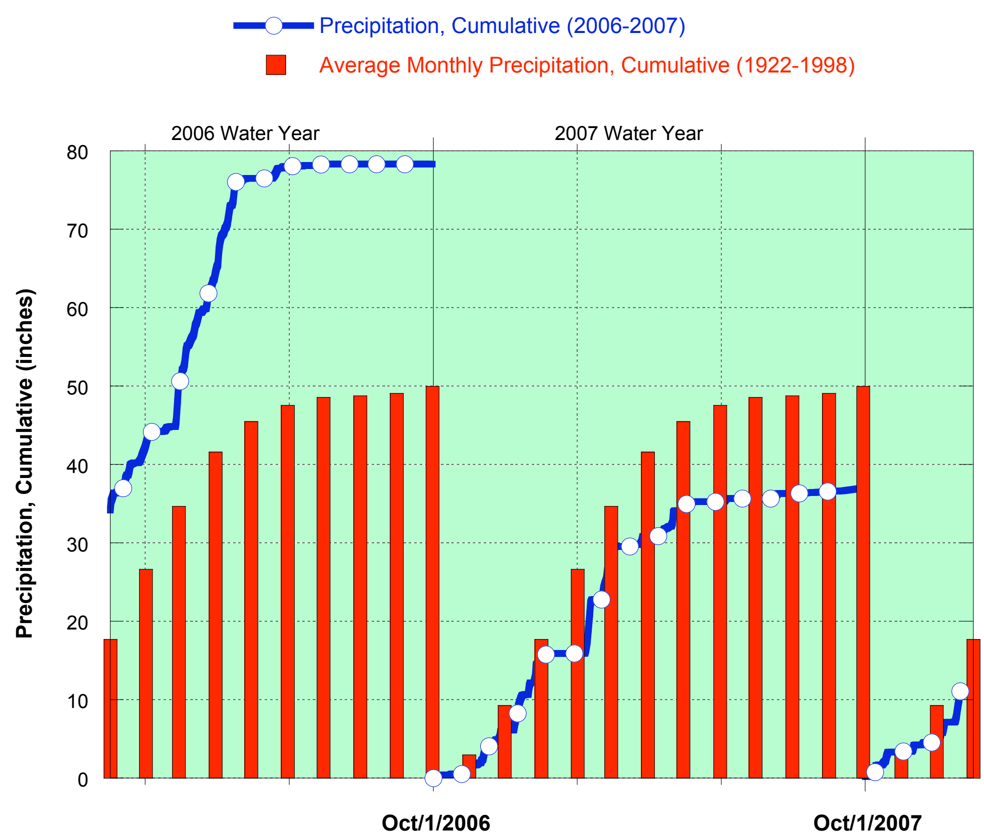
[3] The average of eight precipitation stations serves as a wetness index for the Sacramento River hydrologic region. It provides a representative sample of the region's major watersheds: the upper Sacramento, Feather, Yuba, and American Rivers. The eight stations are: Blue Canyon, Brush Creek Ranger Station, Mineral, Mount Shasta City, Pacific House, Quincy Ranger Station, Shasta Dam, Sierraville Ranger Station.

[4] Climate data for Sacramento-Delta region available at: http://www.wrcc.dri.edu/monitor/cal-mon/frames_version.html

below average mean temperatures). In 2007, agricultural irrigation began earlier than typical due to below-average precipitation during the 2007 wet season. Based on climatic data available for the Sacramento Executive Airport weather station, 1.34 inches of rain fell in April, and a record total of 0.41 inches fell in May (more than half of this amount occurred during a 24-hour period spanning May 3-4). A trace amount of precipitation occurred on July 11, and no precipitation occurred in June or August. A record-setting 0.06 inches of rain fell in September, and 1.05 inches fell in October. The maximum temperature exceeded 90˚F on one day in April, four days in May, 12 days in June, 20 days in July, 21 days in August, and five days in September. Record-setting high temperatures occurred throughout the Sacramento Valley in July and August, with average daily maximum temperatures at the Sacramento Executive Airport of 91.5˚F and 91.8˚F, respectively. Figures illustrating precipitation at other representative locations in the watershed are provided in Appendix C.

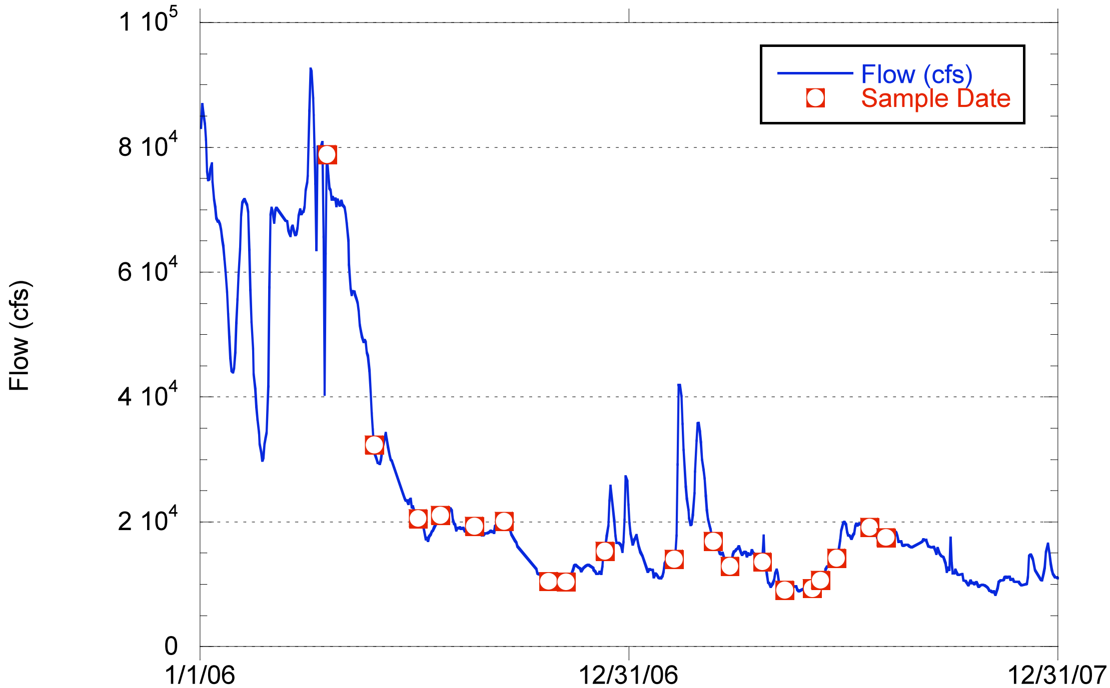
Figure 6. Eight-Station Precipitation Index, 2006-2007



Sampling Events and Flows

During the 2006 wet season (December 2005 – March 2006), flows throughout the watershed exhibited typical wet season variability with high wet season flows in the months of January and March (illustrated for Sacramento river at Freeport in **Figure 7**). The stream flows throughout the watershed declined rapidly during the month of February. During the 2007 wet season (December 2006 – March 2007), stream flows throughout the watershed exhibited less variability and flows were much lower than normal. Flows throughout the watershed decreased nearly to dry season levels by the month of February in 2007. Additional figures illustrating flows or river stage at other sites in the watershed are provided in Appendix C.

Figure 7. Flows and Sample Event at Sacramento River at Freeport, 2006-2007



MONITORING RESULTS

The categories of water quality data considered in this review are parameters of concern related to drinking water, aquatic toxicity, and pesticides, and bioaccumulative pollutants in water and fish tissue. This report describes data collected from 2006-2007 by the SRWP and from programs coordinating with the SRWP. These water chemistry, aquatic toxicity, and fish tissue data are used to evaluate the attainment of beneficial uses and potential impairment of surface waters of the Sacramento River watershed, and to assess spatial and temporal distributions of a variety of important water quality characteristics. The linkage between monitoring parameters and beneficial uses is illustrated in **Table 1**. Locations discussed in this summary are illustrated in **Figure 2**. The findings and conclusions of this review of SRWP data are provided in the following sections.

Water Quality Data

Quality Assurance Summary

The precision and accuracy of the majority of monitoring results meet the SRWP data quality objectives (DQOs) and there were no systematic sampling or analytical problems in 2006-2007. The data generated are adequate for the purposes of the SRWP's monitoring program and few results required qualification. Of the 12,837 analytical results generated from April 2006 – August 2007, 191 results required qualification, resulting in 98.5% valid and unqualified data with no restrictions on use. Of the 191 total qualified data:

- 68 results were qualified as *estimated* due to high variability in lab or field replicate analyses
- 24 results were qualified as *estimated* due to high variability in matrix spike recovery analyses
- 16 results water chemistry were qualified as *estimated* based on holding time exceedances. 19 *Selenastrum* results, 10 *Ceriodaphnia* results, and 7 *Pimephales* results were qualified as *estimated* based on holding time exceedances due to control performance that did not meet EPA requirements for these tests.
- 20 results were qualified as *high biased* or *low biased*, and
- 69 results were potentially affected by contamination and qualified as *upper limits*. Of the results qualified as *upper limits*, 17 were below the QL, and none of the data qualified as *upper limits* were exceedances of water quality objectives.

The objectives for completeness are intended to apply to the monitoring program as a whole. All 234 planned water column sample events were successfully conducted, and all of the collected samples were analyzed, for an overall sampling success rate of 100%.

Additional details of quality assurance evaluations for chemical analyses of water are provided in Appendix D.

Toxicity QA

To evaluate the performance of the Geis modification for fathead minnow toxicity tests under "real world" testing conditions, field replicate samples and an associated lab control were analyzed using the EPA 4th edition procedure modification with 20 replicates per test, and compared to the results generated following the Geis *et al*. (2003) method with fewer replicates. Two evaluations were used when comparing the two methods:

- Was the relative percent difference (RPD) <25%? This benchmark is typically used for the comparison of duplicate samples.
- Were conclusions consistent regarding the presence/absence of toxicity?

The general trend in these data was that the results were similar and consistent for most events. For three comparisons, the Geis *et al.* (2003) method was more sensitive in terms of fathead minnow growth, and for two comparisons, the opposite was true. For one set of comparisons, the Geis *et al.* (2003) method was more sensitive in terms of fathead minnow survival (i.e., detected survival toxicity when the EPA method did not); in no case was the opposite true. When the entire data set is considered, the results of the two methods were fairly consistent, with primarily only minor differences in the finding of growth toxicity.

The quality control data indicate that the toxicity testing performed under this study met programmatic quality assurance requirements, and that these data are acceptable for their intended uses. However, while the comparison of the Geis *et al.* (2003) and EPA methods had considerable agreement, it appears prudent to continue to incorporate periodic comparison analyses of these two methods in future monitoring.

Additional details of toxicity quality assurance evaluations are provided in Appendix E.

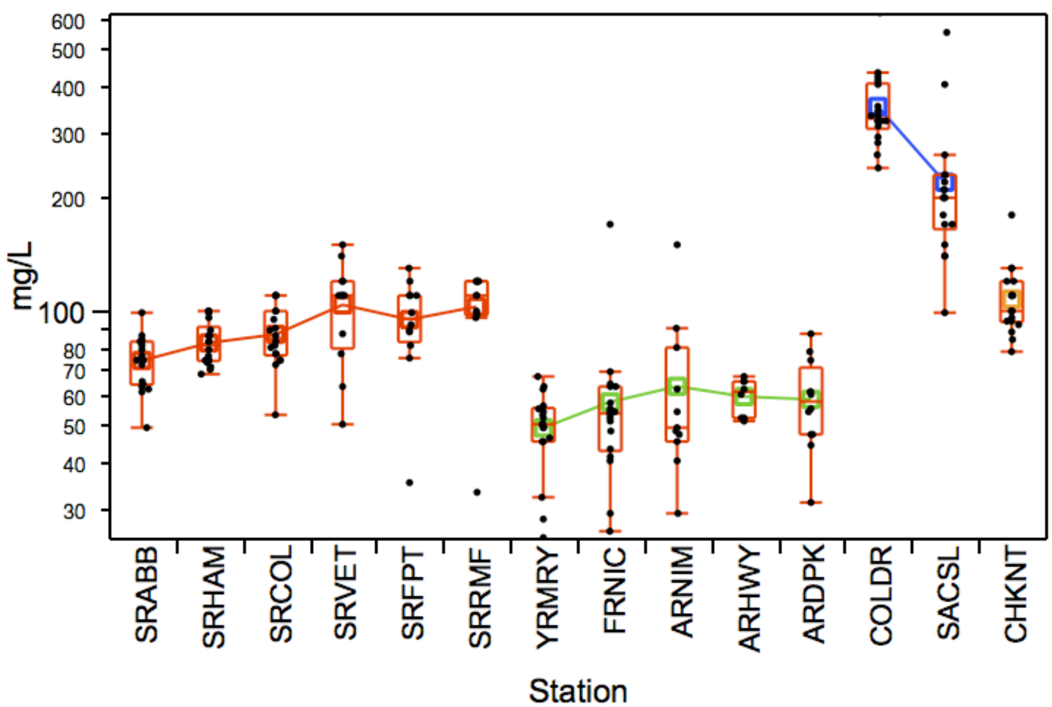
Physical, Chemical, and Microbiological Parameters

For the purposes of these analysis, parameters relevant to drinking water supplies are grouped into four categories: total dissolved solids, nitrogen and phosphorus compounds, organic carbon and ultraviolet absorbance, and bacterial pathogen indicators. The parameters included in each category are discussed below in terms of their attainment of beneficial uses, and spatial and temporal distribution patterns are described qualitatively.

TDS and Conductivity

Total Dissolved Solids (TDS) concentrations in surface waters monitored in the Sacramento River watershed have been observed to exceed CDHS and USEPA's Secondary Drinking Water Standard Maximum Contaminant Level (MCL) of 500 mg/L once in Sacramento Slough and twice in Colusa Basin Drain. Median concentrations for 2006-2007 were well below the 500 mg/L MCL at both sites, and compliance with the TDS limit is estimated to be greater than 96% for Colusa Basin Drain and 97% for Sacramento Slough. TDS concentrations were not observed to exceed the 500 mg/L MCL at any other sites. Concentrations were not observed to exceed 500 mg/L at any site in SRWP 2003-2004 monitoring. The Central Valley Basin Plan also includes a site-specific objective for TDS in the American River (125 mg/L as a 90th percentile) from Folsom Dam to the Sacramento River. This objective was exceeded in only one sample collected from the American River.

Figure 8. Total Dissolved Solids Spatial Distribution, 2006-2007



Mainstem sites are connected by red lines and are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are connected by green lines (YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites are connected by blue line: COLDR=Colusa Drain; SACSL=Sacramento Slough). The urban creek site is CHKNT (Churn Creek).

Nitrogen and Phosphorus Compounds

Of the nitrogen and phosphorus compounds monitored by the SRWP, only nitrite and nitrate currently have relevant water quality objectives. Nitrite plus nitrate (as N) was not observed to exceed or approach the MCL for nitrate (10 mg/L as N) at any site. Although excessive nutrient concentrations in source waters can be a factor in increased algal growth (and consequently taste and odor problems and increased treatment costs for domestic water suppliers), the effect of nutrient concentrations is generally not easily separated from the effects of storage and transport (e.g., increased temperature and sunlight exposure), and no specific limits for nutrients in source water have been developed to address or evaluate these problems.

Spatial trends in nutrients were similar to those reported previously by SRWP (2004). These are illustrated for TKN and total phosphorus in Figure 9 and Figure 10. Spatial trends were similar for TKN, nitrate, total phosphorus and orthophosphate, and organic carbon. The highest nutrient concentrations were observed in agricultural drainage sites, as has been noted in previous reports, with concentrations approximately three times those observed in the mainstem river. Nutrients were also relatively low in the three major tributaries (similar to or lower than at lower mainstem sites). Concentrations were the most variable in Churn Creek, but with median ("typical") phosphorus and nitrogen concentrations similar to the upper mainstem river.

Within the mainstem sites, nutrient concentrations increased from upstream to downstream. This pattern corresponds with increasing percentages of agriculture and urban development (and decreasing open space) in the watershed.

No strong seasonal trends were observed in most nutrients, and wet and dry season concentrations were similar. The notable exception was nitrate nitrogen, which was consistently higher in wet season in all of the site categories.

Figure 9. Total Phosphorus Spatial Distribution, 2006-2007

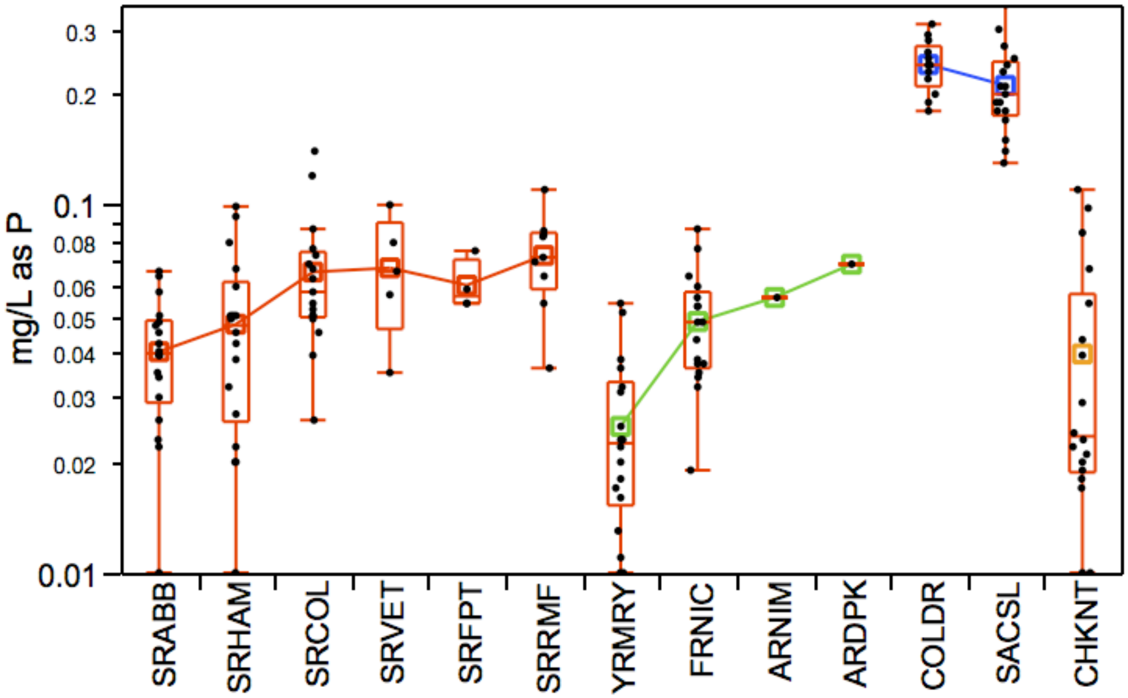
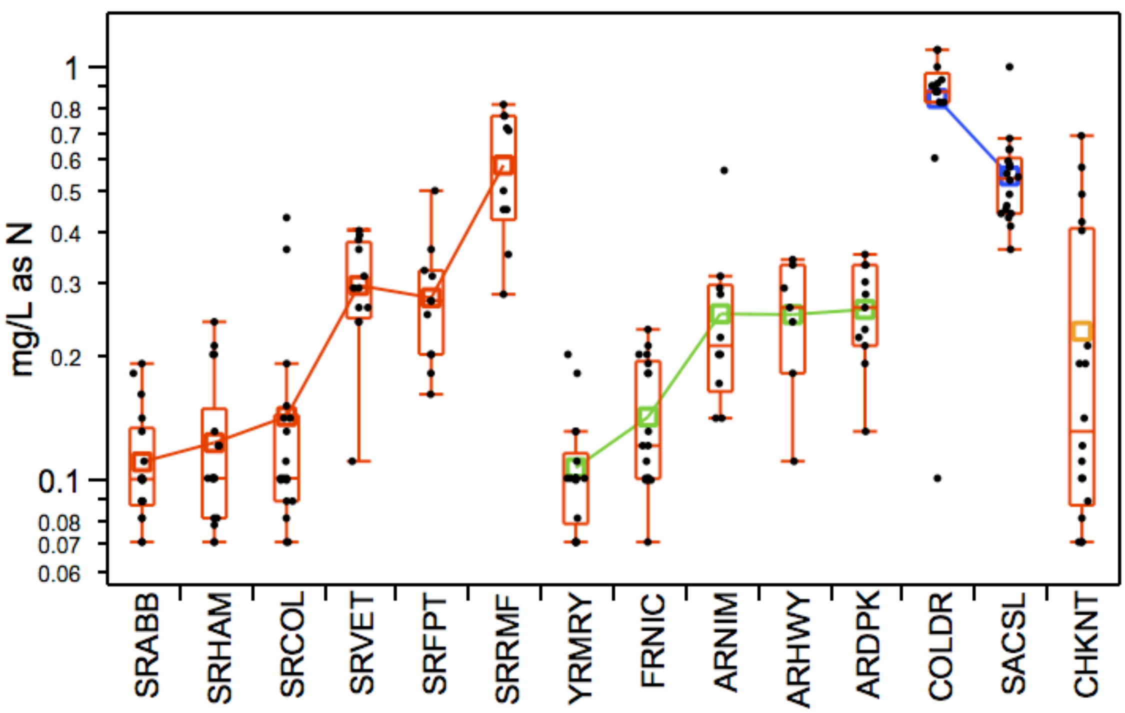


Figure 10. Total Kjeldahl Nitrogen Spatial Distribution, 2006-2007



Mainstem sites are connected by red lines and are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are connected by green lines (YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites are connected by blue line: COLDR=Colusa Drain; SACSL=Sacramento Slough). The urban creek site is CHKNT (Churn Creek).

Organic Carbon

Total organic carbon (TOC) concentrations were compared to the 2 mg/L and 4 mg/L TOC treatment threshold included in the Stage 1 Disinfectants/Disinfection By-products (D/DBP) Rule. This regulation is designed to limit precursors to disinfection byproducts such as trihalomethanes, which are human carcinogens. In cases where the running annual average TOC in source water (measured at water treatment plant intakes) is 2.0–4.0 mg/L, water utilities may be required to remove up to 35% of the TOC (depending on source water alkalinity) unless they meet other specific quality or treatment technology requirements[5]. If the running average source water TOC is greater than 4 mg/L, water utilities may be required to remove up to 45% of the TOC in their influent. Total organic carbon concentrations occasionally exceeded the D/DBP 2 mg/L goal at all sites evaluated. TOC concentrations measured in Sacramento Slough and the Colusa Basin Drain exceeded the 2 mg/L D/DBP treatment threshold in every sample analyzed, and exceeded the 4 mg/L threshold in more than 70% of samples collected. TOC in Churn Creek (a primarily urban drainage) exceeded the 2 mg/L threshold in about 40% of samples, and exceeded the 4 mg/L threshold in just two samples. The percentage of TOC concentrations in the mainstem Sacramento River exceeding the 2 mg/L D/DBP threshold value increased from Keswick to River Mile 44. The American River exhibited higher TOC concentrations than the Yuba River and Feather River and was above the 2 mg/L treatment threshold in more than half of the samples collected. Concentrations of TOC in all of these major tributaries were below the 4 mg/L threshold in nearly every sample. Median TOC concentrations were greater than 2.0 mg/L in the Sacramento River below Veterans Bridge, the American River, and both agricultural drain sites.

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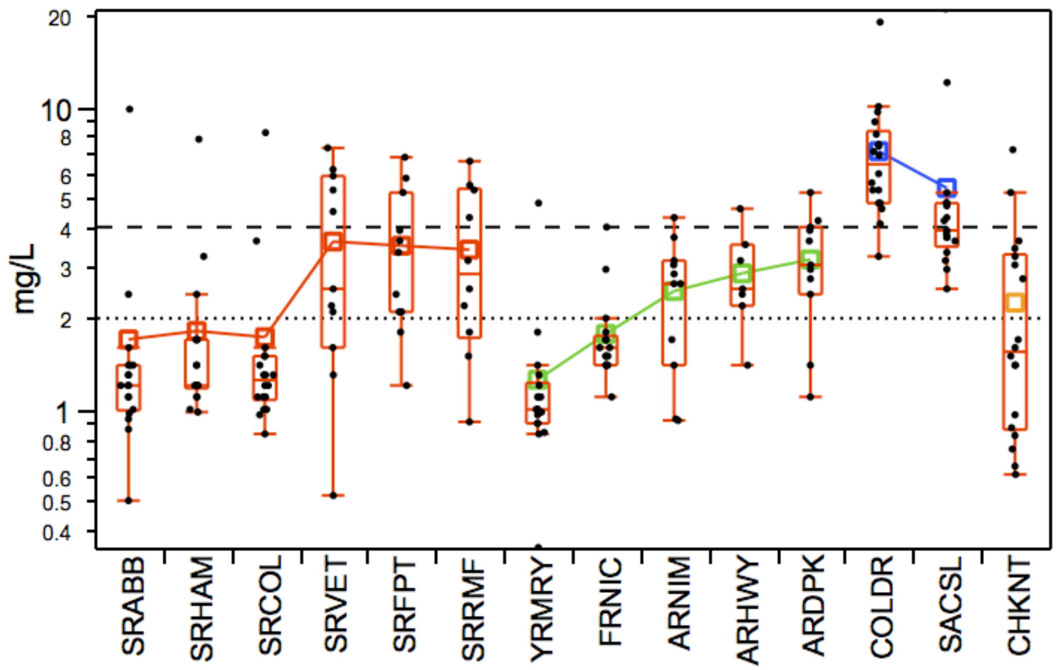
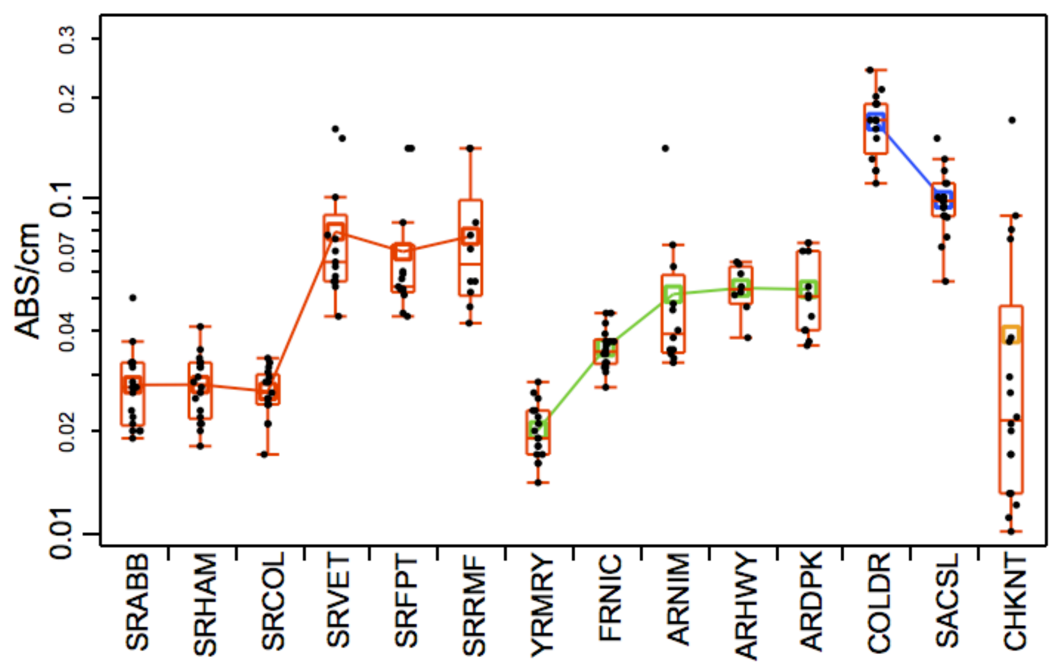
[5] Utilities would not have to meet these removal requirements if they meet <u>one</u> of several possible conditions: (1) average TOC in their treated water less than 2.0 mg/L; (2) average levels of haloacetic acids and trihalomethanes below 30 µg/L and 40 µg/L, respectively, or a clear commitment to implement treatment to meet these levels by June 2005; or (3) average Specific UV Absorbance (SUVA) less than 2.0 L/mg-m in source water <u>or</u> treated water.

Figure 11. Total Organic Carbon Spatial Distribution, 2006-2007



Upper dashed line indicates 4 mg/L D/DBP Treatment Threshold. Lower dotted line indicates 2 mg/L D/DBP Treatment Threshold.

Figure 12. UVA 254 Spatial Distribution, 2006-2007



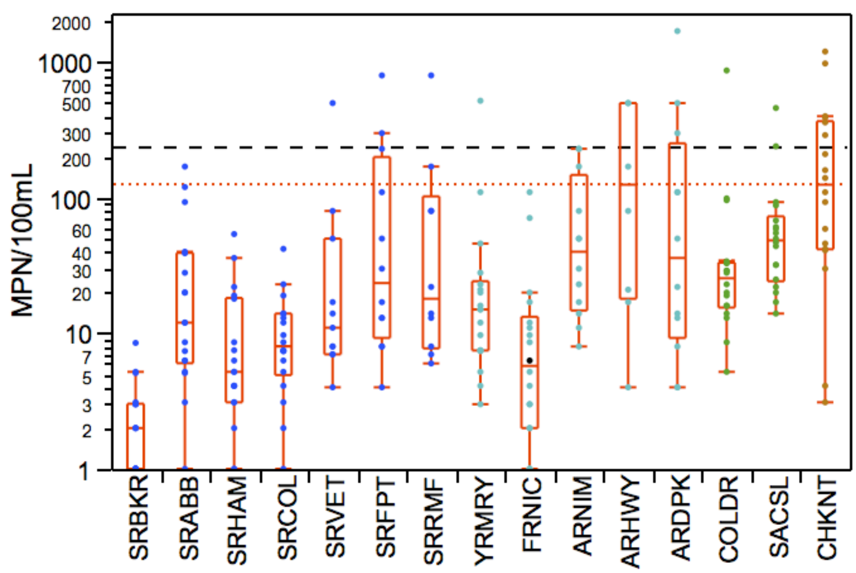
Mainstem sites are connected by red lines and are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are connected by green lines (YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites are connected by blue line: COLDR=Colusa Drain; SACSL=Sacramento Slough). The urban creek site is CHKNT (Churn Creek).

Pathogen Indicators

Although they are included in the category of parameters relevant to drinking water, coliform bacteria data are primarily relevant to the beneficial use of contact recreation. USEPA has identified as a priority the transition to using *E. coli* and *Enterococcus* bacteria (instead of total and fecal coliform bacteria) as indicators of microbial contamination (Action Plan for Beaches and Recreational Waters; EPA/600/R-98/079, March 1999). In 2002, CVRWQCB staff recommended adopting the recommended limits for *E. coli* in the Basin Plan for the Central Valley (CVRWQCB 2002), and the objective was adopted into the Basin Plan. This amendment to the Basin Plan has never received final approval from the Office of Administrative Law and the U.S. Environmental Protection Agency, however. For the purpose of evaluating achievement and potential impairment of contact recreational uses, *E. coli* data were compared to the adopted Basin Plan objectives of 126 MPN/100 mL (implemented as a five-sample 30-day geometric mean) and 235 MPN/100 mL as a single sample maximum. The single-sample limit for *E. coli* was not exceeded at upper mainstem sites above Veterans Bridge, and infrequently exceeded at lower mainstem sites, tributary sites, and agricultural drain sites. The single-sample objective was exceeded most frequently in Churn Creek (about 33%), but medians did not exceed the 126 MPN/100 mL objective at any site.

E. coli exceeded the Basin Plan single sample objective more frequently in wet season (~32% of samples), and rarely exceeded this objective in dry season (7% of samples). This was true for most sites, except the agriculture drainage sites, which did not exhibit higher concentrations of bacteria during wet season. The highest bacteria concentrations were observed at the sites with the greatest urban land use percentages: lower Sacramento River sites, the lower American River sites, and Churn Creek.

Figure 13. E. coli Bacteria Spatial Distribution, 2006-2007



Upper dashed line indicates 235 MPN/100mL 5-sample geometric mean objective. Lower dotted line indicates 126 MPN/100mL single-sample maximum objective. Mainstem sites are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites: YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites: COLDR=Colusa Drain; SACSL=Sacramento Slough. The urban creek site is CHKNT (Churn Creek).

Mercury

Mercury and methylmercury were analyzed for the SRWP in 2006-2007. The distribution of mercury and methylmercury in the Sacramento River mainstem and tributaries reflects the historical sources of mercury from gold mining, and to a lesser extent, mercury mines and natural geological sources. Total and dissolved mercury were lowest in the upper mainstem river to Colusa, but unfiltered mercury was seen to increase in this reach along with suspended solids and turbidity. Dissolved mercury concentrations showed no change from Bend Bridge to Colusa, possibly because the main sources of mercury in this reach are natural geological deposits in the coastal range. Naturally occurring mercury from the coastal range is primarily in the form of relatively insoluble cinnabar (mercury sulfide), and enters with the flows from the west side of the Sacramento valley (Elder Creek, Cottonwood Creek, Thomes Creek, and Stony Creek). Mill Creek on the east side of the valley also carries significant natural mercury concentrations from geothermal sources in the Lassen area. Mercury concentrations showed a marked increase below the mainstem confluence with the Feather River and Yuba River watersheds where the most intensive gold mining was done. Methylmercury exhibited a slightly different pattern – a substantial increase in methylmercury was observable at Colusa, above the influence of the major tributaries and intensive historical gold mining (**Figure 14**). This increase in methylmercury did not correspond to an observable increase in total mercury at this site (**Figure 15**), but was consistent with a similar increase in suspended solids observed at Colusa (**Figure 16**). Unfiltered total mercury and methylmercury were also higher in the two agricultural drainage sites, and these elevated concentrations also corresponded to elevated suspended solids and turbidity at these sites. Dissolved mercury and methylmercury in the agricultural drainage sites were not elevated relative to concentrations in the lower mainstem or major tributaries.

Sulfate concentrations were also analyzed at six mainstem sites to evaluate possible relationships with methylmercury concentrations. Sulfate concentrations increased steadily from Sacramento River at Bend Bridge to River Mile 44 below Sacramento. The largest increase was observed between Colusa and Veterans Bridge, with a second notable increase below the Sacramento Regional Wastewater Treatment Plant below Freeport (**Figure 17**). Although the overall increasing downstream trend was consistent with the general trend in mercury and methylmercury concentrations, the spatial pattern of increases in sulfate did not correspond well with the pattern of increases in methylmercury.

Figure 14. Total Methylmercury Spatial Distribution, 2006-2007

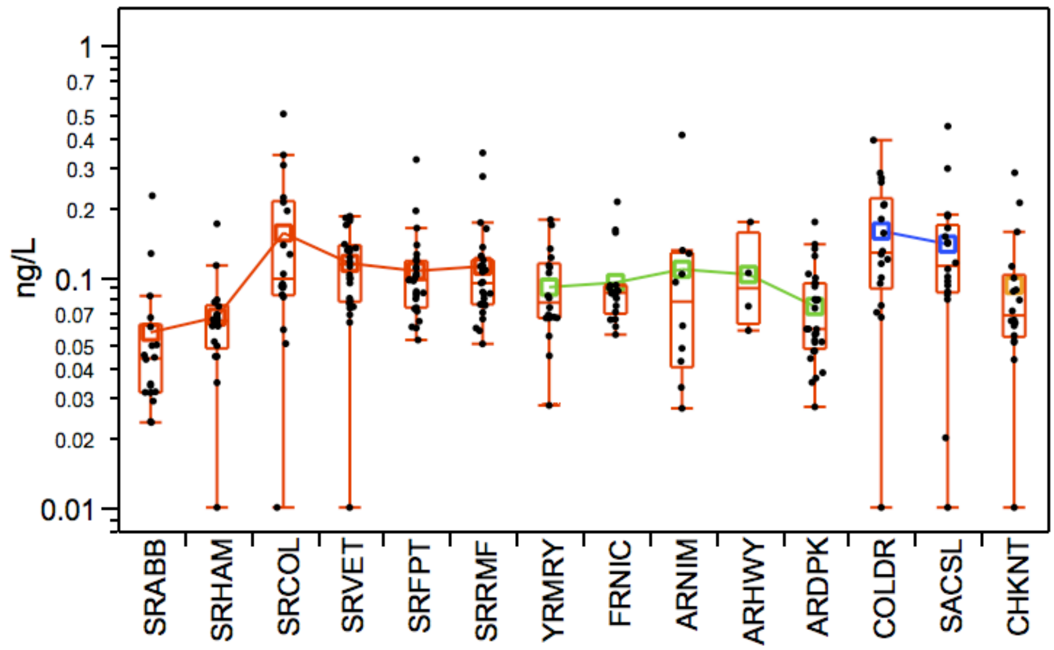
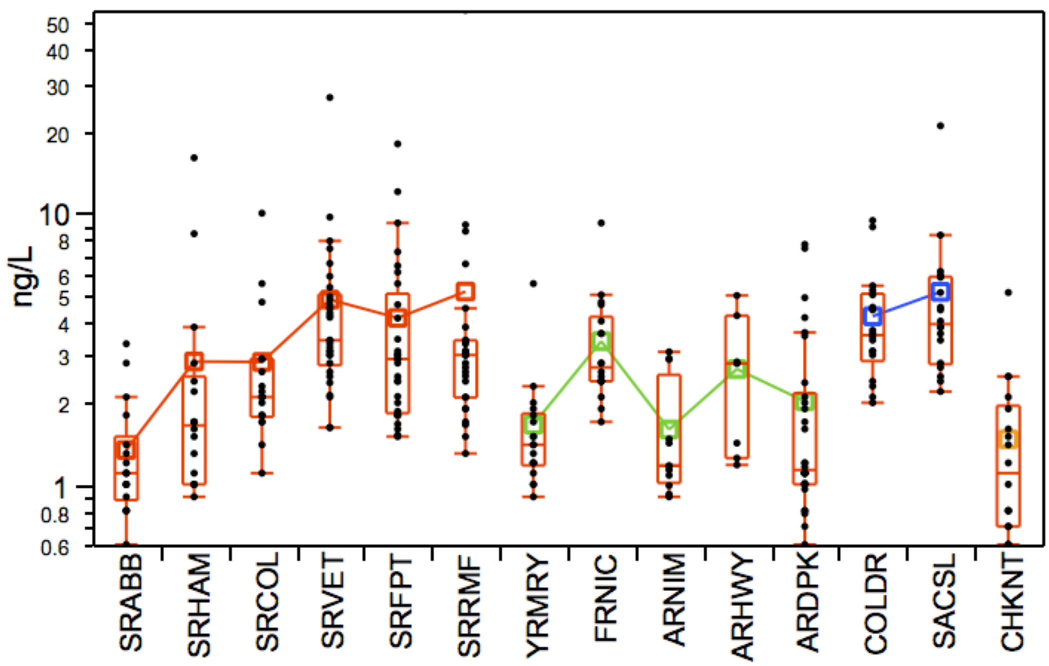
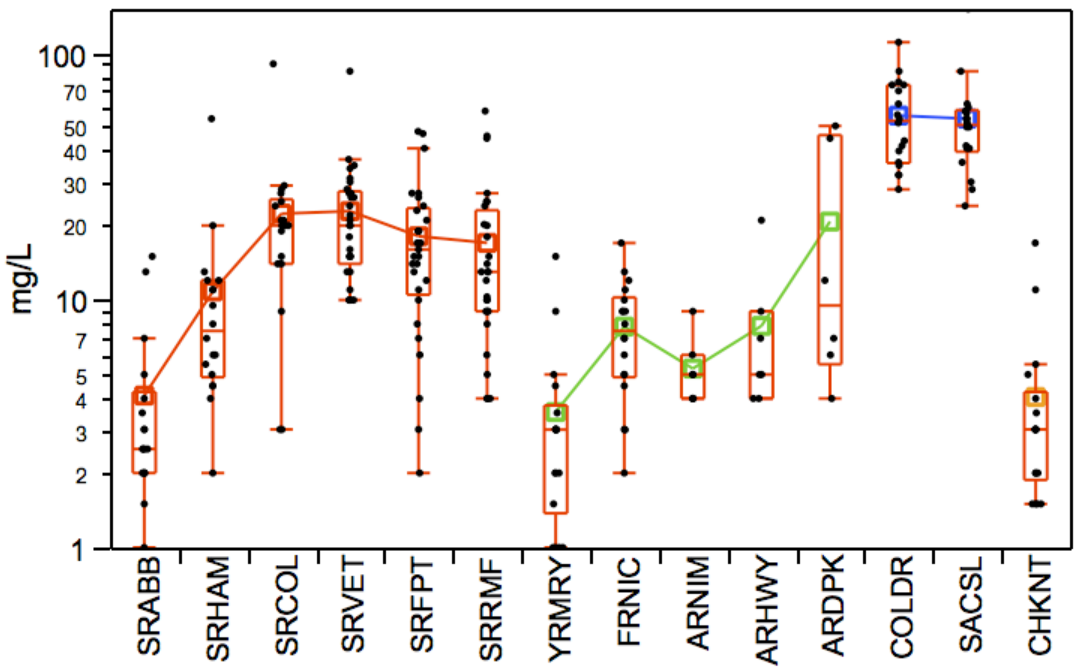


Figure 15. Total Mercury Spatial Distribution, 2006-2007



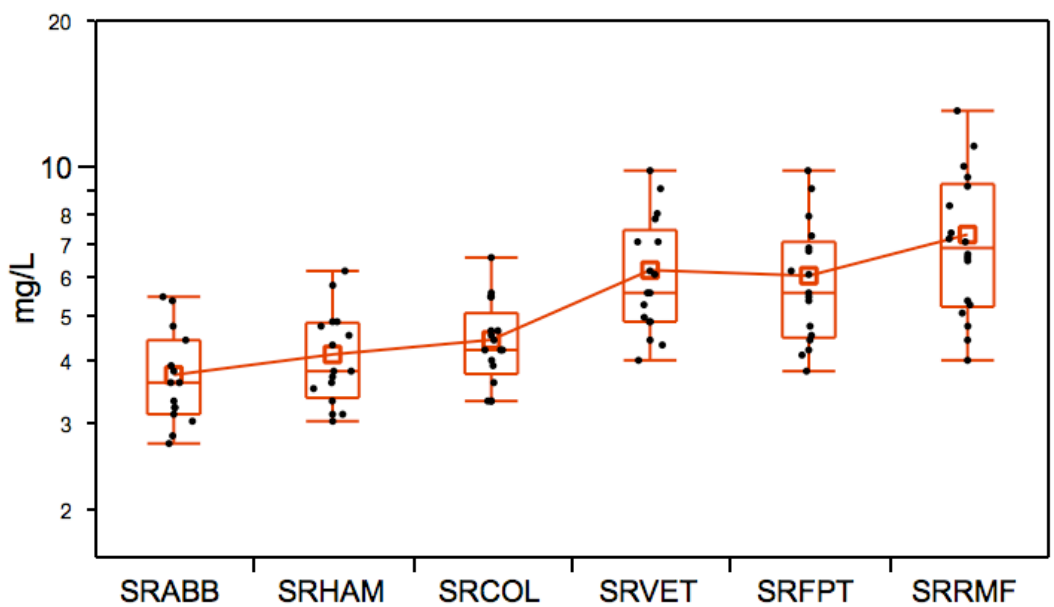
Mainstem sites are connected by red lines and are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are connected by green lines (YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites are connected by blue line: COLDR=Colusa Drain; SACSL=Sacramento Slough). The urban creek site is CHKNT (Churn Creek).

Figure 16. Total Suspended Solids Spatial Distribution, 2006-2007



Mainstem sites are connected by red lines and are ordered from upstream to downstream, left to right: SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44. Tributary sites are connected by green lines (YRMRY=Yuba River; FRNIC=Feather River; ARNIM, ARHWY, and ARDPK= American River, from upstream to downstream. Ag drain sites are connected by blue line: COLDR=Colusa Drain; SACSL=Sacramento Slough). The urban creek site is CHKNT (Churn Creek).

Figure 17. Sulfate Spatial Distribution in the Mainstem Sacramento River, 2006-2007



Sacramento River sites are ordered from upstream to downstream, left to right. Site means are indicated by small red squares. SRABB=Bend Bridge; SRHAM=Hamilton City; SRCOL=Colusa; SRVET=Veterans Bridge; SRFPT= Freeport; SRRMF=River Mile 44.

Pesticides

Pesticides analyzed for SRWP included organophosphates, pryrethroids, triazines, urea and uracil herbicides, legacy organochlorine pesticides, and carbamate insecticides and herbicides. There were a total of 51 pesticide detections in 34 individual samples. A total of 224 environmental samples were analyzed for pesticides, providing approximately 9,342 analytical results for environmental samples.

The pesticide detected in the most samples in 2006-2007 monitoring was prallethrin. Prallethrin was detected at multiple sites during the July 25, 2006 sample event and at the agricultural drainage-dominated sites in two other events. Prallethrin is a pyrethroid insecticide with no registered agricultural uses and is used almost exclusively for structural pest control (e.g., for termites) and landscape maintenance. It is photo-labile (breaks down rapidly in sunlight) and has a short environmental half-life on the order of just hours. Detected prallethrin concentrations did not approach levels known to cause toxicity to sensitive invertebrate species. However, there is relatively little toxicity data available for this pesticide, and two of the sites with prallethrin detections in July 2006 exhibited significant reductions in *Ceriodaphnia* reproduction (Colusa Drain and Sacramento River at Colusa). However, other sites with similar and higher detected concentrations of prallethrin exhibited no significant toxicity to *Ceriodaphnia*, so it is not clear that prallethrin was the cause of the toxicity in these two samples.

There were a total of 21 detections of organophosphate pesticides. Diazinon, dimethoate, chlorpyrifos, and malathion were each detected in two or more samples. Demeton, disulfoton, merphos, parathion, phorate, and trichloronate were each detected in only one sample. Five of the detections were observed at the two agriculture drainage sites and four were observed in the urban creek (Churn Creek). The remainder of organophosphate detections were distributed among the mainstem and tributary sites. Most of these detections occurred in the wet season, although a greater proportion of samples were collected in the dry season. Generally, detection of pesticides coincided with the periods of greatest use in the watershed. Diazinon and dimethoate were detected in February and March 2007 following the dormant spray season. The herbicides diuron, simazine, and bromacil were detected in winter 2006 through early spring 2007 during the period when agricultural use of herbicides is highest. The rice-specific herbicides molinate and thiobencarb were detected in June 2006 and July 2007 during the period when rice fields are typically drained.

Eight different herbicides were detected a total of 19 times at six different sites. The majority (10 detections) occurred at the two agricultural drainage sites. None of the herbicide detections exceeded objectives or concentrations known to adversely impact sensitive species. Although this evaluation does not account for potential additivity or synergism of mixtures of herbicides, this is empirically measured by *Selenastrum* toxicity tests. Additionally, detected concentrations were typically a small fraction of concentrations known to have adverse impacts.

Overall, only a few samples had pesticides exceeding or approaching water quality objectives or concentrations expected to cause toxicity in sensitive species:

- Malathion was detected in the June 5, 2007 Churn Creek sample (0.15 ug/L) at a concentration that exceeded the aquatic life-based criterion of 0.1 ug/L, but there was no significant toxicity to *Ceriodaphnia* or other test species in this sample.
- Diazinon was detected in the February 8, 2007 Churn Creek sample (0.58) at a concentration that approached but did not exceed the chronic Basin Plan objective (0.1 ug/L), but again there was no significant toxicity in this sample.
- Chlorpyrifos was detected in the July 25, 2006 Feather River sample (0.0176 ug/L) at a concentration that exceeded the chronic Basin Plan objective (0.015 ug/L), but again there was no significant toxicity observed in this sample.

Table 4. Advisory Criteria and Other Threshold Values for Pesticides Detected in SRWP 2006-2007 Monitoring

	Units = µg/L			
Pesticide	**Chronic Aquatic Life Criterion (CCC)**	**MCL**	**IRIS RFd**	**Minimum Toxicity Thresholds (1) (threshold type, taxonomic class)**
Chlorpyrifos	0.015 (2)	—	21	0.028 (minimum LC_{50}, crustacea)
Diazinon	0.1 (2)	—	—	0.2 (minimum LC_{50}, crustacea)
Malathion	0.1 (4)	—	140	1.5 (minimum LC_{50}, crustacea)
Molinate	13	20	14	220 (minimum EC_{50}, aquatic plants)
Prometon	—	—	100	98 (minimum EC_{50}, aquatic plants)
Simazine	10.0(3)	4	3.5	36 (minimum EC_{50}, aquatic plants)
Thiobencarb	3.1	70 (1˚ MCL) 1 (2˚ MCL)	70	17 (minimum EC_{50}, aquatic plants)

(1) From U.S. EPA's Environmental Fate and Effects Division of the Office of Pesticide Programs Pesticide Ecotoxicity Database, (USEPA 2003).
(2) Central Valley Basin Plan Amendment, 2007
(3) U.S. Environmental Protection Agency, *Water Quality Criteria, 1972* (1973) [*The Blue Book*]
(4) Applied as instantaneous maximum. U.S. Environmental Protection Agency, *Water Quality Criteria for Water, 1976* (1976) [*The Red Book*]

Table 5. Summary of Detected Pesticides and Frequency

Constituent	Classification	Primary Use	Number of Detections	Number of Samples
Prallethrin	Pyrethroid	Insecticide	10	75
Diazinon	OP Pesticide	Insecticide	5	163
Dimethoate	OP Pesticide	Insecticide	5	163
Simazine	Triazine	Herbicide	4	103
Chlorpyrifos	OP Pesticide	Insecticide	3	163
Molinate	Carbamate	Herbicide	3	12
Prometon	Triazine	Herbicide	3	103
Thiobencarb	Carbamate	Herbicide	3	12
Diuron	Urea Pesticides	Herbicide	2	67
Malathion	OP Pesticide	Insecticide	2	163
Atraton	Triazine	Herbicide	1	103
Bromacil	Uracil Pesticides	Herbicide	1	67
DDD(p,p')	Legacy Chlorinated Pesticide	None	1	38
DDT(o,p')	Legacy Chlorinated Pesticide	None	1	38
DDT(p,p')	Legacy Chlorinated Pesticide	None	1	38
Demeton-s	OP Pesticide	Insecticide	1	163
Disulfoton	OP Pesticide	Insecticide	1	163
Merphos	OP Pesticide	Herbicide	1	163
Parathion, Methyl	OP Pesticide	Insecticide	1	163
Phorate	OP Pesticide	Insecticide	1	163
Trichloronate	OP Pesticide	Insecticide	1	163
		Total	**51**	

Table 6. Comparisons of Detected Pesticide Concentrations to EPA Aquatic Life Pesticide Benchmarks

Pesticide	Use	Site ID	Date	Result, ug/L		Minimum EPA Benchmark[1] or EC50	Sensitive Species
Atraton	Herbicide	YRMRY	5/16/07	0.006	J[1]	NA	No toxicity data
Bromacil	Herbicide	COLDR	3/28/07	0.21	J	6.8	Algae
Chlorpyrifos	Insecticide	SACSL	4/20/06	0.0115		0.04	Invertebrate
Chlorpyrifos	Insecticide	FRNIC	7/25/06	0.0176[(2)]		0.04	Invertebrate
Chlorpyrifos	Insecticide	SRVET	8/23/06	0.0114		0.04	Invertebrate
DDD(p,p')	None	COLDR	4/20/06	0.0055		1	Invertebrate
DDT(o,p')	None	COLDR	4/20/06	0.0052		1	Invertebrate
DDT(p,p')	None	COLDR	4/20/06	0.028		1	Invertebrate
Demeton-s	Insecticide	FRNIC	7/25/06	0.0029		5	Invertebrate
Diazinon	Insecticide	CHKNT	2/8/07	0.0584[(2)]		0.1	Invertebrate
Diazinon	Insecticide	COLDR	2/9/07	0.0082		0.1	Invertebrate
Diazinon	Insecticide	FRNIC	2/10/07	0.0125		0.1	Invertebrate
Diazinon	Insecticide	SACSL	2/10/07	0.0179		0.1	Invertebrate
Diazinon	Insecticide	COLDR	3/29/07	0.0475		0.1	Invertebrate

Continues on following page…

Pesticide	Use	Site ID	Date	Result, ug/L		Minimum EPA Benchmark[1] or EC50	Sensitive Species
Dimethoate	Insecticide	CHKNT	3/29/07	0.0701		21.5	Invertebrate
Dimethoate	Insecticide	COLDR	3/29/07	0.0352		21.5	Invertebrate
Dimethoate	Insecticide	SACSL	3/29/07	0.0193		21.5	Invertebrate
Dimethoate	Insecticide	SRCOL	3/29/07	0.0104		21.5	Invertebrate
Dimethoate	Insecticide	SRHAM	3/29/07	0.015		21.5	Invertebrate
Disulfoton	Insecticide	FRNIC	7/25/06	0.001	J	0.037	Invertebrate
Diuron	Herbicide	COLDR	12/12/06	0.26	J	2.4	Algae
Diuron	Herbicide	COLDR	3/28/07	0.25	J	2.4	Algae
Malathion	Insecticide	CHKNT	2/8/07	0.045		0.06	Invertebrate
Malathion	Insecticide	CHKNT	6/5/07	0.149(2)		0.06	Invertebrate
Merphos	Herbicide	FRNIC	7/25/06	0.0073		1300	Fish
Molinate	Herbicide	SACSL	7/6/06	0.45	J	105	Fish
Molinate	Herbicide	SACSL	6/6/07	1.2		105	Fish
Molinate	Herbicide	SRVET	6/7/07	0.18	J	105	Fish
Parathion, Methyl	Insecticide	FRNIC	7/25/06	0.0089		0.02	Invertebrate
Phorate	Insecticide	SRVET	3/29/07	0.0084	J	0.21	Invertebrate
Prallethrin	Insecticide	SACSL	4/20/06	0.0233	J	6.2	Invertebrate
Prallethrin	Insecticide	CHKNT	7/24/06	0.0504		6.2	Invertebrate
Prallethrin	Insecticide	COLDR	7/25/06	0.112		6.2	Invertebrate
Prallethrin	Insecticide	FRNIC	7/25/06	0.0674		6.2	Invertebrate
Prallethrin	Insecticide	SACSL	7/25/06	0.246		6.2	Invertebrate
Prallethrin	Insecticide	SRCOL	7/25/06	0.0155	J	6.2	Invertebrate
Prallethrin	Insecticide	SRHAM	7/24/06	0.009	J	6.2	Invertebrate
Prallethrin	Insecticide	SRVET	7/26/06	0.064		6.2	Invertebrate
Prallethrin	Insecticide	COLDR	11/10/06	0.06		6.2	Invertebrate
Prallethrin	Insecticide	SACSL	11/10/06	0.065		6.2	Invertebrate
Prometon	Herbicide	CHKNT	3/29/07	0.0074	J	98	Algae
Prometon	Herbicide	CHKNT	4/24/07	0.007	J	98	Algae
Prometon	Herbicide	CHKNT	5/15/07	0.005	J	98	Algae
Simazine	Herbicide	COLDR	3/29/07	0.0595		36	Algae
Simazine	Herbicide	CHKNT	4/24/07	0.023		36	Algae
Simazine	Herbicide	SACSL	4/26/07	0.006	J	36	Algae
Simazine	Herbicide	CHKNT	5/15/07	0.006	J	36	Algae
Thiobencarb	Herbicide	COLDR	7/6/06	0.11	J	1	Invertebrate
Thiobencarb	Herbicide	COLDR	6/6/07	0.33	J	1	Invertebrate
Thiobencarb	Herbicide	SACSL	6/6/07	0.35	J	1	Invertebrate
Trichloronate	Insecticide	FRNIC	7/25/06	0.0077		0.1	Invertebrate

(1) "J" indicates that value was detected below the quantitation limit and is considered an estimate of the true concentration

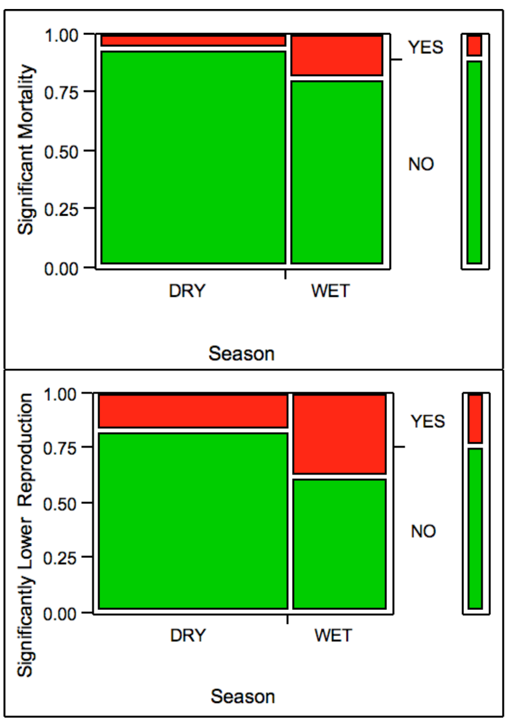
(2) No toxicity was observed in this sample. Highlighted results are also discussed in the text.

Toxicity Evaluation

Geographical and Seasonal Distribution of Toxicity

Algae Toxicity – Toxicity tests with *Selenastrum* indicated that ambient toxicity to algae was infrequent – only four samples (less than 2% of the samples tested) exhibited a reduction in algal growth. The most common response was a significant increase in growth compared to the control. Because the toxicity was so infrequently observed, there was no consistent spatial or temporal trend in algal toxicity. However, there was an indication of increasing growth response from the most upstream Sacramento River location to Colusa that corresponded with the spatial pattern of increasing nutrients in this reach of the mainstem river. In the few samples that were toxic, the toxicity was not determined to be attributable to detected pesticides or other toxicants in any samples.

***Ceriodaphnia* Toxicity** – The frequency and magnitude of toxicity to *Ceriodaphnia dubia* was markedly greater than was observed for algae – approximately 10% of the samples exhibited significant reductions in *Ceriodaphnia* survival, with an additional 13% of the samples exhibiting a significant reduction in reproduction. Furthermore, 19 of the 20 samples that exhibited a significant reduction in survival resulted in ≤50% survival, with most of those causing complete mortality of the test organisms.



There was no consistent spatial trend in the *Ceriodaphnia* responses in these waters, and there were no discernible trends in toxicity for different types of water bodies (tributary vs. main stem vs. urban drainage dominated vs. agricultural drainage dominated). There was a seasonal trend for toxicity, with a significantly higher percentage of toxic samples observed in wet season samples than in dry season. Thirty-one of the 48 toxic samples (65%) were collected during the five rainy months (December through April), and only 17 of the toxic samples were collected in the remaining dry season months of the study period. This was not unexpected, as numerous studies have indicated that stormwater runoff can be a significant source of toxicity to receiving water ecosystems. Of particular note was the event during and following the first major storm system of the season affecting the watershed (December 11-13, 2007). Of the 12 water samples collected during this event, 11 caused complete mortality of the test organisms in the initial tests. Toxicity Identification Evaluations (TIEs) were performed on each of the 11 toxic samples, including centrifugation to remove particulate-associated toxicants, C-8 solid phase extraction column to remove non-polar organic toxicants, Chelex® column extraction to remove transition metals, and piperonyl butoxide (PBO) to counteract the effects of specific metabolically-activated toxicants (e.g., organophosphorus pesticides). The results of these TIEs indicated that toxicity in most samples was caused by a dissolved, metabolically-activated organic compound. However, there were no pesticides or other toxicants detected in the samples that were consistent with the TIE results, and probable responsible toxicant(s) were not identified.

A total of 20 TIEs were performed with *Ceriodaphnia*. TIEs were typically initiated within 24 hours of observing the trigger condition of 50% mortality, between three and seven days of collecting the initial sample. There was no correlation between the elapsed time to TIE initiation and persistence of toxicity. Toxicity was not persistent (nine samples), or took longer to occur than in the original test (ten samples), or was decreased in magnitude (one sample) in each of the TIEs, indicating that the responsible toxicants were degrading or becoming less bioavailable over time. In the 11 samples with persistent toxicity, the following patterns were seen:

- Particulate-associated contaminants and metabolically-activated substances, or a substance with both properties, caused the toxicity for three samples;
- Dissolved, non-polar organic contaminants and metabolically-activated substances, or a substance with both properties, caused the toxicity for six samples;
- Dissolved, non-polar organic contaminants caused the toxicity for one sample; and
- Dissolved, non-polar organic contaminants, divalent cations, and metabolically-activated substances, or a substance with all of these properties, caused the toxicity for one sample.

The lack of persistent toxicity in many of the samples, coupled with the delayed onset and decreased magnitude of toxicity for many samples, indicates that persistent toxicants (e.g., metals) were not likely to have caused the observed toxicity in most of the samples. Because pesticides have a history of causing toxicity in the Sacramento River watershed, the analytical results for the toxic samples were also evaluated to determine if there were any contaminants that could have been responsible for the observed toxicity. The consistent result of this evaluation was that monitored pesticides were not detected or were well below concentrations toxic to *Ceriodaphnia* in toxic samples. Samples analyzed for pesticides were extracted from one to four days after sample collection, *i.e.*, well before the initial toxicity tests were completed, indicating that pesticides present at toxic concentrations would have been detectable in the chemical analyses. In no cases were individual pesticides detected at concentrations that would explain the observed toxicity to *Ceriodaphnia*.

There have been numerous, previous ambient water toxicity studies performed in the watershed, San Francisco Estuary, Salinas River (Hunt *et al*. 2003), and Calleguas Creek (Anderson *et al*. 2002) that have identified the organophosphorus (OP) pesticides diazinon and chlorpyrifos as significant causes of observed toxicity. TIE profiles of toxic SRWP samples suggested that the toxicity was most frequently due to a dissolved non-polar organic metabolically-activated substance, and in few cases a particulate-associated metabolically-activated substance. Similar TIE profiles have been reported in other watersheds, including the Salinas River watershed (Hunt *et al.* 2003), Santa Maria River watershed (Anderson *et al*. 2006), and the New River in southern California (Phillips *et* *al.* 2007). The patterns observed in most SRWP TIEs for samples with persistent toxicity were similar to profiles typically observed for diazinon or chlorpyrifos toxicity:

- The baseline ambient sample was toxic when retested for the TIE (i.e., toxicity was persistent in the sample);
- C8 solid phase extraction columns completely eliminated toxicity in all TIEs with persistent toxicity (suggesting a dissolved, non-polar organic caused the toxicity); and
- Piperonyl butoxide eliminated (9 TIEs) or reduced (2 TIEs) the toxicity (suggesting that the toxicant responsible for the toxicity is metabolically activated).

Fathead Minnow Toxicity – Approximately 7% of the samples exhibited significant reductions in larval fathead minnow survival, with an additional 9% of the samples exhibiting a significant reduction in growth. Six of the 14 samples that exhibited a significant reduction in survival resulted in ≤50% survival, with one of those causing complete mortality of the test organisms.

There was a suggestion of a spatial trend in the fathead minnow responses in the mainstem Sacramento River, with more frequent mortality and lower growth in the two most upstream sites. There were no other discernible trends in toxicity for different types of water bodies (tributaries vs. main stem vs. urban drainage dominated vs. agricultural drainage dominated). As with the *Ceriodaphnia*, there was a significant seasonal trend, with 16 of the 36 (44%) samples collected during the 5 wet season months causing toxicity (December through April), and only 20 toxic samples (13%) of the 155 total samples collected during the dry season months of the study period.

Six TIEs were performed with fathead minnows. TIEs were initiated as soon as possible after observing the trigger condition of 50% mortality. The additional time required to aquire appropriately aged larval fish meant that TIE initiation occurred from five to nine days after collecting the initial samples. There was no correlation between the elapsed time to TIE initiation and persistence of toxicity. TIE manipulations were the same as conducted for *Ceriodaphnia* (centrifugation, C-8 solid phase extraction column, Chelex® extraction, and PBO). Toxicity was persistent for five of these samples and one could not be interpreted due to interferences from 'pathogen-related mortality' in the ambient water samples[6]. Toxicity was delayed or decreased in four of these five samples, a pattern consistent with contaminants that were degrading or becoming less bioavailable over time. Of the 5 samples with persistent toxicity, the following patterns occurred:

- Dissolved, non-polar organic contaminants caused the toxicity in one sample;
- Dissolved, non-polar organic contaminants, divalent cations, and metabolically-activated substances, or a substances with a combination of these properties, caused the toxicity in one sample;
- Particulate-associated contaminants and/or divalent cations caused the toxicity in one sample;
- None of the TIE treatments removed the toxicity in two samples.

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[6] The fish provided for the November 2006 TIE appeared to be of less than optimal quality (i.e., swim bladders were not inflated) and evidence of pathogen related mortality (high inter-replicate variability and fungal halos) was observed in several TIE treatments with decreased survival during testing.

As was found with the *Ceriodaphnia* results, there were no pesticides or other toxicants detected in the samples that were consistent with the TIE results, and probable responsible toxicant(s) could not be identified. Toxic samples analyzed for pesticides were extracted 2.5 days after collecting the December 2006 samples (before completion of the initial toxicity tests) and 6.5 days after collecting the January 2007 samples (at initiation of the TIE), indicating that pesticides present at toxic concentrations would have been detectable in the chemical analyses.

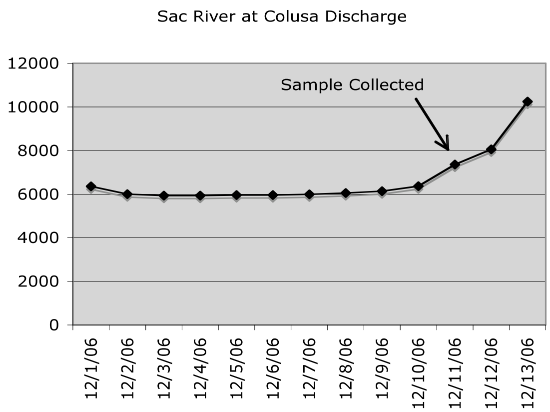
Timing of Onset of Toxicity

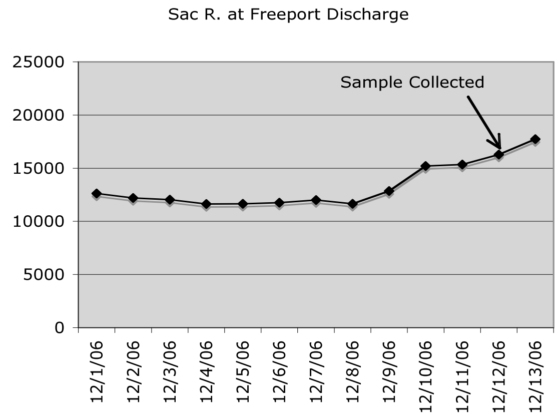
Although there were similarities in the SRWP TIE profiles with the previous studies and the studies being performed in other watersheds, the SRWP 2006-2007 data differ in the regularly observed reduced magnitude of toxicity and delay in the onset of toxicity in toxicity for the TIEs when compared to the initial toxicity test. This is in contrast to historical studies in which toxicity has often been linked to chlorpyrifos and diazinon, with persistent toxicity exhibited from the time of the initial toxicity test through the TIE process. In the current study period, 26 of the 27 samples that qualified for TIEs exhibited a delay in the onset of toxicity, a decrease in the magnitude of toxicity, or both, relative to the initial toxicity test. This phenomenon is by no means unprecedented, as similar cases of "fugitive toxicity" have been observed by the UC Davis Aquatic Toxicology Laboratory for malathion (Linda Deanovic, personal communication), the CVRWQCB's Phase I Irrigated Lands Regulatory Program (ILRP), and more recent ILRP testing in the Sacramento and the San Joaquin River watersheds.

December 2006 Event Case Study

The event conducted in December 2006 occurred during the early wet season. The monitoring event was initiated on Monday, December 11, and was preceded by a storm event that began on Saturday, December 9. The storm was widespread in the watershed and deposited greater than 0.5 inches of rainfall throughout the Sacramento River watershed, which in turn resulted in increased flows at SRWP monitoring sites (see representative plots for mean daily flows at Sacramento River at Colusa and at Freeport, **Figure 18**. The samples captured during this event represent a seasonal "first flush" that may not have been as effectively characterized in previous SRWP monitoring events. During previously monitored events targeting a first flush event, samples were typically collected beginning on the first day following significant rainfall. Because of the size of the watershed, the timing of effect of storm runoff on mainstem river flows is difficult to predict and is often delayed. During the December 2006 event, sampling was initiated approximately 2 days after the rain event, and the additional day after the beginning of storm runoff resulted in samples that were particularly well-synchronized with the initial increases in river flows resulting from this runoff event.

Figure 18. December 2006 Event Flows





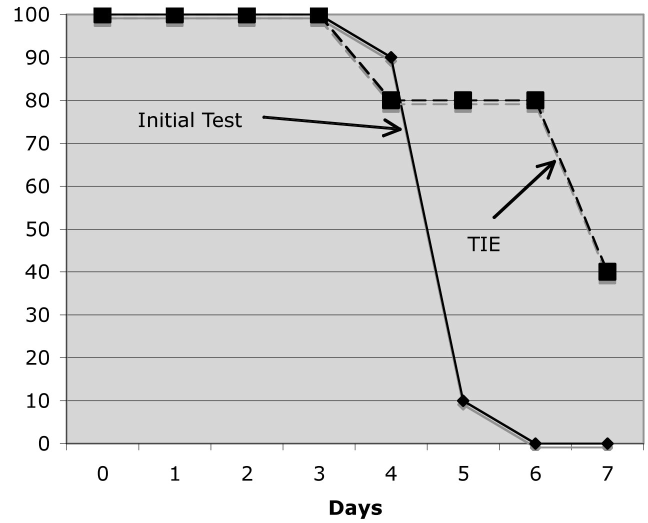
SRWP toxicity testing performed with samples collected December 11-13, 2006 resulted in a unique and intriguing set of data compared to historical SRWP data, and provides a case study that warrants review. The initial toxicity testing for the 12 samples collected can be summarized as follows:

- None of the samples were toxic to *Selenastrum*;
- 11 samples significantly decreased *Ceriodaphnia* survival and the remaining sample significantly decreased *Ceriodaphnia* reproduction; and
- 5 samples significantly decreased fathead minnow survival and 2 samples significantly decreased fathead minnow growth.

For the majority of the December 2006 samples, the magnitude of the toxicity was reduced and the time to the onset of the toxicity was delayed when retested for TIEs. The characteristic profile of delayed toxicity and reduced magnitude of toxicity to *Ceriodaphnia* that was observed is presented in **Figure 19** for the Sacramento River at Keswick Reservoir sample.

This pattern suggests that the toxicity observed in the December 2006 samples was caused by contaminant(s) of relatively low stability that are susceptible to significant degradation over the course of the four to eight days between sample collection and TIE initiation. The data from the overwhelming majority of the TIEs suggest that the toxicant was a dissolved organic that is metabolically activated. Historically, this pattern of TIE toxicity removal has been associated with OP pesticides such as chlorpyrifos and diazinon – however these two pesticides are relatively stable through the performance of Phase I TIEs. The December 2006 samples were analyzed for carbamates, OP pesticides, pyrethroids, triazines, and organochlorine pesticides within four days of sampling. With the exception of a low concentration of diuron in the Colusa Basin Drain sample, all of the individual pesticides were below detection for this event. This is not entirely surprising since the toxicity profile of rapidly-degrading toxicity is not consistent with most of the pesticides analyzed, and the use of pesticides from October through mid-December is typically low throughout the watershed (**Figure 5**).

Figure 19. Onset of *Ceriodaphnia* Toxicity in Sample Collected at Sacramento River Below Keswick Reservoir, December 2006.



It should be noted that the chemical analyses data performed for SRWP do not represent the entire suite of agricultural (and non-agricultural) chemicals that are applied in the watershed. An evaluation of pesticides applications reported in the California Department of Pesticide Regulation's Pesticide Use Reporting database for seven of the SRWP counties during the one-month period preceding this event (November 11 – December 11, 2006) reveals that over 200 different chemicals were applied during this period. The application of such a diverse suite of chemicals provides for the possibility of a very dynamic and complex water chemistry matrix. The number of pesticides applied in this watershed in this one-month period alone illustrates the challenge in trying to evaluate toxicity causation on the basis of pesticide concentration data.

There are several reasons to suspect that causes of the toxicity were not related to agricultural activities. In spite of the large variety of agricultural chemical applications reported, overall pesticide applications (and agricultural activities in general) are typically lowest during this season of the year. Additionally, the widespread occurrence of the toxicity in the watershed is not consistent with runoff of recently applied pesticides. This event was the first substantial storm and increase in flows after the dry season, and may have captured the first significant runoff of a variety of potential atmospherically deposited pollutants, including ash and polycyclic aromatic hydrocarbons (PAHs) from the numerous wildfires that occurred in and around the watershed during the dry season. Although PAHs are not directly acutely toxic to aquatic organisms, their toxicity is also potentiated by UV light, which produces the reactive oxygen species that actually cause the toxicity. The toxicity of these compounds is also metabolically activated by the same physiological mechanism as organophosphate pesticides and would be similarly reduced by piperonyl butoxide (PBO) treatment. If PAHs are a significant cause of toxicity during early wet season events, their effects would be widespread in the watershed because of their many sources and their pattern of atmospheric deposition. The SRWP program did not analyze samples for PAHs, so it could not be determined directly whether these compounds may have contributed to the widespread toxicity. Although it may have been possible to analyze for PAHs in the in the original samples or in TIE eluates, the hypothesis for PAHs as a potential toxicant was identified after monitoring was completed in 2007, and the Toxicity Focus Group did not have an opportunity to pursue this question. However, this is a hypothesis that deserves additional evaluation through literature review and possibly through future monitoring focus. One avenue of investigation that is still open is to re-read the chromatograms for samples analyzed for organophosphorus pesticides for evidence of the presence of PAHs.

Integration and Historical Overview

Toxicity that was observed over such a large geographical scale in December 2006 is not unprecedented in the Sacramento River watershed. Widespread toxicity was reported in May 1988 (fathead minnow mortality) and during several monitoring events in 1988 and 1989 (*Ceriodaphnia* mortality) throughout the Sacramento River watershed (Connor and Foe, 1993). Although the specific cause of the toxicity during the 1980s study varied, the authors hypothesized that much of the toxicity in the upper watershed was likely due to trace metals and that much of the toxicity in monitored agricultural drainages may have been due to rice pesticides (especially *Ceriodaphnia*). Since the Connor and Foe study, significant and successful efforts have been made to clean up runoff and drainage from Iron Mountain Mine in the upper watershed, and these have resulted in dramatic improvements in metals-related water quality in the Sacramento River.

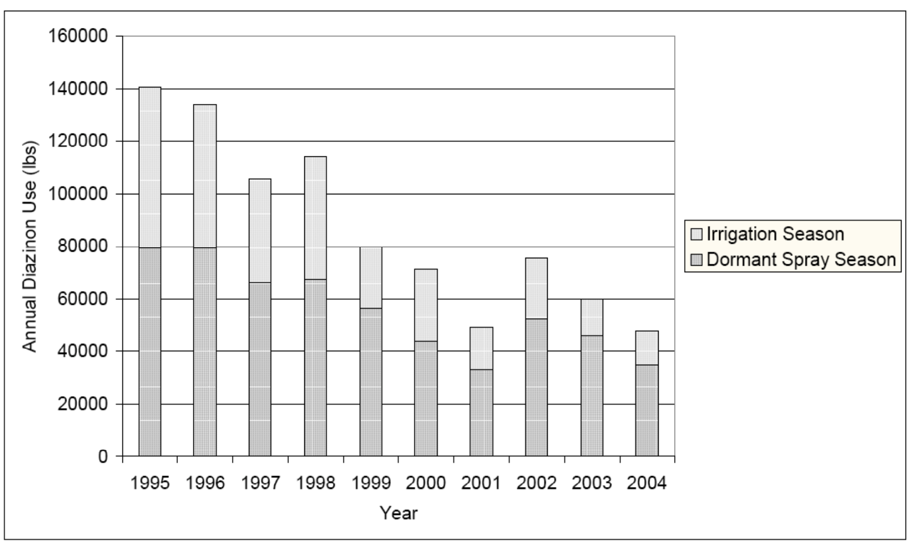
Toxicity within the Sacramento River watershed has been associated with specific land use activities. Foe and Connor (1991) documented *Ceriodaphnia* toxicity over 19 days (from May to June) in 1989 in the Colusa Basin Drain, and toxicity was observed as far downstream as the Sacramento River at Rio Vista. The toxicity in the Colusa Basin Drain was attributed to carbofuran and methyl parathion (both of which were extensively used in rice cultivation), and malathion. Foe and Connor (1991) concluded that rice runoff water was the source of the toxicity. The rice industry has long since implemented pesticide management practices that have largely addressed the toxicity that occurred in the early 1990s – a success story demonstrating how changes in management practices can result in dramatic reductions in toxicity in the watershed. Domagalski (2000) also reported that significant reductions in the concentrations of rice pesticides occurred following the implementation of management practices.

Historical Role of Diazinon and Chlorpyrifos as Primary Toxicants

Toxicity to *Ceriodaphnia* from pulses of OP pesticides, such as chlorpyrifos and diazinon, were reported over a 10-year period throughout the Sacramento Valley in waters that receive pesticide runoff from orchards (de Vlaming *et al.,* 2000), as well as in tributaries that receive urban runoff following rainfall. As part of the U.S. Geological Survey's National Water Quality Assessment Program, Domagalski (2000) reported that diazinon was present in stormwater runoff at a number of sites in 1994, and in non-storm flows during 1996 through 1998. Domagalski *et al.,* (2000) also reported that diazinon concentrations in a Sacramento River watershed urban drainage and agricultural drainages were among the highest in the nation. Larsen *et al*. (1998) reported that for samples collected from the Sacramento River watershed in 1996-1997, diazinon and chlorpyrifos were responsible for toxicity observed in urban creek samples (i.e., Arcade Creek) and that diazinon from dormant spray applications was responsible for toxicity observed in agricultural drainage waters (i.e., Sacramento Slough). Bailey *et al.* (1996) reported that diazinon and chlorpyrifos water quality criteria were often exceeded in samples collected between October 1994 and May 1995 from streams, sumps, and sloughs in the city of Sacramento, and that TIEs identified one or both of these compounds as the cause the toxicity.

In response to the observations of ambient water toxicity, the Central Valley Regional Water Quality Control Board placed the Sacramento and Feather Rivers on the Clean Water Act Section 303(d) list due to toxicity caused by diazinon in 1994. Several Sacramento urban creeks were also added to the 303(d) list due to toxicity caused by diazinon and chlorpyrifos in 1998. In 2003, a Basin Plan amendment for the control of diazinon in the Sacramento and Feather Rivers was adopted (Karkoski et al. 2003). The TMDL was amended in 2007 to include chlorpyrifos (Hann *et al*. 2007). In addition, and in response to Food Quality Protection Act-required risk assessments, the US EPA banned the majority of non-agricultural uses of chlorpyrifos in 2001, and all non-agricultural sales of diazinon in 2004. Restrictions have also been placed on the use of diazinon and chlorpyrifos for some crops. These actions have been effective: the CVRWQCB (Hann *et al*. 2007) has reported that that there has been a 67% reduction in the agricultural use of diazinon from 1995-through 2004 (**Figure 20**). A similar analysis of chlorpyrifos was found to be difficult due to previous analytical limitations and inconsistent analytical approaches, but the outcome is likely similar to diazinon.

Figure 20. Annual Dormant Spray and Irrigation Season Applications of Diazinon in the Sacramento River and Feather River Watersheds (from Hann *et al*. 2007).



As a result of these regulatory actions, the concentrations of diazinon and chlorpyrifos in the Sacramento River system have decreased significantly. Hall (2003) analyzed diazinon monitoring data from the Sacramento and Feather River watersheds, and reported that waterborne diazinon concentrations have decreased from 1994 to 2000, including a significant decrease during rain events. The corresponding reduced role of diazinon and chlorpyrifos (whose toxicity tends to persist through the duration of initial testing and follow-up TIEs) is consistent with the current observations of more frequent observations of non-persistent toxicity.

With the decline in use of diazinon and chlorpyrifos, the use of alternative pesticides has increased. Of particular note (and some concern) is the increased use of pyrethroid pesticides (Amweg 2005; Oros and Werner 2005). The shift in pesticide applications from OP pesticides to pyrethroid pesticides has been hypothesized to result in concomitant shifts in the patterns of toxicity observed in monitoring programs. Relative to the OP pesticides, pyrethroid pesticides have a much greater affinity for binding with particulates, which should reduce the concentration of bioavailable pesticides in surface waters. However, scientists and regulators have become increasingly concerned that this partitioning of pyrethroids to particulates may be causing increased sediment toxicity. Weston *et al*. (2004) reported significant toxicity was observed for sediment samples collected from Sacramento Valley agricultural-dominated water bodies and that pyrethroid concentrations were strongly correlated with this mortality. Amweg *et al*. (2005) reported similar findings, and that pyrethroids were primary contributors to toxicity in all but 20% of the samples collected in the Central Valley. Weston *et al.* (2005) also reported that *Hyalella azteca* exhibited >90% mortality in 9 of 21 sediment samples collected from a suburban creek near Roseville, and that the mortality was highly correlated with pyrethroid concentrations. The increase in the use of pyrethroid pesticides coupled with the reduction of the availability and use of specific OP pesticides (e.g., chlorpyrifos and diazinon) may explain much of the change in the reduced observations of toxicity in water samples from the Sacramento River watershed. However, it is important to note that toxicity is still observed in water samples within the watershed, and that this toxicity can be widespread as was observed in December 2006.

Hypotheses for Observed Changes in Toxicity Patterns

One hypothesis for changes observed in toxicity patterns is changes in land use activities. These could include a shift in pesticide use to compounds that are efficacious for pest control when sprayed on the plants, but have short half-lives in water so as to have little or no deleterious environmental affect on non-target organisms. There are quite a few examples of changes in pesticide applications that have resulted in quantifiable changes in patterns of toxicity.

When the toxicity met the TIE trigger for SRWP samples collected from April 2006 – August 2007, there was a fairly consistent pattern of rapidly degrading toxicity. When toxicity was persistent in the TIE, there was often a reduction in the magnitude of the toxicity, as well as a delay in the time to the onset of toxicity. For cases of persistent toxicity, the TIE profile typically suggested that the toxicant was a dissolved, non-polar organic that is metabolically activated. This pattern of degrading toxicity with a loss of magnitude of toxicity suggests that the toxicity was due to compounds with a short half-life that could rapidly degrade during the period of time that elapses between sample collection and the completion of a TIE. This still includes a large number of potential pesticides – Sinclair and Boxall (2003) reported that 41% of pesticide degradates were less toxic than their parent compounds.

Compounds that are volatile or readily adsorb to testing materials (e.g., sample containers and exposure chambers) could also be responsible for the toxicity. The TIE pattern would typically exclude metals, and diazinon and chlorpyrifos (i.e., OP pesticides that persist for upwards of 30 days in laboratory storage conditions), both of which have been historically responsible for toxicity observed in the watershed. An OP pesticide with a very short half-life would fit this TIE profile, as would any interactive toxicity that included an OP pesticide as one of the participating contaminants. In addition, the TIE profile of a dissolved, non-polar organic that is metabolically activated may suggest OP pesticides, but there may be many compounds that fit this set of chemical properties. Pyrethroid pesticides are not indicated as a likely cause of the observed toxicity for a couple of reasons. Although many pyrethroid pesticides tend to adsorb to particulates, sample containers, and exposure chambers, the toxicity of pyrethroids is increased by addition of PBO and this is inconsistent with the TIE profiles for most of the observed toxicity. Additionally, the only pyrethroids detected were well below concentrations expected to be toxic to sensitive species. One strategy to identify other possible candidate compounds would be to review the California Department of Pesticide Regulation Pesticide Use Reporting database for the entire period of this study for changes in the use of compounds consistent with this profile. There are numerous pesticides being applied in the watershed that are not being regularly monitored by SRWP or any other program. Although pesticide use is generally trending toward lower risk pesticides and increased cultural management practices to reduce overall pesticide use and runoff, the lack of direct ambient data for many newer, widely used pesticides is a significant information gap for the watershed.

Fish Tissue Data

Mercury in Fish Tissue: FMP Report

The CALFED Fish Mercury Project (FMP) is conducting an extensive monitoring effort focused on mercury in Delta sport fish. The FMP is using an integrated approach that includes monitoring mercury in fish tissue, developing consumption advice, and communicating risk. One of the primary contributions of SRWP to the FMP was to fund the analysis of trace organics in archived fish samples collected by the FMP. The purpose of these analyses was to complement the data and consumption advice based on mercury with information about risks from chlorinated pesticides and PCBs, and to conduct an initial screening of the risks from PBDEs. This complementary data would ensure that consumption advice designed to minimize the risks of mercury would not inadvertently increase consumers' risks from these trace organic pollutants.

The FMP will continue through August 2008. Final products for the FMP will include reporting of results for 2006 and 2007, and safe eating guidelines for the Sacramento River and North Delta. Select findings and recommendations of the FMP to date are summarized below (SFEI 2007).

- Mercury concentrations vary by location, fish species, and the size and age of fish. Predatory fish that eat other fish generally have higher concentrations of mercury than fish that eat invertebrates. However, the spatial patterns in mercury are generally consistent in different species. Mercury concentrations were higher in the Sacramento and San Joaquin rivers and their tributaries than in the Delta.
- An evaluation of long-term trends (10-20 year) found that mercury concentrations in fish were not changing significantly. This finding is consistent with the hypothesis that mercury is moving slowly through the Delta system, and highlights the need for safe consumption guidelines while efforts to clean up mercury in the environment continue.
- Geographic differences and shorter-term variability in mercury trends can be effectively investigated using small "biosentinel" fish species that respond more rapidly to changes in mercury concentrations.
- Expected "hot spots" such as seasonal wetlands were not always high in mercury. Mercury concentrations in fish from the Central Delta and in a restored portion of Napa Marsh were unexpectedly low. These preliminary results suggest that restoration of wetlands in the watershed may not increase problems of mercury contamination in fish tissue.
- Risks can be reduced by eating lower on the food chain, consuming a variety of fish species from a variety of locations, and eating the smaller individual fish of a particular species.

Organics in Fish Tissue: SRWP Results

Forty composite fish tissue samples were analyzed for trace organic compounds. These samples were collected in 2005 for the CALFED Fish Mercury Project from 23 different sites in the Sacramento River watershed, including nine mainstem river sites from Bend Bridge to Rio Vista, the three major tributaries, Bear River, two agricultural drain sites, and five hatchery sites. Seven fish species were tested: carp, channel catfish and white catfish, Chinook salmon, rainbow trout, redear sunfish, and Sacramento sucker.

Concentrations of organochlorine pesticides and PCBs in fish tissue were compared primarily to California Office of Environmental Health Hazard Assessment (OEHHA) screening values (OEHHA 1999; OEHHA 2006). OEHHA's updated 2006 screening values are based on a fish consumption rate of 90 g/day (equivalent to twelve 8 oz. meals of fish per month) and updated IRIS reference doses and cancer slope factors. These screening values are "*…specific guidance tissue levels used to identify situations where contaminant concentrations in fish are of potential health concern and further action (e.g., additional sampling or developing consumption advice) is recommended*" (OEHHA 2006) . The screening values are based on levels of daily human exposure to a chemical that is likely to be without significant increased risk of adverse effects or developing cancer during a lifetime. Note that these risk-based human health limits are based on assumptions of specific fish consumption rates that are typically averages for the general population. For individuals or populations consuming more fish than assumed for a specific limit or screening value (e.g. sport fisherman or some ethnic populations), the risk of adverse health effects is increased.

The following observations were made based on comparisons of fish tissue results to OEHHA screening values:

- None of the composite fish samples exceeded OEHHA screening values for aldrin, chlordanes, endrin, heptachlor, PBDEs, endosulfan, or toxaphene.
- DDT exceeded the OEHHA 1999 screening value (100 ppb) in two composite fish samples: a carp sample from the Sacramento River at Rio Vista (144 ppb), and a catfish composite from Sacramento River at Veterans Bridge (104 ppb). Both of these samples were well below updated screening value of 560 ppb calculated by OEHHA in 2006.
- Dieldrin exceeded the OEHHA 1999 screening value (2 ppb) in four composite catfish samples collected from the Sacramento River at Colusa (2.03 ppb), Sacramento River at Grimes (3.7 ppb), and Sacramento Slough (3.05 ppb and 2.35 ppb). All of these samples were well below updated screening value of 16 ppb calculated by OEHHA in 2006.
- PCBs exceeded the OEHHA 1999 and 2006 screening value (20 ppb) in 11 composite samples from eight different sites, in carp, channel catfish, and Sacramento suckers. Exceedances of screening values were observed in fish from the lower Sacramento River (Veterans Bridge to Rio Vista), the lower American River, Sacramento Slough, and in one composite from Clear Creek. The highest PCB concentration (213 ppb) was observed in a catfish composite from Sacramento River at Colusa.
- Trace organic concentrations in the two lower trophic level species (trout and redear sunfish) and an anadromous migratory species (Chinook salmon) were uniformly low compared to carp, suckers, and catfish.
- PBDEs were detected in all samples tested, but did not approach an estimated screening value of 1786 ppb. This estimated screening value was calculated using USEPA and OEHHA methodology, an assumption of 12 meals/month of 227 g/meal (equivalent to 90 g/day) and the IRIS reference dose of 2 ug/kg-d for Pentabromodiphenyl ether.

Based on comparisons to screening values for organochlorine pesticides and PCBs in fish tissue, consumers who eat a variety of fish from different locations appear to be at relatively low risk from these compounds in fish tissue. However, potential risks increase for people selectively consuming a limited number of higher trophic level species (e.g. white catfish, largemouth bass, striped bass), and for individuals consuming more fish than the 90 g/day (about 12 half-pound servings per month) on which the 2006 screening values were based.

There were no consistent differences in tissue concentrations between different site types (mainstem vs. tributary), but there was a distinct geographic pattern in the tissue concentrations of trace organics in the mainstem Sacramento River. Trace organic concentrations in Sacramento suckers increased from upstream to downstream, as illustrated in **Figure 21** and **Figure 22**. This pattern was consistent for PCBs, DDT, dieldrin, and chlordanes. This spatial pattern is consistent with the distribution of the primary land uses associated with these pollutants (e.g., agriculture and urban developed areas). In general, concentrations of these five trace organics were highly correlated in all of the samples (**Figure 23**), indicating that the causative sources or mechanisms were similar at most locations. Correlation coefficients among PCBs, DDT, dieldrin and chlordane were generally greater than 0.6 and were statistically significant. Correlations with PBDEs were lower and were not significant, except with DDTs.

These comparisons of tissue concentrations to screening values supports the delisting of one of the waterbodies cited on the 2002 303(d) list for impairment due to organochlorine pesticides (CVRWQCB 2003). The results indicate that the Regional Board's listing of the lower Feather River for "Group A" pesticides (aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexanes including lindane, endosulfan, and toxaphene) may not be necessary. None of the Feather River samples tested exceeded OEHHA's 1999 or proposed updated 2006 screening values. This is consistent with previous SRWP monitoring results for these "Group-A" pesticides in Feather River fish (SRWP 2004) and recommendations to reevaluate this 303(d) listing.

Table 7. Summary of Results for Organochlorines, PCBs, and PBDEs in Tissue

			Tissue concentrations and Screening Values (ppb, wet weight)		
	Number of samples	**Number of Detections**	**Max detected concentration**	**OEHHA 1999(1)**	**OEHHA 2006(2)**
Aldrin	42	1	0.139	50	—
Chlordanes	42	29	6.3	30	200
DDTs	42	42	144.1	100	560
Dieldrin	42	32	3.7	2	16
Endrin	42	1	0.758	1000	—
Heptachlor Epoxide	42	11	0.734	4	—
PBDEs	11	11	106.5	—	1786(3)
PCB Arochlors	42	37	213	20	20
Total Endosulfan	42	2	4.01	20000	—
Toxaphene	42	2	21.1	30	220

(1) OEHHA (1999). These screening values are based on consumption of 21 g fish per day (equivalent to approximately six quarter-pound servings per month), and IRIS RfD or Cancer Slope Factors.

(2) OEHHA updated screening values (OEHHA 2006). Guidance levels shown are based on consumption of 12 meals per month with 225 g/fish per meal (approximately 8 oz), and updated IRIS RfD or Cancer Slope Factors.

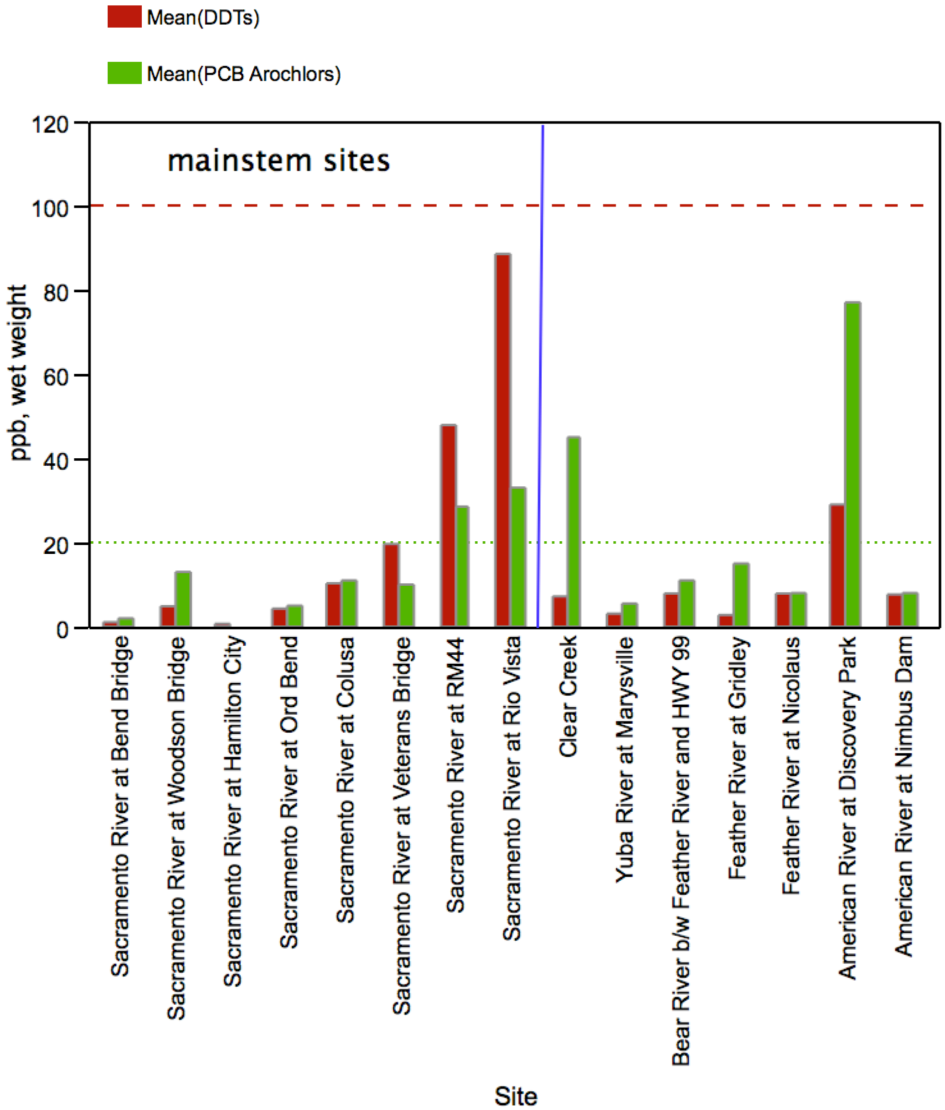
(3) No screening values have yet been developed for PBDEs by OEHHA. The screening value of 1786 ppb was estimated using USEPA and OEHHA methodology, an assumption of 12 meals/month of 227 g/meal, and the IRIS reference dose of 2 ug/kg-d for Pentabromodiphenyl ether.

Table 8. Organochlorine Pesticides, PCB, and PBDEs in Fish Tissue (ppb, Wet Weight)

Site	Species	DDTs	PCB Arochlors	Chlordanes	Dieldrin	PBDEs
Feather River at Nicolaus	Sacramento sucker	7.9	8	0.825	0.459	
Feather River at Nicolaus	Carp	24.1	16	0.273	0.36	
American River at Discovery Park	White catfish	9.0	7	0.647	ND	12.18
Sacramento River at Rio Vista	Sacramento sucker	88.5	**33**	2.774	1.73	
Sacramento River at Rio Vista	Carp	144.1	**24**	2.103	0.944	
Sacramento River at Bend Bridge	Sacramento sucker	1.1	2	ND	ND	3.5
Sacramento River at Bend Bridge	Rainbow trout	1.9	12	0.221	0.234	
Clear Creek	Sacramento sucker	7.2	**45**	1.308	0.4	
Clear Creek	Rainbow trout	4.0	19	0.285	0.227	–
Darrah Springs Hatchery	Rainbow trout	1.9	7	ND	0.225	–
Sacramento River at Woodson Bridge	Sacramento sucker	4.9	13	0.665	0.304	–
Sacramento River at Ord Bend	Sacramento sucker	4.3	5	0.221	ND	–
Sacramento River at Colusa	Channel catfish	83.8	**213**	4.26	2.03	38.5
Sacramento Slough at Karnak	Channel catfish	58.5	**25**	1.404	3.05	–
Sacramento Slough at Karnak	Channel catfish	45.8	**37**	1.36	2.35	–
Colusa Basin Drain at Rd 99E	White catfish	41.6	ND	ND	0.7	–
Colusa Basin Drain at Rd 99E	Carp	63.5	ND	ND	1.14	–
Sacramento River at Rio Vista	White catfish	27.8	18	1.005	0.654	–
Mount Shasta Fish Hatchery	Rainbow trout	0.8	2	ND	0.248	–
American River Hatchery	Rainbow trout	1.1	2	ND	ND	–
Sacramento River at Veterans Bridge	Sacramento sucker	19.6	10	0.77	0.424	13.5
Sacramento River at Veterans Bridge	Carp	57.4	**43**	2.7	0.98	–
Sacramento River at Veterans Bridge	Channel catfish	103.9	**76**	3.53	1.49	–
American River at Nimbus Dam	Sacramento sucker	7.7	8	0.201	0.215	3.1
Feather River at Gridley	Sacramento sucker	4.7	15	0.267	0.274	–
Feather River at Gridley	Sacramento sucker	0.9	ND	ND	ND	–
Yuba River at Marysville	Sacramento sucker	4.9	9	ND	ND	–
Yuba River at Marysville	Sacramento sucker	1.3	2	ND	ND	–
Yuba River at Marysville	Rainbow trout	10.5	7	ND	ND	–
Feather River Hatchery	Chinook	8.4	7	0.249	0.374	–
Sacramento River at RM44	Sacramento sucker	41.2	**26**	1.576	0.864	99.3
Sacramento River at RM44 (duplicate)	Sacramento sucker	54.5	**31**	1.882	1.03	106.5
Sacramento River at RM44	Chinook	15.3	17	0.931	0.794	2.9
Sacramento River at RM44 (duplicate)	Chinook	15.1	16	0.932	0.786	2.7
Sacramento River at Colusa	Sacramento sucker	10.3	11	0.26	0.218	–
Sacramento River at Grimes	Channel catfish	41.6	15	1.041	3.74	–
American River at Discovery Park	Sacramento sucker	29.0	**77**	6.26	1.62	51.8
Nimbus Fish Hatchery	Chinook	11.8	11	0.781	0.539	2.8
Sacramento River at Hamilton City	Sacramento sucker	0.7	ND	ND	ND	–
Bear River b/w Feather River and HWY 99	Sacramento sucker	7.9	11	0.416	0.215	–
Bear River b/w Feather River and HWY 99	Redear sunfish	2.39	ND	ND	ND	–
Bear River b/w Feather River and HWY 99	Redear sunfish	4.1	3	ND	0.232	–
	OEHHA 1999 SV	*100*	*20*	*30*	*2*	—
	OEHHA 2006 SV	*560*	*20*	*200*	*16*	*1786*

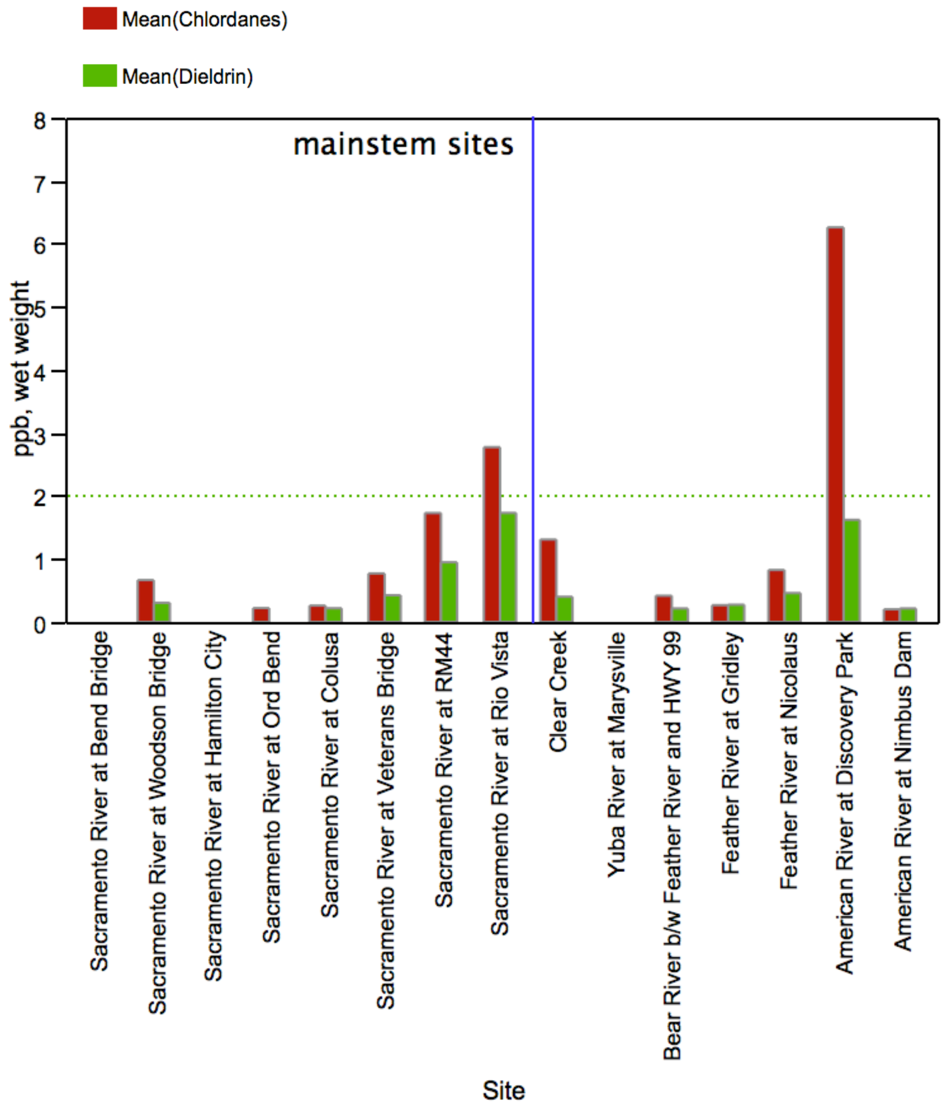
Bold values exceed OEHHA's 2006 Screening Values. "–" indicates sample was not analyzed for PBDEs.

Figure 21. DDTs and PCB Aroclors in Sacramento Suckers



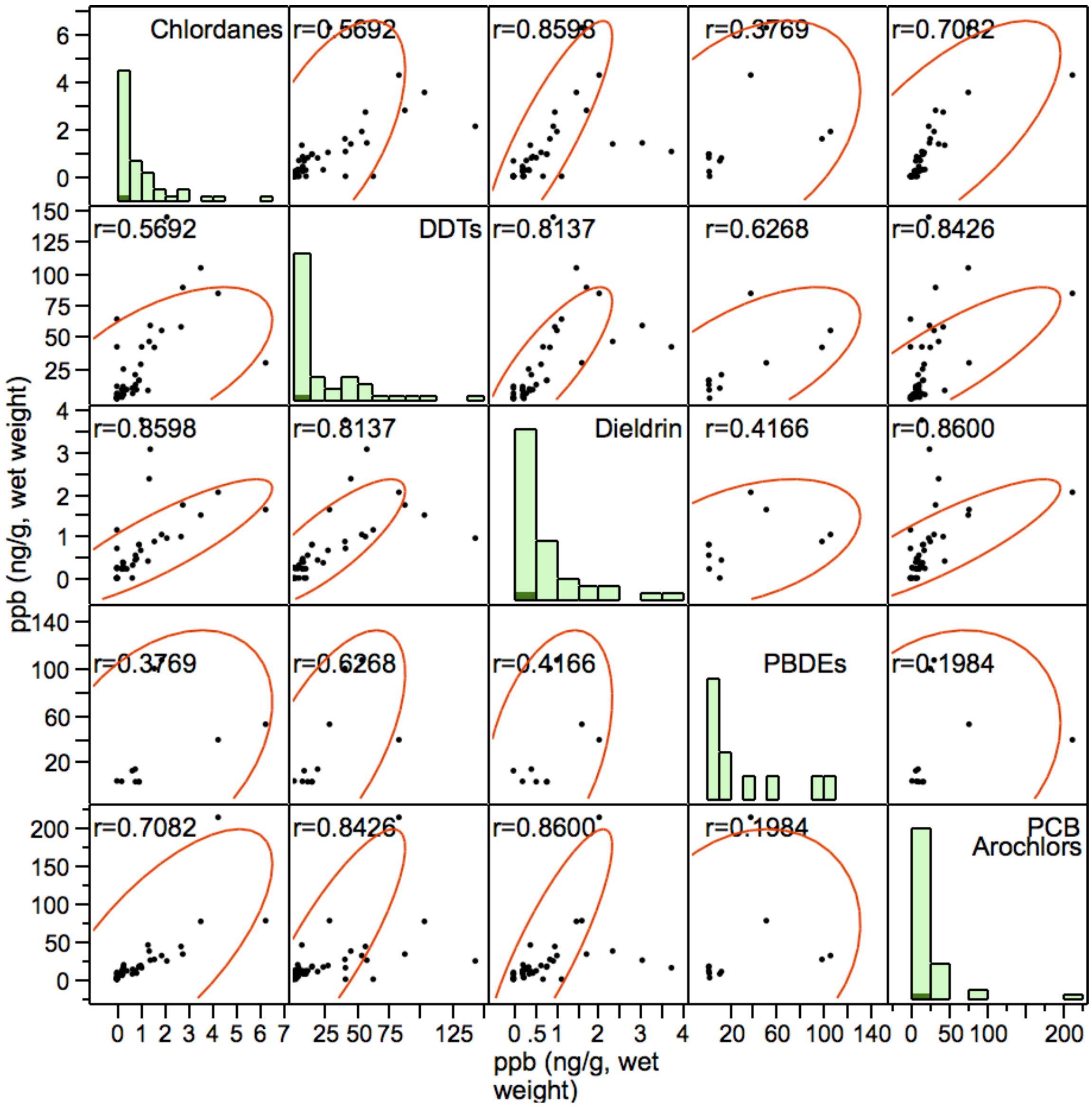
Mainstem sites are arranged upstream to downstream, from left to right. The red dashed line is the OEHHA's 1999 100 ppb screening value for total DDTs in fish tissue. The updated 2006 screening value for DDTs is 560 ppb. The green dotted line is the 20 ppb screening value for PCBs.

Figure 22. Chlordanes and Dieldrin in Sacramento Suckers



Mainstem sites are arranged upstream to downstream, from left to right. OEHHA's 1999 screening value for chlordanes is 30 ppb in fish tissue. The updated 2006 screening value for chlordanes is 200 ppb. The green dotted line is OEHHA's 2 ppb screening value for dieldrin. The updated 2006 screening value for dieldrin is 16 ppb.

Figure 23. Scatterplot Matrix: Trace Organics Analyzed in Fish Tissue



CONCLUSIONS

Conclusions based on the results of SRWP monitoring conducted in 2006-2007 are summarized for parameters relevant to drinking water and recreational uses, toxicity and pesticides, and bioaccumulative pollutants in fish.

Parameters Relevant to Drinking Water, Agriculture, and Recreational Uses

Dissolved and suspended solids, turbidity, nitrogen and phosphorus compounds, organic carbon, and bacteria were measured by the SRWP for their relevance to the evaluation of the attainment of a variety of uses, including drinking water supply, recreation, aesthetics, aquatic habitat, and agricultural supply. The mainstem Sacramento River and major tributaries (the Yuba, Feather, and American rivers) consistently meet water quality goals and objectives for drinking water-related parameters. Based on these indicators, SRWP monitoring results suggest that designated beneficial uses of the Sacramento River and tributaries as sources of municipal and agricultural supply water and recreational uses are generally being achieved within the watershed.

Sacramento River water from Hood and upstream is considered to be of high quality for drinking water and agricultural uses. However, the quality of water in the Central and Southern Sacramento–San Joaquin Delta is often marginal for drinking water supply and compliance with increasingly stringent drinking water objectives is becoming more difficult. The Sacramento River alone provides up to 75% of the water entering the Delta, including a large portion of seasonal organic carbon and TDS mass loads. Although the Sacramento River has a substantial effect on the quality of Delta drinking water supply sources, there are also significant internal sources of TOC and TDS within the Delta and from the San Joaquin River. Current regulations may not adequately protect sources of drinking water for several of the parameters of primary concern for drinking water quality, such as TDS, nutrients, TOC, and pathogens. For example, drinking water utilities are regulated on the amount of TOC and pathogens (i.e., *Cryptosporidium* oocysts) present in their source waters, but there are no ambient water quality objectives for TOC or pathogens. As a result, monitoring for these constituents in discharges is not routinely required and limits are not included in permits. Expected changes in Sacramento River watershed land uses (e.g. increased urbanization and development) have the potential to increase regulated point source discharges and (relatively) unregulated non-point source discharges, and therefore to increase loads of TOC, TDS, and pathogens to the Delta. In order to address these and other drinking water concerns, the CVRWQCB is implementing a work plan for the development of an effective drinking water policy. This policy is expected to address these parameters and eventually to establish water quality objectives for inclusion in a revised Basin Plan.

There was a general trend for concentrations of several parameters (TDS, organic carbon, nutrients) to increase in the mainstem Sacramento River from the upper watershed to the lower watershed. This trend can be attributed to a combination of natural and anthropogenic sources, and is moderated by high quality Sierra tributary inflows. It generally follows a similar trend in land uses of increasing urban development and agricultural uses, and decreasing open space as water moves from the upper to the lower watershed. The highest concentrations of most parameters of concern for drinking water were generally observed in agricultural drains (Sacramento Slough and Colusa Basin Drain). These findings were consistent with results of SRWP monitoring conducted prior to 2006. However, the urban drainage monitored in 2006-2007 (Churn Creek) was not elevated for most of these drinking water related parameters, and did not fit the pattern observed for urban drainages and creeks monitored prior to 2006 (Natomas East Main Drain, Arcade Creek) which were elevated for most parameters.

Salinity and Dissolved Solids

Salinity is a regional issue that affects the entire Central Valley and Sacramento-San Joaquin Delta. The Central Valley Water Board and State Water Board have initiated a comprehensive effort to address salinity problems in California’s Central Valley and adopt long-term solutions that are intended to lead to enhanced water quality and economic sustainability. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is an effort by these agencies and other stakeholders to develop and implement a comprehensive salinity management program. The CV-SALTS program is a multi-year effort anticipated to continue through 2012.

The major sources of dissolved solids (TDS) in Central Valley waters have already been categorically identified, and include urban and rural water users, industrial users, surface water and groundwater sources, natural geological sources, and agricultural users. The primary source of TDS is dissolution of naturally-occurring minerals from the landscape, although TDS is directly affected by consumptive uses of water, which don’t add salts but remove water (such as agricultural irrigation and municipal drinking water uses). Agricultural contributions include direct importation from surface or groundwater supplies, evapoconcentration of supply water, addition of salts by dissolution of naturally occurring salts in soils, and intentional addition of salts as fertilizers or soil conditioners. TDS is also increased by direct intentional addition of salts from residential use of water softeners. Currently urban development is increasing and agricultural land uses in the watershed are stable or declining slightly, leading to concerns about increasing dissolved solids in water. Although these projected increases are not of direct concern for drinking water uses in most of the Sacramento River watershed, they are expected to affect many more water users outside of the watershed by reducing the ability to adequately dilute lower quality sources of water for drinking and irrigation.

Nitrogen and Phosphorus (Nutrients)

Nitrogen and phosphorus compounds have both natural and anthropogenic sources, including fertilizers, animal wastes and applied manure, septic tanks, municipal sewage treatment systems, and decaying plant matter. Nitrate appears to meet USEPA and CDHS MCLs at all locations monitored in the Sacramento River watershed. Other nitrogen and phosphorus compounds monitored (total Kjeldahl nitrogen, total phosphorus, and dissolved orthophosphate) currently have no relevant regulatory thresholds for comparison. There are currently no scientifically credible criteria for nutrients based on thresholds for protection of aquatic life beneficial uses or prevention of excessive algae growth in streams, so review of nutrient compounds is essentially a qualitative and relative evaluation. The results of SRWP monitoring indicate that nutrient concentrations are not impairing beneficial uses within the watershed. However, concerns remain that nutrients in Sacramento River waters may contribute to excessive and nuisance algae growth in the Delta and in the drinking water supply system outside of the watershed.

Organic Carbon in Water

The organic content of water (measured as total and dissolved organic carbon, or TOC and DOC) is a parameter important to drinking water suppliers. A high concentration of organic compounds in source waters contributes to the production of disinfection by-products (trihalomethanes and halo-acetic acids) as a result of conventional water treatment. Some of these by-products are carcinogenic and pose human health problems at relatively low concentrations. Additionally, the Stage 1 Disinfectants and Disinfection By-Product Rule (effective January 2002) requires drinking water systems serving at least 10,000 people to meet specified TOC removals dependant on source water TOC concentrations. For these reasons, baseline data on typical organic carbon concentrations and seasonal variability of those concentrations in the Sacramento River system are important to the assessment of drinking water uses. Some organic compounds commonly found in wastewaters and natural surface waters (lignin, humic and fulvic acids, and some aromatic compounds) strongly absorb ultraviolet radiation. Strong correlations have been demonstrated with organic carbon and precursors of trihalomethanes and other disinfection by-products (APHA *et al*. 1998). Ultraviolet absorbance at 254 nm is considered to be a useful surrogate indicator for the ability of organic compounds to form these disinfection by-products.

Total organic carbon concentrations measured in the lower mainstem Sacramento River below Colusa often exceed the Stage 1 Disinfectant/Disinfection By-Product (D/DBP) Rule treatment threshold of 2 mg/l. The 2 mg/L threshold is significant because exceedance of this threshold may require utilities to remove up to 35% of TOC in their source water, if other treatment benchmarks are not met. Treatment technologies currently in use by many utilities are already able to remove ≥35% of source water TOC from Sacramento River water. If additional TOC removal is necessary, this requirement would not limit the water supply use but could incur additional costs for water providers and ultimately for water users. Specific UV Absorbance (SUVA) data indicate that average SUVA in surface waters of the Sacramento River watershed is generally also greater than D/DBP alternative criterion (2.0 L/mg-m) and would not provide relief from additional treatment requirements.

Pathogen Indicators

Pathogens are disease-producing organisms (protozoa, bacteria, and viruses) that adversely affect the quality of drinking water and/or may pose human health risks for water contact recreation. In addition to viruses and other pathogenic organisms, two pathogens of particular concern to providers and consumers of dinking water are *Giardia lamblia* and *Cryptosporidium parvum.* The USEPA recommends monitoring *E. coli* and *Enterococci* as the preferred indicators of pathogen organisms. SRWP has monitored total and fecal coliforms in previous years, and focused only on *E. coli* in 2006-2007. *E. coli* are a normal component of the intestinal fauna of all warm-blooded animals and consequently are very general indicators of fecal contamination. Sources of *E. coli* contamination in the watershed include (but are not limited to) waterfowl (ducks and geese), a variety of mammalian wildlife, companion animals (dogs and cats primarily), cattle and dairy operations and agricultural manure applications, and human sources, primarily via septic systems and treated wastewater. This variety of sources also presents a range of risks, in that not all sources of fecal contamination carry the same risks of human illness (e.g., there are relatively lower risks to humans from exposure to pathogens carried by water fowl than by other humans).

For the purpose of evaluating achievement and potential impairment of contact recreational uses, *E. coli* data were compared to adopted Basin Plan objectives of 126 MPN/100 mL (implemented as a 5-sample 30-day geometric mean) and 235 MPN/100 mL as a single sample maximum. The single sample Basin Plan limit for *E. coli* was exceeded occasionally at most locations monitored (except at upper mainstem sites above Veterans Bridge) and more frequently at lower mainstem sites, tributary sites, and agricultural drain sites. The highest concentrations of bacteria were observed at the sites with the greatest urban land use percentages: the lower Sacramento River sites, the lower American River sites, and in Churn Creek. The single-sample objective was exceeded most frequently in Churn Creek (about 33%), but median bacteria concentrations for 2006-2007 did not exceed the 126 MPN/100 mL objective at any site. *E. coli* exceeded the Basin Plan objectives more frequently in wet season (~32% of samples), and rarely exceeded the objectives in dry season (7% of samples). This was true for most sites, except the agricultural drainage sites, which did not exhibit higher concentrations of bacteria during the drier than normal 2006-2007 wet season.

Toxicity and Pesticides

Ambient samples of water and sediment were tested in the laboratory for toxicity to provide an indication of the conditions that exist in the natural environment. Toxicity is deemed to occur when test species are significantly adversely affected by exposure to toxicants in ambient water or sediment as compared to laboratory controls. For SRWP monitoring, the results of toxicity testing are also used to trigger further investigations to determine the cause of observed toxicity. These toxicity identification evaluations (TIEs) include the consideration of a number of factors, including contributing watershed characteristics, chemical characteristics of the water, biology, and additional toxicity testing wherein classes of toxicants are selectively removed or rendered non-toxic. Results from these weight-of-evidence investigations can be useful in identifying potential water quality problems in the watershed.

Low concentrations of pesticides in water can affect the growth, reproduction and/or survival of sensitive aquatic species. The SRWP monitored a wide variety of insecticides and herbicides, including the most widely used pesticides and those of particular concern, such as diazinon, chlorpyrifos and the most widely used pyrethroids. These classes of pesticides have been identified as being of potential concern to aquatic life in the Sacramento River system and are responsible for the presence of several Sacramento River watershed water bodies on the 303(d) list of impaired water bodies. SRWP data were used to quantify ambient concentrations of pesticides in surface waters of the Sacramento River watershed and to assess whether these concentrations are potentially adversely affecting uses. It should be noted that not all pesticides of potential concern to aquatic life and human health have been monitored by the SRWP (or other programs).

The results of the 2006-2007 monitoring and previous SRWP aquatic toxicity monitoring efforts have confirmed that significant toxicity to test organisms continues to occur sporadically in surface waters throughout the watershed, and throughout the monitoring period. *Ceriodaphnia dubia* toxicity attributable to organophosphate pesticides in agricultural runoff and urban runoff has previously been definitively shown by SRWP monitoring and other studies. This appears to have declined substantially in recent years due to changes in practices and decreases in the applications of the most commonly used organophosphorus pesticides – there were no cases of toxicity attributed to diazinon or chlorpyrifos in the 2006-2007 monitoring period. There were no substantial differences in the frequency of toxicity observed at the different types of sites (mainstem, tributary, agricultural drainage, and urban creeks).

Monitoring conducted from 1998–2007 has been valuable in evaluating the overall frequency and distribution of observed water column toxicity, and for identifying and confirming the causes of some of the observed toxicity. SRWP monitoring has been successfully conducted over a wide range of environmental conditions and events. However, spatial coverage of the watershed by SRWP (and other programs) is far from comprehensive, and significant questions remain regarding the sources, severity, persistence, and ecological significance of periodic toxicity in surface waters of the Sacramento River watershed. Definitively addressing these questions will require monitoring and studies of different scope (and greater cost) than the recent efforts by SRWP and other programs.

Toxicity tests with *Selenastrum* indicated that ambient toxicity to algae was infrequent, with most samples exhibiting a significant increase in growth compared to the control. Because of the infrequently observed toxicity, there was no consistent spatial or temporal trend observed in algal toxicity. However, there was a suggestion of increasing growth response in the mainstem Sacramento River that was consistent with increasing percentages of the agricultural and urban development land uses that contribute nutrients to the river. Toxicity that was observed was not attributable to any individually detected pesticides or other toxicants, or to any known synergistic or additive effects.

The frequency and magnitude of toxicity to *Ceriodaphnia dubia* was markedly greater than was observed for algae – approximately 10% of the samples exhibited significant reductions in *Ceriodaphnia* survival, with an additional 13% of the samples exhibiting a significant reduction in reproduction. Nearly every sample that caused a significant reduction in survival resulted in ≤50% survival, and most of those caused complete mortality of the test organisms.

There was no consistent spatial trend in the *Ceriodaphnia* responses, and there were no discernible trends in toxicity for different types of water body. This differs somewhat from past SRWP findings that observed more frequent toxicity in the urban creek sites monitored in previous years. There was a seasonal trend in *Ceriodaphnia* toxicity, with significantly higher percentage of toxic samples observed in wet season samples than in dry season. This result is consistent with previous SRWP reports and many other studies that indicate that stormwater runoff is a frequent source of toxicity in many aquatic systems.

In the 20 TIEs performed with *Ceriodaphnia*, the most common result was a lack of persistence of the toxicity, a significant decrease in toxicity, or a delay in onset of toxicity. Based on the elapsed time between initial sample collection and testing and TIE initiation, significant loss or degradation of toxicity was observed in samples tested within three days after sampling and in samples tested as long as eight days after sampling. In the 11 samples with persistent toxicity, metabolically activated organic substances were most frequently indicated as the cause of toxicity.

The lack of persistent toxicity in many of the samples, coupled with the delayed onset and decreased magnitude of toxicity for many samples, indicates that persistent toxicants (e.g., metals) were not likely to have caused the observed toxicity in most of the samples. Because pesticides have a history of causing toxicity in the Sacramento River watershed, the analytical results for the toxic samples were also evaluated to determine if there were any contaminants that could have been responsible for the observed toxicity. The consistent result of this evaluation was that monitored pesticides were not detected or were well below concentrations toxic to *Ceriodaphnia* in toxic samples. In no cases were pesticides detected at concentrations that would explain the observed toxicity to *Ceriodaphnia*.

Approximately 7% of the samples exhibited significant reductions in larval fathead minnow survival, with an additional 9% of the samples exhibiting a significant reduction in growth.

There was a suggestion of a spatial trend in the fathead minnow responses in mainstem Sacramento River, with more frequent mortality and lower growth in the two farthest upstream sites. There were no other discernible trends in toxicity for different types of water body. As with the *Ceriodaphnia*, there was a significant seasonal trend, with 44% samples collected during the wet season months causing toxicity and only 13% causing toxicity in the dry season months of the study period.

Six TIEs were performed with fathead minnows. Toxicity was persistent for five of these samples and one could not be interpreted due to interferences from ‘pathogen-related mortality’ in the ambient water samples. Toxicity was delayed or decreased in four of these five samples, consistent with contaminants that were degrading or becoming less bioavailable over time. Of these 5 samples with persistent toxicity, the patterns in TIE results were similar to *Ceriodaphnia*, with metabolically-activated organic substances being indicated most frequently. As was found with the *Ceriodaphnia* results, there were no combinations or individual pesticides or other toxicants detected in the samples that were consistent with the TIE results, and the specific probable responsible toxicant(s) were not identified.

Overall, pesticides were detected infrequently. They rarely exceeded or approached water quality objectives or concentrations known to be toxic to sensitive species, and were not definitively associated with toxicity in any sample collected by SRWP in 2006-2007.

The results of the 2006-2007 monitoring and previous SRWP aquatic toxicity monitoring efforts have confirmed that significant toxicity to test organisms continues to occur sporadically in surface waters throughout the watershed, and throughout the monitoring period. *Ceriodaphnia* toxicity attributable to organophosphorus pesticides in agricultural runoff and urban runoff has previously been demonstrated by SRWP monitoring and other studies. This appears to have declined in recent years due to changes in practices and decreases in the applications of the most commonly used organophosphate pesticides – there were no cases of toxicity attributed to diazinon or chlorpyrifos in the 2006-2007 monitoring period, and relatively few detections of these pesticides. There were no substantial differences in the frequency of toxicity observed at the different types of sites (mainstem, tributary, agricultural drainage, and urban).

Monitoring conducted from 1998–2007 has been valuable in evaluating the overall frequency and distribution of observed water column toxicity, and for identifying and confirming the causes of some of the observed toxicity. SRWP monitoring has been successfully conducted over a wide range of environmental conditions and events. However, spatial coverage of the watershed by SRWP (and other programs) is far from comprehensive, and significant questions remain regarding the sources, severity, persistence, and ecological significance of periodic toxicity in surface waters of the Sacramento River watershed. Definitively addressing these questions will require monitoring and studies of different scope (and greater cost), and broader regional coordination than recent efforts by SRWP and other programs.

Bioaccumulative Pollutants

Mercury and certain organic contaminants (including legacy organochlorine pesticides, PCBs, and PBDEs) are readily accumulated directly from water or through the food web from low levels in water, resulting in concentrations in fish tissue which may be of concern to humans and wildlife. Monitoring levels of these pollutants in fish provides an effective way to assess potential human health hazards due to contamination of the Sacramento River system. Because fish accumulate contaminants throughout their life span and their habitat, measurements of contaminant concentrations in fish tissue provide an indication of average conditions over space and time. Fish tissue data can be useful in the determination of long term levels and trends of bioaccumulative contaminants (such as mercury, DDT and PCBs) in the watershed. This long-term data set can be used to measure the effectiveness of activities to control these pollutants. Mercury was also measured in water, primarily to supplement existing data, and planned and ongoing monitoring efforts.

The results of the analyses of organochlorine pesticides and PCBs in fish tissue were similar to those from past SRWP monitoring years. However, some of the conclusions based on these results have changed, primarily due to updates of OEHHA's fish tissue screening values. Although the risks from consuming fish contaminated with these organic compounds appears lower than was concluded in previous SRWP reports, there are still potentially significant risks, particularly from PCBs.

Based on comparisons to screening values for organochlorine pesticides and PCBs in fish tissue, consumers who eat a variety of fish from different locations appear to be at relatively low risk from these compounds in fish tissue. However, potential risks increase for people selectively consuming a limited number of higher trophic level species (e.g. white catfish, largemouth bass, striped bass), and for individuals consuming more fish than the 90 g/day on which OEHHA's 2006 screening values were based (about 12 half-pound servings per month).

Trace organic concentrations were consistently lower in lower trophic level species and an anadromous non-resident migratory species (Chinook salmon) compared to carp, suckers, and catfish. This highlights the value of OEHHA's guidance to reduce risks by consuming a variety of species and including species lower on the food chain.

None of the composite fish samples exceeded OEHHA screening values for "Group-A" organochlorine pesticides (aldrin, chlordanes, endrin, heptachlor, PBDEs, endosulfan, and toxaphene). In previous SRWP monitoring, dieldrin and DDT were found to exceed the 1999 screening values at many locations. No fish were found to exceed the updated 2006 screening values for dieldrin and DDT. There appears to be little risk to human consumers from contamination of fish tissue with these pesticides. These results also continue to support SRWP's previous recommendations to consider "delisting" the lower Feather River for impairment due to Group A pesticides.

PBDEs were detected in all samples tested, but did not approach an estimated screening value of 1786 ppb calculated using USEPA and OEHHA methodology with similar consumption assumptions and the IRIS reference dose of 2 ug/kg-d for Pentabromodiphenyl ether. Based on these results, there also appears to be little risk to human consumers from contamination of fish tissue with these common flame retardants.

The results and risks associated with PCBs were little changed from previous evaluations by SRWP. PCBs exceeded the OEHHA 2006 screening value (20 ppb) in 11 out of 40 composite samples in a variety of species from eight different sites. Screening values were exceeded in fish from the lower Sacramento River (Veterans Bridge to Rio Vista), the lower American River, Sacramento Slough, and in one composite from Clear Creek. The highest PCB concentration (213 ppb) was observed in a catfish composite from Sacramento River at Colusa. This overall rate of exceedance of the PCB screening value (39%) was essentially the same as observed in previous SRWP monitoring conducted prior to 2005 (38%).

RECOMMENDATIONS FOR FUTURE SRWP MONITORING

Monitoring in the Sacramento River watershed should be continued, expanded, and integrated with other regional monitoring efforts. SRWP has recently launched an effort to develop a long-term, sustainable regional monitoring program for the watershed. A number of ecological and regulatory factors drive a continued need for expanded and integrated regional monitoring in the watershed, including the Pelagic Organism Decline (POD) in the Delta, Central Valley Drinking Water Quality Policy development, sediment quality objectives, 303(d) listings of impaired waters and a number of ongoing and upcoming TMDLs, expanding NPDES permit ambient monitoring requirements, and the Irrigated Lands Regulatory Program (ILRP). Implementation of the State Water Board's Strategic Plan and POD Resolution are recent regulatory responses to these issues and recognition of the need for additional and more focused monitoring. It is anticipated that a major portion of the funding for the program envisioned by the SRWP will come from the program's many stakeholders. This regional program will be consistent with the SRWP's existing goals and objectives, but could be expanded to establish baseline conditions for sediment quality, biodiversity and ecological health. Additional focus will be placed on understanding pollutant fate and transport, linking water quality to beneficial uses and sources to impairment, evaluating emerging contaminants, and evaluating longer term trends in conditions.

Additional specific changes in future monitoring strategies for the Sacramento River watershed are recommended for consideration below.

Conventional Parameters and Microbiological Monitoring

The causes and spatial patterns of salinity and dissolved solids in the watershed are fairly well characterized and understood. Future SRWP monitoring for associated parameters should be focused on better characterization of long-term tracking of temporal trends in the lower watershed. Because of the close relationship between different parameters that characterize “salinity”, long and short-term variation can be efficiently evaluated using inexpensive surrogate measurements, e.g., conductivity.

Nutrient monitoring should be re-evaluated to determine whether the analyses can be more closely linked to the effects of concern. These effects include potential stimulation of excessive algaal growth in the Delta, stimulation of nuisance algae associated with undesirable tastes and odors in water delivery systems, and whether current concentrations and ratios of nitrogen and phosphorus compounds currently support desirable levels of production in the Delta.

Additional investigation of the sources of *E. coli* in the Sacramento River and its tributaries should be undertaken to better characterize the risk to human health associated with these indicator organisms. This recommendation is based on the fact that the use of bacteria as indicators is closely tied to the assumption that the bacteria are of human origin, and there are many other sources of coliform bacteria in the watershed. The Central Valley Water Board and the ILRP are in the process of developing studies to pursue this goal in agricultural waters and smaller tributaries. These efforts to identify sources of pathogens and indicator organisms should be extended and validated in the Sacramento River and major tributaries.

Pesticides and Toxicity

An important component of any monitoring program is to incorporate adaptive management strategies into the monitoring design. The SRWP has, through the Monitoring Committee, adapted the monitoring program to reflect changes in land use activities and pesticide applications since its inception. Clearly, toxicity is still occurring in the Sacramento River watershed, and monitoring should continue to determine the cause(s). However, monitoring results for 2006-2007 indicate that toxicity and analytical monitoring strategies need to be modified to address an emerging trend for the lack of persistent toxicity that is occurring for the SRWP and other monitoring programs (e.g., ILRP monitoring). In addition to continuing to monitor for toxicity to *Selenastrum*, *Ceriodaphnia*, and fathead minnows, the following options should be considered during the development of future monitoring efforts:

- Sample collection during storm events should be targeted to result in sample collection during a rising hydrograph (i.e., during storm events) whenever possible so as to increase the likelihood that any runoff-related toxicity is captured;
- Require immediate extraction of all pesticide samples at the analytical labs to reduce the time available for sample degradation and to better synchronize the pesticide analysis timing with that of the initiation of the toxicity testing (i.e., 36 hr holding time limit);
- Encourage additional development of analytical methods that provide detection limits at environmentally relevant concentrations, and faster development of chemical analyses for newer pesticides.
- Complete a comprehensive pesticide use study from ~2002 to the present to determine which pesticides, if any, are experiencing increased use and if such pesticides have relatively short half lives. Expand the organic analysis list for the monitoring program to include compounds of interest;
- Immediate treatment of an aliquot of the samples using C8-SPE columns. If toxicity of the sample is observed, then the TIE could include testing and chemical analysis of the C8-SPE column eluate. If budgets permit, side-by-side testing of the C8-treated sample with the initial test of the untreated sample is also possible.
- Perform Phase II TIEs on samples that are determined to be toxic.
- Additional investigation of different pesticide and non-pesticide potential causes of the sporadic and apparently widespread toxicity that continues to be observed in the Sacramento River watershed should be undertaken. Because the toxicity data suggests that a rapidly degrading compound (or compounds) is causing much of the observed toxicity, an initial option should be considered to perform library searches on the existing EPA 625 analytical results to identify specific pesticides of interest, but also to identify unknown peaks and degradation products that may be more toxic than the parent compounds.
- Current pesticide use information should be reviewed for changes in pesticide use, particularly for increases in newer and unmonitored pesticides.
- Modify pesticide monitoring to evaluate widely used and previously unmonitored higher risk pesticides. Eliminate or reduce analysis of less frequently used and low-risk pesticides, and for pesticides that are never or rarely detected in ambient waters. Additional evaluation of data from the ILRP is recommended to refine the list of pesticides that pose significant risks in the Sacramento River watershed.
- The success in reducing the region-wide toxicity problems associated with diazinon and chlorpyrifos indicates that a reduced emphasis on these pesticides is warranted.

Bioaccumulative Pollutants in Fish Tissue

The results for mercury and PCBs in fish tissue clearly indicate that these pollutants will continue to be a human health risk in the watershed for the foreseeable future. The CALFED FMP in collaboration with OEHHA will produce consumption guidance with the goal of minimizing this risk. However, the results indicate that long term monitoring for trends in fish tissue should be continued. Because the expectation is that improvements will be slow, a long-term approach in monitoring seems warranted. In areas of known risks, future monitoring should be focused on benchmark species that will allow efficient tracking of changes in mercury and PCBs in fish. Where risks are not adequately defined, the methods of the FMP appear to be a robust means of characterizing these risks, as well as investigating the underlying causes and factors contributing to bioaccumulation of excessive mercury and PCBs.

REFERENCES

Amweg EL, Weston DP, Ureda NM (2005). Use and toxicity of pyrethroid pesticides in the Central Valley, California. Environmental Toxicology and Chemistry, 24:966-972 (erratum in Vol. 24, number 5).

Anderson BS, de Vlaming V, Larsen K, Deanovic, Birosik S, Smith DJ, Hunt JW, Phillips BM, Tjeerdema RS (2006) Evidence of pesticide impacts in the Santa Maria watershed, California, USA. Environmental Toxicology and Chemistry. 25(4): 1160-1170.

Anderson BS, Phillips BM, Hunt JW, Worcester K, Adams M, Kapellas N, Tjeerdema RS (2002) Ambient toxicity due to chlorpyrifos and diazinon in a central California coastal watershed. Environmental Monitoring and Assessment. 78: 131-151.

APHA, AQQA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition. American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). Wash. DC.

Bailey H, C DiGiorgio, K Kroll, J Miller, D Hinton, and G Starrett. 1996. Development of procedures for identifying pesticide toxicity in ambient waters: Carbofuran, diazinon, and chlorpyrifos. *Environmental Toxicology and Chemistry* 15: 837-845.

Connor V, Foe C (1993) Sacramento River Basin Biotoxicity Survey Results: 1988-1990. Staff Report. California Regional Water Quality Control Board. Central Valley Region. Sacramento, CA.

CVRWQCB 1995. The Water Quality Control Plan (Basin Plan) for the Central Valley Region, 4th Edition. California Regional Water Quality Control Board – Central Valley Region (CVRWQCB). Sacramento, California.

CVRWQCB 2002. Amendment To The Water Quality Control Plan For The Sacramento River And San Joaquin River Basins For Bacteria. Staff Report And Functional Equivalent Document, *Draft, May 2002*. California Regional Water Quality Control Board – Central Valley Region (CVRWQCB). Sacramento, California.

CVRWQCB 2003. 2002 CWA Section 303(D) List Of Water Quality Limited Segments (*July 2003*). California Regional Water Quality Control Board – Central Valley Region (CVRWQCB). Sacramento, California.

CVRWQCB 2007. The Water Quality Control Plan (Basin Plan) for the Central Valley Region, 4th Edition. California Regional Water Quality Control Board – Central Valley Region (CVRWQCB). Sacramento, California.

de Vlaming VV, Connor V, DiGiorgio C, Bailey HC, Deanovic LA, Hinton DE (2000) Application of whole effluent toxicity test procedures to ambient water quality assessment. Environmental Toxicology and Chemistry, 19: 953-964.

Domagalski J, P Dileanis, D Knifong, C Munday, J May, B Dawson, J Shelton, and C Alpers. 2000. Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998. U.S. Geological Survey Open-File Report 00-391. United States Geological Survey, Sacramento, California.

Domagalski JL (2000) Pesticides in surface water measured at selected sites in the Sacramento River Basin, California, 1996-1998. U.S. Geological Survey Water Resources Investigation Report 00-4203.

Domagalski JL, Knifong DL, Dileanis PD, Brown LR, May JT, Connor V, Alpers CN (2000) Water Quality in the Sacramento River Basin, California, 1994-1998. U.S. Geological Survey.

Foe C, Connor V (1991) Rice Season Toxicity Monitoring Results. Staff Report. California Regional Water Quality Control Board. Central Valley Region. Sacramento, CA.

Geis, S., K Fleming, A Mager, L Reynolds. 2003. Modifications to the fathead minnow (Pimephales promelas) chronic test method to remove mortality due to pathogenic organisms. Environmental Toxicology and Chemistry, Vol. 22: 2400-2404.

Hall LH (2003) Analysis of diazinon monitoring data from the Sacramento and Feather River watersheds: 1991-2001. Environmental Monitoring and Assessment. 86: 233-253.

Hann P, Davis G, Karkoski J (2007) Basin Plan Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Diazinon and Chlorpyrifos Runoff Into the Sacramento and Feather Rivers. May 2007 Final Staff Report. Central Valley Regional Water Quality Control Board, Sacramento, CA.

Hunt JW, B.S. Anderson, B.M. Phillips, P.N. Nicely, R.S. Tjeerdema, H.M. Puckett, M. Stephenson, K. Worcester, and V. de Vlaming. 2002. Ambient toxicity due to chlorpyrifos and diazinon in a central California coastal watershed. Environmental Monitoring and Assessment. 82: 83-112.

Karkoski J, Davis G, Dyke J, McClure D, Menconi M (2003) Basin Plan Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Orchard Pesticide Runoff and Diazinon Runoff Into the Sacramento and Feather Rivers. 2007 Final Staff Report. Central Valley Regional Water Quality Control Board, Sacramento, CA.

Kuivila, K.M. and C.G. Foe. 1995. Concentrations, transport, and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry, 14(7): 1141-1150.

Larsen K, L Deanovic, D Hinton and V Connor. 1998a. Sacramento River Watershed Program Toxicity Monitoring Results: 1996-1997. Staff Report, Central Valley Regional Water Quality Control Board, Sacramento, California.

Larsen K, L Deanovic, D Hinton and V Connor. 1998b. Sacramento River Watershed Program Toxicity Monitoring Results: 1997-1998. Staff Report, Central Valley Regional Water Quality Control Board, Sacramento California.

NCDHHS. 2007. Protocol for Recommending Issuance of a Fish Consumption Advisory Due to Elevated Polybrominated Diphenyl Ethers (PBDEs). Prepared by Dr. Luanne K. Williams, Toxicologist, North Carolina Department of Health and Human Services (NCDHHS).

OEHHA (2006). Development Of Guidance Tissue Levels And Screening Values For Common Contaminants In California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene (DRAFT). Pesticide and Environmental Toxicology Branch, Office of Environmental Health Hazard Assessment (OEHHA), California Environmental Protection Agency. February 2006.

Oros DR, Werner I (2005) Pyrethroid Insecticides: An Analysis of Use Patterns, Distributions, Potential Toxicity and Fate in the Sacramento-San Joaquin Delta and Central Valley. Contribution 415, San Francisco Estuary Institute, Oakland, CA.

SFEI. 2007. The Fish Mercury Project: Monitoring and Reducing Methylmercury Exposure in the Bay-Delta Watershed. SFEI Contribution 531. San Francisco Estuary Institute, Oakland CA.

Sinclair CJ, Boxall ABA (2003) Assessing the ecotoxicity of pesticide transformation products. Environmental Science and Technology 37(20):4617-4625.

SRWP 1998a. Sacramento River Watershed Program Phase 1 Monitoring Plan. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2000. Sacramento River Watershed Program Annual Monitoring Report: 1998-1999. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2001. Sacramento River Watershed Program Annual Monitoring Report: 1999-2000. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2002. Sacramento River Watershed Program Annual Monitoring Report: 2000-2001. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2003. Sacramento River Watershed Program Annual Monitoring Report: 2001-2002. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2004. Sacramento River Watershed Program Annual Monitoring Report: 2002-2003. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2005. Sacramento River Watershed Program Annual Monitoring Report: 2003-2004. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

SRWP 2006. Quality Assurance Project Plan for Monitoring. Prepared for the Sacramento River Watershed Program by Larry Walker Associates (LWA), Davis, California.

SRWP. 2004. Sacramento River Watershed Program Annual Monitoring Report: 2003-2004. Prepared by Larry Walker Associates for the Sacramento River Watershed Program (SRWP).

USEPA 1986. Quality Criteria for Water. EPA 440-5-86-001. U.S. Environmental Protection Agency (USEPA), Office of Water. Washington DC.

USEPA 1987. Clean Water Act (CWA), 33 U.S.C. §§ 1251 *et seq*.

USEPA 1991. Methods for Aquatic Toxicity Identification Evaluations: Phase I Toxicity Characterization Procedures. EPA 600/6-91-003. Office of Research and Development.

USEPA 1992. Toxicity Identification Evaluation: Characterization of Chronically Toxic Effluents, Phase I. EPA 600/6-91-005F. U.S. Environmental Protection Agency (USEPA), Office of Research and Development.

USEPA 1993. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 1, Fish Sampling and Analysis, Second Edition. EPA 823-R-93-002. U.S. Environmental Protection Agency (USEPA), Office of Water, Washington, DC.

USEPA 1993a. Methods for Aquatic Toxicity Identification Evaluations: Phase II Toxicity Identification Procedures for Samples Exhibiting Acute and Chronic Toxicity (EPA 600/R-92-080). U.S. Environmental Protection Agency (USEPA), Office of Research and Development.

USEPA 1993b. Methods for Aquatic Toxicity Identification Evaluations: Phase I and III Toxicity Identification Procedures for Samples Exhibiting Acute and Chronic Toxicity (EPA 600/R-92-081). U.S. Environmental Protection Agency (USEPA), Office of Research and Development.

USEPA 1996. Drinking water Regulations and Health Advisories. EPA-822-B-96-002. U.S. Environmental Protection Agency (USEPA), Office of Water.

USEPA 1998a. National Primary Drinking Water Regulations: Interim Enhanced Surface Water Treatment. Final Rule. 40 CFR Parts 9, 141, and 142 Federal Register. Vol. 63 No. 241. December 16, 1988. Rules and Regulations.

USEPA 2006. National Recommended Water Quality Criteria. EPA 822-Z-99-001. U.S. Environmental Protection Agency (USEPA), Office of Water. Washington, DC.

USEPA 2000. Final California Toxics Rule (CTR), Vol. 65, No. 97, Federal Register, §§31682 *et seq*..

USEPA 2001a. Water Quality Criterion for the Protection of Human Health: Methylmercury (Final). EPA-823-R-01-001. U.S. Environmental Protection Agency, Office of Water, Washington DC.

Weston DP, You J, Lydy MJ (2004) Distribution and toxicity of sediment-associated pesticides in agricultural-dominated water bodies of California's Central Valley. Environmental Science and Technology. 38: 2752-2759.

Weston, D.P., R.W. Holmes, J. You, and M.J. Lydy. 2005. Acute toxicity due to residential use of pyrethroid insecticides. Environmental Science and Technology. 39(24): 9778-9784.

Weston D, J You, M Lydy. 2004. Distribution and Toxicity of Sediment-Associated Pesticides in Agriculture-Dominated Water Bodies of California's Central Valley *Environ. Sci. Technol.* 38(10); 2752-2759

Appendices

The following appendices are provided on the accompanying CD-ROM.

A. SRWP QAPP

B. Maps

- SRWP monitoring sites
- Land uses for individual SRWP monitoring sites
- Individual site maps
- Annual precipitation in the Sacramento River watershed

C. Precipitation and Flow Time Series

D. Quality Assurance Assessments

E. Toxicity Report for the Sacramento River Watershed Program's Proposition 50 Monitoring. Prepared for SRWP for Pacific EcoRisk 2008.

F. Water Quality Data Summary Statistics

G. Water Quality Data Plots

- Time series plots
- Box Plots
- Cumulative Precipitation Plots