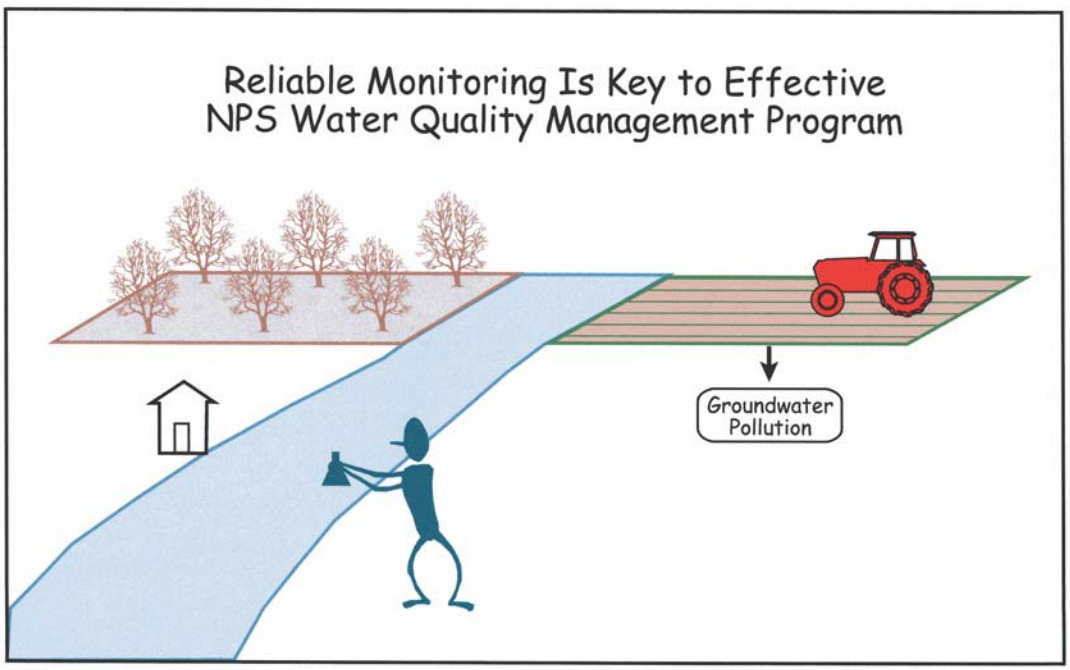
CALIFORNIA WATER INSTITUTE

Report TP 02-07

Issues in Developing a Nonpoint Source Water Quality Monitoring Program for Evaluation of the Water Quality - Beneficial Use Impacts of Stormwater Runoff and Discharges from Irrigated Agriculture in the Central Valley, CA



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State Water Resources Control Board
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Central Valley Regional Water Quality Control Board
Sacramento, California

December 2002

DISCLAIMER

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Disclosure Statement

Funding for this project has been provided in part by the U.S. Environmental Protection Agency (US EPA) pursuant to Assistance Agreement No. C9-989268-99-0 and any amendments thereto, which has been awarded to the State Water Resources Control Board (SWRCB) for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the US EPA or the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

This project was conducted by Drs. G. Fred Lee and Anne Jones-Lee as employees of the California Water Institute, California State University, Fresno. In addition to the support provided to this project by the US EPA, support was provided by the California Water Institute, California State University, Fresno, the Central Valley Regional Water Quality Control Board and G. Fred Lee & Associates, El Macero, California.

Acknowledgment

The authors appreciate the assistance provided by Jerrold Bruns, Rudy Schnagl, Joe Karkoski and Kelly Briggs of the Central Valley Regional Water Quality Control Board, and Stephen Clark and Scott Ogle of Pacific EcoRisk for supplying cost information on chemical and other parameter measurements. We also wish to acknowledge the initial support given this project by Dr. Valerie Connor of the State Water Resources Control Board, formerly of the CVRWQCB, who was responsible for originally initiating the project. The assistance of various scientists and engineers who provided information which served as the basis for this report is greatly appreciated.

California Water Institute
California State University, Fresno

The California Water Institute was started with seed money provided by the Proposition 13 Water Bond Measure, approved by voters in 2000. The Institute is housed at the California State University, Fresno.

The goal of the Institute is to provide a place where agricultural, urban, and environmental interests can be brought together in an unbiased, open, collaborative process to develop a shared vision of how to best utilize our water resources. It is the stated purpose of the Institute to work on collaborative solutions to pressing water issues facing the State. The staff of the Institute includes economists, chemists, crop water usage specialists, resource specialists, and environmental engineers. In addition, faculty at the California State University, Fresno, collaborate with the Institute in important research efforts.

Executive Summary

As part of the Central Valley Regional Water Quality Control Board's (CVRWQCB's) implementation of the State Water Resources Control Board's (SWRCB, 2000, 2001a) Plan for California's Nonpoint Source Pollution Control Program (NPS Program Plan), there is need to develop a nonpoint source water quality monitoring program for the Central Valley of California. Presented herein is guidance on the development of this monitoring program. Particular attention is given to assessing the potential impacts of irrigated agricultural stormwater runoff and irrigation tailwater and subsurface drain water discharges, as they may impact the beneficial uses of Central Valley waterbodies.

In addition to monitoring for the purpose of assessing the impacts of constituents in irrigated agricultural stormwater runoff and tailwater/subsurface drain water discharges on receiving water quality, consideration is given to monitoring the discharges of managed wetlands in the Central Valley. There are substantial acreages of wetlands devoted to federal and state refuges, as well as private duck clubs, that, at times, discharge waters from the areas to the State's waters. These waters can have a significant concentration of potential pollutants that can cause violations of water quality objectives and/or impairment of the beneficial uses of the State's waters.

Further, in connection with the potential renewal of waivers from waste discharge requirements (WDRs) for discharges from irrigated agricultural lands in the Central Valley, there is need to develop a water quality monitoring program to determine whether constituents in irrigated agricultural stormwater runoff, tailwater and subsurface drain water cause violations of water quality objectives and/or impair the beneficial uses of the State's waters. The Central Valley Regional Water Quality Control Board staff has been working with the agricultural community to develop a Phase I water quality monitoring program that will provide information that can be used by the CVRWQCB to determine if WDR waivers for irrigated agriculture in the Central Valley should be renewed. This Phase I monitoring program is recognized to be an initial monitoring program that will need to be expanded to determine if constituents in irrigated agricultural stormwater runoff, tailwater and subsurface drain water impair the beneficial uses of the State's waters.

Scope of Agricultural Waiver Monitoring Program. CVRWQCB Resolution No. 5-01-236, "Control of Discharges from Irrigated Lands," adopted on September 7, 2001, defines that the agricultural waiver monitoring program is to cover the *basin*, *drain* and *field* level runoff/discharge monitoring. A preliminary draft Phase I agricultural waiver monitoring program (see Appendix A) focuses on the *drain* level, where the CVRWQCB staff have developed a "strawman" monitoring program that included 56 sites to be monitored about monthly for toxicity, sediment and constituents on the 303(d) list, including organophosphate pesticides (diazinon/chlorpyrifos), selenium, salt, boron, nutrients, dissolved oxygen, biochemical oxygen demand and temperature. The agricultural community has proposed a revised Phase I agricultural waiver monitoring program that includes 29 sites. At this time (early December 2002) the Phase I monitoring program is still under development.

This report presents guidance on issues that need to be considered in developing a comprehensive agricultural waiver water quality monitoring program to evaluate the water quality impacts of irrigated agricultural stormwater runoff and tailwater/drain water discharges, which includes the components that need to be covered to achieve the requirements of CVRWQCB Resolution No. 5-01-236.

The comprehensive agricultural waiver monitoring program and the nonpoint source water quality monitoring program for agriculturally derived constituents have the same overall objective, with the result that the water quality monitoring program guidance presented herein has applicability to both programs.

The first step in developing a comprehensive nonpoint source water quality monitoring program is to clearly define the objectives of the program. Once the objectives of the monitoring program have been defined, there is need to determine the desired reliability of defining the water quality impacts of irrigated agricultural stormwater runoff and discharges. With information on the variability of irrigated agricultural runoff/discharges from various types of irrigated agricultural settings, it is possible to begin to develop a water quality monitoring program that will achieve the objectives of the program.

Waterbodies of Concern. In the early 1990s, the CVRWQCB (1992) (see Appendix C) developed a list of Central Valley waterbodies that are considered to be dominated by irrigated agricultural runoff/discharges. The 1992 CVRWQCB-listed waterbodies were categorized into:

- Natural waterbodies dominated by agricultural drainage water
- Natural waterbodies dominated by agricultural supply water
- Constructed facilities designed to carry agricultural flows or drainage
- Constructed facilities designed to carry irrigation water and may, at times, carry recycled return flows
- Natural dry washes that have been altered and now carry agricultural supply water or return flows during time periods

The CVRWQCB September 7, 2001, Resolution defines that the waterbodies of primary concern are those dominated by agricultural drainage and constructed waterbodies used for conveying or holding agricultural drainage.

Monitoring Site Selection. A list of initial NPS water quality monitoring sites has been developed based on the information available from monitoring programs that have been conducted in the Sacramento and San Joaquin River watersheds. The selection of a specific site for monitoring of a waterbody should be based on an understanding of the plumbing and hydrology of the waterbody's watershed upstream of where the monitoring is proposed. As information is gained on the role of agriculturally derived discharges/runoff of potential pollutants to these waterbodies, additional waterbodies will be added to the list of recommended waterbodies for NPS water quality monitoring. As the NPS water quality monitoring program develops, particular reference needs to be given to what, if anything, is representative of the watershed upstream of the monitoring point that would cause this waterbody either to be different from other waterbodies or to be representative of a group of waterbodies with similar irrigated agricultural and other land use activities in the watershed.

A similar approach needs to be followed for all of the agricultural drains and agriculturally dominated waterbodies in the CVRWQCB (1992) report. Each watershed upstream of the sampling point should be characterized based on the agricultural activities conducted within the watershed – i.e., crops produced, chemicals used and other factors that could influence the concentrations of constituents in the stormwater runoff or agricultural irrigation water discharges. The constructed agricultural drains and agriculturally dominated waterbodies should be prioritized with respect to their potential representativeness and importance in impacting the beneficial uses of the waters of the State. This prioritization would be used to determine which waterbodies are monitored based on the funding available.

Organizing a Water Quality Monitoring Program. The development of a comprehensive nonpoint source water quality monitoring program involves consideration of each of the following:

- Clearly establish the objectives of the monitoring program.
- Understand the nature of "water quality," water quality concerns, beneficial uses, and their assessment for the waterbodies of concern.
- Select the parameters to be measured and justify potential significance of each parameter selected.
- Examine previous studies to understand variability in each area of the waterbody to be monitored.
- List factors that can influence results of the monitoring program and how they may influence the results.
- Determine the level of confidence at which the objective is to be achieved.
- For each area of each waterbody to be monitored, determine the number and location of samples to be collected.
- If no data are available from previous studies or if existing data are inadequate to define variability and other characteristics needed to establish a reliable monitoring program, conduct a pilot study of representative areas to define the characteristics of the area that are needed to develop a reliable water quality monitoring program.
- If the purpose of the monitoring program is to determine changes in water quality characteristics, select the magnitude of change that is to be detected and design the monitoring program accordingly.
- Select sampling techniques and methods of analysis to meet the objectives and level of confidence desired.
- Verify that analytical methods are appropriate for each area of the waterbody and at various seasons.
- Conduct studies to evaluate precision of sampling and analytical procedures and technique, reliability of preservation, and variability of the system.
- Critically examine the relationship between present and past studies.
- Determine how the data will be analyzed, with respect to compliance with Basin Plan objectives, using existing data or synthetic data that is expected to be representative of the site.
- Screen/evaluate data as they are collected.

- Analyze, interpret and store data, and report on the results of the analysis and interpretation.

Information on each of these areas is presented in this report.

One of the most important steps in developing a credible monitoring program to assess the impact of constituents derived from a particular source on the beneficial uses of receiving waters is an explicit statement of the objectives of the monitoring program. The agricultural waiver policy and the CVRWQCB and staff have identified a number of objectives that need to be met in developing a water quality monitoring program to evaluate the impact of constituents in irrigated agricultural stormwater runoff, tailwater and subsurface drain water on receiving water beneficial uses. These include violations of Basin Plan water quality objectives (WQOs), which also include California Toxics Rule criteria and the CA Department of Health Services drinking water Maximum Contaminant Levels (MCLs).

Of particular concern, relative to the waiver conditions adopted in 1982, was whether the amount of sediment derived from irrigation return water caused Basin Plan turbidity objectives to be exceeded. Further of concern was whether the discharge contained constituents in sufficient concentrations to be toxic to fish and wildlife. It is anticipated that future reviews of agricultural drainage will contemplate a far wider range of constituents and impacts. In terms of the current understanding of agriculturally derived constituents that are potential threats to the State's waters' beneficial uses, there continues to be concern about agricultural runoff/discharges containing constituents, such as pesticides, which are toxic to humans and/or aquatic and terrestrial life, through excessive bioaccumulation. The legacy pesticides, such as DDT, chlordane, dieldrin and toxaphene, were extensively used in Central Valley agriculture and have been found in agricultural runoff/discharge waters and in edible aquatic life at concentrations which are a threat to human health and/or higher-trophic-level aquatic and terrestrial life through consumption of the aquatic organisms.

In order to reliably monitor stormwater runoff-associated constituents and their potential impacts, it is necessary to base the monitoring program on when the constituents of potential concern are applied to the agricultural areas and during stormwater runoff events or other times when there would be expected transport of the constituent of concern from the areas where it was applied. This event-based, episodic monitoring requires a significantly different approach and resources than the traditional monitoring, involving periodic (i.e., monthly) sampling at a fixed location, such as that proposed by the CVRWQCB staff in their draft Phase I Water Quality Monitoring Program for Discharges from Irrigated Lands (Appendix A).

The appropriate approach to take in developing a reliable monitoring program for runoff/discharges from irrigated lands is to first define the constituents that are potentially present in the runoff/discharges that could occur at sufficient concentrations to impair the beneficial uses of the receiving waters for the runoff. Next it is necessary to gain an understanding of when, where and how various chemicals, or sources of potential pollutants, use/apply/release the constituents of concern. Further, there is need to understand, for each constituent defined as a potential pollutant, how that constituent potentially impacts the beneficial uses of a downstream waterbody. With this information, it will be possible to develop a reliable water quality monitoring program to assess whether irrigated agricultural runoff/ discharges adversely impact the beneficial uses of the State's waters. Without this critical review and implementation of this approach, the water quality monitoring program can be of limited value in reliably achieving the objectives of the nonpoint source water quality monitoring program, as well as the agricultural waiver monitoring program, since it has not been properly designed to meet the objectives of these programs.

Another significant problem with the spring 2002 proposed CVRWQCB irrigated agriculture Phase I water quality monitoring program is that many of the monitoring stations represent agriculturally dominated waterbody discharge points near where the constructed or natural drain/creek discharges to the State's mainstem rivers. This sampling does not provide the upstream information on specific sources or practices that can cause excessive concentrations of the constituents at the monitoring point. It is inappropriate to assume that there are no upstream water quality problems caused by irrigated agricultural runoff/discharges just because monitoring at the drain discharge point did not detect a problem. Since upstream tributaries can be important fish and other aquatic life reproduction/development areas, and since chemicals used in one part of a watershed can cause localized water quality impacts, it is important to evaluate whether waters from other tributaries which may not have the chemical at critical concentrations or at any concentration are diluting the concentrations at the downstream monitoring point sufficiently so that the interpretation of the data at that location leads to an erroneous conclusion that there are no upstream water quality problems due to the use of that chemical in a part of the watershed.

Accounting for Variability. Since the measurements of irrigated agricultural runoff/discharge-derived constituent concentrations at any particular time and location have a certain amount of variability associated with them, a monitoring program should evaluate the magnitude of the variability about any particular measurement, as well as for measurements made of different systems or at different times. This then introduces the need to evaluate the variability for each system monitored, and then establish, as part of the monitoring program goals, the amount and type of monitoring that is needed to achieve a certain prescribed degree of reliability of the measured concentrations of potential pollutants and associated water quality impacts associated with a particular discharge/runoff. Addressing these issues should involve appropriate statistical techniques, where, *a priori*, a degree of reliability in detecting concentrations and water quality impacts is established.

Because of the year-to-year variability in rainfall runoff and agricultural practices, the initial phase of the NPS monitoring program should be conducted for three to five years. Normally this period of time is needed to begin to establish the range of conditions that are encountered in NPS runoff.

Review of Existing Data. Before finalizing a monitoring program, a systematic effort should be made to collect and carefully review all existing data pertaining to the area of the study. The data collected in previous studies, even though inadequate to achieve the objectives of the present study, can still be of significant value to present and future studies in helping to guide the development of future monitoring programs.

List Factors that Can Influence Results of the Study. Water quality characteristics in particular waterbody types tend to behave according to certain fairly well-defined principles of physics, chemistry and biology. While the details of many of the processes that control the concentrations in runoff/discharge waters may not be fully understood, there is considerable knowledge about them and how they influence the manifestation of "water quality," which should be used to develop a more efficient monitoring program. Understanding these processes should allow a better assessment to be made of the significance of changes in concentration and distribution of contaminants between sampling dates, and whether changes in concentrations measured are related to a natural driving force or result from man's activities and hence are potentially controllable. For each sampling point, an estimate should be made of the expected range of concentrations of the parameters being measured and, most importantly, the factors influencing these concentrations. This information should be used to guide the development of the monitoring program, to be certain that it covers the conditions that are likely to be encountered in the monitoring program.

Parameters of Concern. This report presents a discussion of the water quality parameters of potential concern in irrigated agricultural stormwater runoff and tailwater discharges. Reasons for the water quality concern and regulatory limits are discussed. The parameters include pH, color, taste and odors, total suspended solids, turbidity, nitrate, nitrite, ammonia, total Kjeldahl nitrogen, biostimulatory substances, phosphorus, boron, total and fecal coliforms, *E. coli*, dissolved oxygen, biochemical oxygen demand, temperature, organophosphate pesticides, organochlorine pesticides, herbicides, other potentially toxic chemicals, unknown-caused toxicity, sediment toxicity, PCBs, dioxins, furans, total organic carbon, dissolved organic carbon, heavy metals (Cu, Zn, Pb, Cd, Ni, Cr), mercury and selenium.

In addition to evaluating the impact of irrigated agricultural stormwater runoff and tailwater releases on surface water quality, there is also need to evaluate the impact on groundwater quality. This is especially true in light of the fact that there is a potential of causing even greater groundwater quality problems than are occurring now, as a result of trying to minimize surface water quality problems associated with irrigated agriculture's ponding of waters to minimize discharges to surface waters.

In addition to considering the chemicals that are added to/used on irrigated agricultural lands (such as pesticides, fertilizers, soil amendments, etc.), there is also need to consider the chemicals that are released from these lands that are generated on these lands. The monitoring program should include measurements of transformation products of added chemicals, such as nitrate that is formed from the nitrification of ammonia that is added as a fertilizer to the agricultural lands. Total organic carbon (TOC), dissolved organic carbon (DOC), total dissolved solids/electrical conductivity (TDS/EC), total suspended solids (TSS), nitrogen and phosphorus compounds and turbidity should be monitored as part of assessing the potential for constituents generated on or from irrigated agricultural lands to be present at concentrations that could impair the beneficial uses of the receiving waters for runoff/discharges from these lands. Boron, selenium, and other constituents which are present in the soils of the area and are mobilized by agricultural practices so that they occur at potentially significant concentrations in runoff/ discharge waters should be included in the monitoring program. The US EPA standard three-species aquatic life toxicity tests should be conducted to determine if toxicity is present in the runoff/discharge waters from agricultural lands.

There is considerable interest in assessing whether the aquatic organism assemblages in a waterbody potentially impacted by agricultural runoff/discharges are altered by constituents in these discharges. Reliably assessing the impacts of agricultural runoff/discharges on aquatic organism assemblages within the Central Valley is difficult because of a lack of suitable reference sites, where the numbers and types of organisms present at these sites can be compared to those with similar habitat characteristics that are potentially influenced by agricultural runoff/discharges. Considerable work needs to be done learning how to collect and utilize benthic organism assemblage information in Central Valley waterbodies, in order to be able to reliably interpret whether the cause of an apparently altered organism assemblage is due to agricultural discharges or other factors. A component of this situation is whether the sediments in a waterbody are toxic to benthic and epibenthic organisms because of agricultural discharges of constituents that cause sediments to become toxic. While pesticides that tend to strongly sorb on sediments (such as the pyrethroids) are of concern because of their potential to cause sediment toxicity, agricultural discharges of nutrients which develop into algae that die, settle and become part of the sediments can be an important source of sediment toxicity due to the release of ammonia from the decay of organic nitrogen in the algal cells.

Since a number of the parameters of particular concern (such as TSS, TOC and nutrients) in irrigated agricultural discharges/runoff do not have water quality objectives that establish specific numeric limits, there is need for the CVRWQCB to establish an approach for interpretation of the data with respect to exceeding narrative water quality objectives, in order to be able to interpret the results of the NPS water quality monitoring program with respect to assessing impairment of the receiving waters for irrigated agricultural discharges/runoff. This could result in the need for a significantly different monitoring program than the minimum initial NPS monitoring program recommended herein, in order to develop the information needed to interpret narrative water quality objectives with respect to impairment of beneficial uses of the waters.

For example, with respect to nutrients, the current CVRWQCB Basin Plan does not have specific numeric concentrations of nitrogen and phosphorus that are considered excessive with respect to impairing the beneficial uses of a waterbody due to excessive growths of algae and/or other aquatic plants. The Basin Plan has a narrative objective for "biostimulatory substances," which requires a subjective assessment of excessive growths of aquatic plants and/or their impacts on the beneficial uses of a waterbody. Monitoring for nitrogen and phosphorus compounds' concentrations in agricultural drains or agriculturally dominated waterbodies cannot be translated to an impairment of beneficial uses without site-specific studies of the receiving waters' beneficial uses. That approach requires a significantly different type of monitoring program than periodic measurements at a particular location in a waterbody. Similar problems occur with respect to TOC, TSS and other constituents which are often present in irrigated agricultural runoff/discharges.

The recommended initial NPS monitoring program includes sampling near the primary and secondary tributary mouths' discharge points to the Sacramento and San Joaquin Rivers.

The specific location for the initial monitoring is to be selected after a critical review of the factors that can influence monitoring results that are discussed herein. All of the constituents that could be derived from agricultural land, such as those listed above, should be monitored. In addition, all chemicals that are added to agricultural lands and the potential transformation products should be included in the monitoring program. The minimum recommended monitoring program involves monthly sampling of a list of waterbodies that, based on previous studies, have been found or are suspected to be impacted by irrigated agricultural runoff/ discharges. In addition, event-based monitoring is recommended to coincide with or immediately follow situations that could lead to runoff/discharges of potential pollutants from agricultural lands. This monitoring would include monitoring of stormwater runoff events, as well as releases/discharges from agricultural lands that follow the application of chemicals to the areas of concern. Since the loads of potential pollutants are of concern, the monitoring stations should be located where gaging of the stream/tributary flow can occur.

Evaluation of the Significance of a Water Quality Objective Violation. A key component of developing a technically valid, cost-effective water quality management program is an evaluation of the water quality significance of exceedance of a water quality criterion/standard/objective. In accord with the requirements of the Clean Water Act, the US EPA water quality criteria were designed to be protective of aquatic life and other beneficial uses in all waterbodies. It has been understood since the early 1970s by those familiar with how chemical constituents impact aquatic life that criteria designed to be protective of aquatic life and other beneficial uses in all waterbodies – i.e., worst-case-based water quality criteria and standards based on these criteria – would, in many waterbodies, for certain constituents (especially heavy metals, certain organics, etc.), be overprotective. As discussed herein, this issue was addressed by the National Academies of Science and Engineering (NAS/NAE, 1973) in their development of the 1972 Blue Book of Water Quality Criteria. This overprotection could lead to greater expenditures for chemical constituent control from its sources than is necessary to protect the aquatic life or other designated beneficial uses of a waterbody. Guidance is provided herein on evaluating the water quality significance of exceeding a numeric water quality objective and/or a narrative toxicity limit.

Evaluation of Runoff BMP Efficacy. This report provides guidance on some of the issues that need to be considered in developing a water quality monitoring program associated with agricultural runoff best management practice (BMP) evaluation. The importance of obtaining pre-BMP implementation data and conducting an adequate monitoring program to overcome the inherent variability of agricultural stormwater runoff chemical constituent concentrations is discussed.

Cost. Unit cost information for sample analysis and collection is provided. Because of limitations on the funding available for NPS monitoring, there will likely be need to prioritize the monitoring locations, parameters monitored, etc. This prioritization should be done by the stakeholders (agricultural dischargers, regulatory agencies, environmental groups and members of the public) to maximize the amount of useful information obtained for the funds expended.

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Acronyms and Abbreviations

ac	acre
ac-ft	acre-feet
ag	agriculture/agricultural
APHA	American Public Health Association
ASTM	American Society for Testing and Materials
BMPs	best management practices
BOD	biochemical oxygen demand
BOD_5	five-day BOD
BOD_{10}	ten-day BOD
BOD_u	BOD ultimate (~30-Day)
CBOD	carbonaceous BOD
cfs	cubic feet per second
CO_2	carbon dioxide
CVRWQCB	California Regional Water Quality Control Board, Central Valley Region (RWQCB)
CTR	California Toxics Rule
CWA	Clean Water Act
CWI	California Water Institute, California State University, Fresno
DFG	California Department of Fish and Game
DO	dissolved oxygen
DOC	dissolved organic carbon
EC	electrical conductivity
EM	evaluation monitoring
ft	feet
ft/sec	feet per second
g	grams
H_2O	water
ISWP	Inland Surface Waters Plan
lbs/day	pounds per day
MCL	maximum contaminant level
m^2	square meters
mg/L	milligrams per liter
mi	miles
µg/L	micrograms per liter
µmhos/cm	micromhos (reciprocal ohms) per centimeter
MM	management measure
MP	management practice
MPN	most probable number
µS/cm	microsiemens per centimeter
m/sec	meters per second
N	nitrogen
NBOD	nitrogenous BOD
ng/L	nanograms per liter
NH_3	un-ionized ammonia or ammonia, which is the sum of NH_3 plus NH_4^+
nitrate-N	nitrate-nitrogen

Acronyms and Abbreviations (continued)

NOAA	National Oceanic and Atmospheric Administration
NO_2^-	nitrite
NO_3^-	nitrate
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRC	National Research Council
NTU	Nephelometric turbidity units
O_2	oxygen
OCls	organochlorine pesticides and PCBs
OEHHA	Office of Environmental Health Hazard Assessment
OP	organophosphate
OrgN	organic nitrogen
P	phosphorus
PCBs	polychlorinated biphenyls
ppt	parts per thousand (salinity)
ppt	parts per trillion (ng/L) (concentrations of chemicals)
QAPP	quality assurance project plan
RWQCB	Regional Water Quality Control Board, Central Valley Region
SAR	sodium adsorption ratio
SJR	San Joaquin River
SJR TAC	San Joaquin River DO TMDL Technical Advisory Committee
SOD	sediment oxygen demand
SWAMP	surface water ambient monitoring program
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
THM	trihalomethane (chloroform and chloroform-like compounds)
TIE	toxicity identification evaluation
TKN	total Kjeldahl nitrogen = NH_3 plus OrgN
TMDL	total maximum daily load
TOC	total organic carbon
TON	threshold odor number
TSMP	Toxic Substances Monitoring Program
TSS	total suspended solids
TUa	toxic units (acute)
USBR	US Bureau of Reclamation
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
VSS	volatile suspended solids
WDR	waste discharge requirement
WQO	water quality objective
WWTP	wastewater treatment plant (domestic)

ISSUES IN DEVELOPING A NONPOINT SOURCE WATER QUALITY MONITORING PROGRAM FOR EVALUATION OF THE WATER QUALITY - BENEFICIAL USE IMPACTS OF STORMWATER RUNOFF AND DISCHARGES FROM IRRIGATED AGRICULTURE IN THE CENTRAL VALLEY, CA

Organization of Report

This report provides guidance on the recommended approach for developing a nonpoint source water quality monitoring program that will determine the impacts of irrigated agricultural stormwater runoff and irrigation tailwater and subsurface drain water discharges on the beneficial uses of Central Valley waterbodies. The topics discussed in this report are also applicable to the development of an initial and a comprehensive agricultural waiver water quality monitoring program. The initial part of this report provides the background information that is pertinent to establishing an NPS and agricultural waiver monitoring program. This background information is followed by specific recommendations on the initial NPS monitoring program, which delineates suggested monitoring locations and parameters. The remainder of the report is devoted to providing information that serves as the technical basis for the recommended NPS monitoring program.

Background to the Development of a Nonpoint Source Water Quality Monitoring Program for Irrigated Agricultural Runoff/Discharges

The State Water Resources Control Board (SWRCB, 2000) developed a Plan for California's Nonpoint Source Pollution Control Program (NPS Program Plan). This Plan was approved by the National Oceanic and Atmospheric Administration (NOAA) and the US Environmental Protection Agency (US EPA) on July 17, 2000. This NPS Program Plan provides general guidance on the approach that is to be used in California to control the pollution of the State's waters by nonpoint sources of pollutants. Each of the Regional Water Quality Control Boards has the responsibility of developing an implementation approach for this NPS Program Plan that is appropriate for their Region. One of the key components of an implementation approach for the Plan is an assessment of the pollution being caused by nonpoint sources. This assessment will be based on conducting a comprehensive water quality monitoring program that will determine, for various types of nonpoint sources of pollutants (such as irrigated agriculture in the Central Valley), the amounts of pollutants discharged, the impairment of the beneficial uses of the State's waters caused by these pollutants, and the effectiveness of control measures implemented to manage nonpoint source pollution within the Regional Board's jurisdiction.

One of the primary components of the NPS Program is to establish a mechanism to determine the success in achieving short-term and long-term goals. The Plan states that it is necessary to:

- Track implementation of management measures,
- Monitor the program's effectiveness in controlling pollution,
- Assess success in achieving objectives and milestones, and
- Report on program effectiveness.

The Plan mentions the following as specific areas of concern related to agriculture:

- Erosion and Sediment Control,
- Facility Wastewater and Runoff from Confined Animal Facilities,
- Nutrient Management,
- Pesticide Management,
- Grazing Management,
- Irrigation Water Management, and
- Education/Outreach.

The Plan states,

"A comprehensive monitoring strategy for the NPS program will soon be complete. This strategy will be designed to provide objective, quantified answers to broad management questions. These questions are then refined into more discrete monitoring objectives that will shape the design of specific monitoring programs. The monitoring strategy will focus primarily on answering the first two questions posed below while coordinating with other monitoring programs to effectively answer all questions.

"1. Are MPs to reduce polluted runoff being implemented (Tracking or Implementation Monitoring)? Our efforts will focus on tracking MM implementation and determine whether practices are implemented in accordance with relevant standards and specifications.

"2. Are the MPs effective in avoiding or minimizing pollution generation (Effectiveness Monitoring, Compliance Monitoring)? We will develop a monitoring strategy that measures the effectiveness of MPs for agriculture, forestry, urban sources, and marinas.

"3. Is water quality being protected and are narrative and numerical water quality criteria being achieved (Baseline Monitoring, Compliance Monitoring)? We will coordinate with ongoing regional monitoring efforts and point-source compliance monitoring to identify impairments and determine the extent, causes, and sources of impairment.

"4. Is reasonable progress being made toward reducing NPS polluted runoff? We will review tracking and monitoring information through external review committees and TACs and assess the state of the Program."

As part of the Central Valley Regional Water Quality Control Board's implementation of the NPS Program Plan, there is need to develop a nonpoint source water quality monitoring program for the Central Valley of California. The monitoring guidance that is contained within this report is designed to be of assistance to the CVRWQCB in complying with the NPS Plan monitoring requirements, with particular reference to management practice (BMP) evaluation. Presented herein is guidance on issues that should be considered in developing this monitoring program. Particular attention is given to assessing the potential impacts of irrigated agricultural stormwater runoff and irrigation tailwater and subsurface drain water discharges on the beneficial uses of Central Valley waterbodies.

In addition to monitoring for the purpose of assessing the impacts of constituents in irrigated agricultural stormwater runoff and tailwater/subsurface drain water discharges on receiving water quality, consideration is given to monitoring the discharges of managed wetlands in the Central Valley. Managed wetlands are areas where water is added to an area for the purpose of developing aquatic life habitat, focusing on migratory birds. There are substantial acreages of wetlands devoted to federal and state refuges, as well as private duck clubs, that, at times, discharge waters from the wetland areas to the State's waters. These waters can have a significant concentration of potential pollutants that can cause violations of water quality objectives and/or impairment of the beneficial uses of the State's waters.

On September 7, 2001, the Central Valley Regional Water Quality Control Board (CVRWQCB, 2001a) adopted Resolution No. 5-01-236, "Control of Discharges from Irrigated Lands." This Resolution specifically addresses the conditional waiving of waste discharge requirements (WDRs) for irrigation return water and stormwater runoff from agricultural lands. The WDRs were originally waived based on the condition that the runoff/discharges from irrigated lands "*… minimize sediment to meet Basin Plan turbidity objectives and to prevent concentrations of materials toxic to fish and wildlife*" and for stormwater runoff "*where no water quality problems are contemplated and no federal NPDES permit is required*." Pursuant to California Water Code § 13269, the waivers of WDRs will terminate on 1 January 2003, unless renewed by the Regional Board.

Baggett (2002), Chair of the State Water Resources Control Board (SWRCB) has discussed the State Water Board's approach for implementing Senate Bill 390 which provides for sunset of the agricultural waiver of WDRs. Baggett has indicated that it is the policy of the SWRCB *"... to reduce the escape of pesticides, fertilizers and other agricultural* [chemicals] *to nearby rivers, streams and groundwater sources."* Baggett stated, *"After sufficient monitoring data have been received and analyzed, new strategies involving waivers and permits can be designed,"* and, *"A well designed monitoring program is clearly the first step. What form that program takes as well as what follows from that program are yet to be determined and the input of all parties will be vital to those decisions."* Baggett announced that the SWRCB is making available $1 million to support agricultural waiver programs.

The CVRWQCB (2001a) September 7, 2001, Resolution states that the irrigation return waters and stormwater runoff from irrigated lands can contain pesticides, nutrients, sediments and other constituents that adversely impact receiving water beneficial uses. It points out that the available monitoring does not allow the Board to identify the source of several pollutants being found in Central Valley mainstem waters. The Resolution states that site-specific information should be used to evaluate compliance with waiver conditions that must be available before a renewed waiver policy can be considered, and that the staff is directed to request agencies and organizations that work with drainage from irrigated lands to establish local water quality monitoring to identify sources of pollutants.

On November 20, 2001, the CVRWQCB (2001b) released a staff report entitled "Development of Monitoring Programs Addressing Discharges from Irrigated Lands." At the December 6, 2001, meeting devoted to this issue, they discussed the level of monitoring issues, referring to the *basin*, *drain*, and *field* monitoring. As discussed, each of these has its place in evaluating the water quality impacts of stormwater runoff and irrigation water releases. The CVRWQCB staff points out in their report that most of the monitoring done thus far is at the *basin* level, which has shown that there are significant water quality problems in a number of Central Valley watersheds which are due to upstream discharges from agricultural activities. The staff points out, however, that while there has been some monitoring at the *drain* level there has been essentially no monitoring at the *field* level conducted in the Central Valley.

At the December 6, 2001, meeting, the staff discussed the water quality monitoring for discharges from irrigated lands proposed in the November 20 staff report. Many of the proposed sites are at existing monitoring locations developed for other purposes. The staff states that "*The goal of the proposed program is to establish a monitoring network in representative agricultural drains and ag-dominated water bodies throughout the Region*." As the staff indicates, this network would not monitor all agricultural drainage, but would help identify whether water quality issues exist. Additional monitoring sites would have to be established in areas where problems are noted to identify sources and track improvements. As a starting point, it was suggested by the staff at the December meeting that the agricultural community conduct a voluntary monitoring program that would include monitoring for toxicity, sediment and constituents on the 303(d) list, including organophosphate pesticides (diazinon/chlorpyrifos), selenium, salt, boron, nutrients, dissolved oxygen, biochemical oxygen demand and temperature. The proposed sampling frequency would be monthly, and analysis of some constituents would be seasonal.

In February 2002 the staff provided additional information on this proposed monitoring program which included 56 sites and measurement of toxicity, sediment and constituents on the 303(d) list, including organophosphate pesticides (diazinon/chlorpyrifos), selenium, salt, boron, nutrients, dissolved oxygen, biochemical oxygen demand and temperature. The nonpoint source monitoring program discussed herein provides guidance on issues of the proposed monitoring program that need to be to addressed for a more comprehensive agricultural waiver monitoring program, which is needed to achieve the objectives set forth by the Board and staff for assessing the water quality impacts of irrigated agricultural area stormwater runoff and irrigation water discharges on the beneficial uses of the State's waters.

The CVRWQCB (2002a) Ag Unit, working with agricultural interests, in the spring 2002 developed a draft proposed "strawman" monitoring program (see Appendix A) to satisfy the requirements of volunteer monitoring of water quality impacts of irrigated agricultural discharges/runoff, which proposed to include 56 monitoring sites. Subsequently, the agricultural community proposed a revision of the "strawman" Phase I agricultural waiver monitoring program, where the number of monitoring sites was reduced to 29. At this time (December 2002) the Phase I agricultural waiver monitoring program is under development. It is recognized that the initial (Phase I) water quality monitoring program for irrigated agriculture being developed by the CVRWQCB is the first step in developing a more comprehensive monitoring program that would provide the information needed to properly assess the water quality impacts of constituents in constructed agricultural drains and agriculturally dominated waterbodies on the beneficial uses of the State's waters. This report presents a discussion of these issues relative to the literature and the authors' expertise and experience (see Appendix B) in the topic area.

Recommended Initial Nonpoint Source Monitoring Program

The development of technically valid, cost-effective monitoring/evaluation programs for nonpoint sources (NPS) of constituents that are potential pollutants should be conducted within a framework of three major components. The first of these is the water quality problem definition phase, where monitoring is done to determine the potential impact of agricultural and other NPS sources of runoff/discharged constituents on the beneficial uses of waterbodies receiving the runoff/discharge. The second is the water quality evaluation phase, where an evaluation is conducted of whether the potential impacts predicted by the exceedance of the worst-case-based water quality standards does, in fact, occur. This phase establishes the framework for the management program for controlling the adverse impacts on the beneficial uses of the State's waters receiving the NPS runoff/discharges. The third phase is devoted to the monitoring associated with management of the real, significant water quality problems associated with NPS discharges/releases. A suggested specific framework for each of these phases is discussed in this section.

While the focus of this discussion is on agriculturally derived potential pollutants, these issues are equally applicable to other nonpoint sources of chemicals, such as runoff from wetlands and riparian lands to State waterbodies. It is also applicable to urban stormwater runoff, which the US EPA defines for administrative purposes as a "point source" discharge.

Phase I: Definition of Potential Water Quality Problem(s)

This section presents a recommended approach for establishing the Phase I nonpoint source water quality monitoring program. Emphasis is given to defining the potential water quality impacts of stormwater runoff, tailwater and subsurface drain discharges from irrigated lands on receiving water water quality-beneficial uses. This program is designed to be a <u>potential</u> water quality problem definition program. The emphasis is on determining whether the NPS discharge/runoff causes a violation of an applicable water quality standard (objective) in the receiving waters for the runoff/discharge.

Overall Objectives of Nonpoint Source Water Quality Monitoring. The initial overall objective of the nonpoint source water quality monitoring should be to define the water quality impacts of stormwater runoff, irrigation tailwater and subsurface drain discharges of chemical constituents and pathogen-indicator organisms that have the potential to impair the beneficial uses of the state of California waters. By "impairment" of beneficial uses, it is meant that, in accord with current Clean Water Act implementation approaches, the runoff/discharges cause an exceedance of a CVRWQCB Basin Plan chemical-specific numeric and/or narrative water quality objective (WQO). In addition to considering the existing WQOs, consideration should also be given to the WQOs that are likely to be adopted within the next five to 10 years, such as chemical-specific numeric nutrient (N and P) and TOC criteria/WQOs.

Waterbodies that should be Included. In the early 1990s, the CVRWQCB defined the "waterbodies dominated by agricultural drainage" (category (b) waterbodies) and "constructed agricultural drains" (category (c) waterbodies). These waterbodies are listed in Table 1 of Appendix C. Every waterbody that has the potential to be impacted by agricultural runoff/discharge-derived potential pollutants should be a candidate for study/evaluation. The "agriculturally dominated" waterbodies are waterbodies that are potentially impacted by agricultural runoff/discharges and should be a high priority for initial study. Based on G. F. Lee's familiarity with the San Joaquin River and the Sacramento River Watershed Program monitoring results, the Delta, and his recently completed work on the occurrence of excessive bioaccumulation of organochlorine pesticides in Central Valley waterbodies, it is proposed that the following approach be used to designate high-priority waterbodies for initial nonpoint source water quality monitoring.

The primary proposed basis for selecting "high-priority" waterbodies is the information that has been developed on locations in the Central Valley where excessive (based on Office of Environmental Health Hazard Assessment [OEHHA] human health fish screening values) organochlorine (OCl) legacy pesticides have been found in fish and clam edible tissue. Many of the waterbodies where fish/clams have been found at any time in the past to contain elevated concentrations of legacy pesticides should be considered high-priority for nonpoint source monitoring. While there is interest in the OCls as current pollutants, the presence of OCls at sufficient concentrations to have been measured in fish tissue in the past is potentially a useful indicator of agricultural runoff that contains other pesticides and other potential pollutants. Many of these waterbodies have been, and may still be, impacted by agriculturally derived runoff/discharges of a variety of potential pollutants. Table 1 lists the waterbodies in the San Joaquin River (SJR) watershed where fish/clams have been examined for excessive OCls. Los Banos Creek should be added to this list.

While the focus of this monitoring program is runoff/discharges from irrigated agriculture, managed wetlands should also be monitored. Managed wetlands used for federal and state wildlife refuges and private duck clubs should be monitored in the same manner as the irrigated and non-irrigated agricultural areas. State waterbodies that receive runoff/discharges from other areas that contribute NPS "unregulated" runoff/discharges that have the potential to impair the beneficial uses of State waters, including causing or contributing to exceedance of CVRWQCB water quality objectives, should be monitored.

An area that needs special attention is the stormwater runoff from urban areas that do not have NPDES stormwater permits, as well as NPDES-permitted urban stormwater runoff that discharges to an NPS-monitored waterbody, where the permit-required water quality monitoring does not provide adequate monitoring data to define the magnitude of the urban contribution of potential pollutants to the NPS monitored tributary. Such situations should be monitored to fill any information gaps that exist in the NPDES permit-required monitoring.

All of the waterbodies in the San Joaquin River watershed that have been part of the SJR DO TMDL monitoring by Kratzer and Dileanis of the USGS and R. Dahlgren of UCD should be high-priority candidates for nonpoint source monitoring. These waterbodies are included in Table 1. Also, all waterbodies that are on the existing and proposed 303(d) list of impaired waterbodies, where the impairment could be due to agriculturally derived constituents, should be on this initial high-priority list.

Table 1
Suggested Locations for High-Priority Nonpoint Source Monitoring

San Joaquin River Watershed

San Joaquin River at Highway 99 (?)*
San Joaquin River at Lander Avenue
Mud Slough mouth
Salt Slough mouth
Los Banos Creek mouth
Merced River mouth
San Joaquin River at Crows Landing
Orestimba Creek, Spanish Grant Drain, Del Puerto Creek, Olive Avenue Drain, Ingram Creek and Hospital Creek, near mouths of each waterbody
Harding Drain (Turlock Irrigation District Lateral #5) near mouth
Morrison Creek mouth
San Joaquin River at Patterson
Stanislaus River and Tuolumne River near the mouths
Dry Creek in Modesto near the mouth
San Joaquin River at Vernalis
San Joaquin River at Mossdale
Federal and State refuges discharges (TOC, TDS and nutrients)
Others?

Sacramento River Watershed

Pit River just downstream and upstream of major agricultural activities
Sacramento River at Keswick (?)
Colusa Basin Drain (at several locations, such as Abel Road and Knights Landing)
Sutter Bypass mouth
Feather River at Nicolaus
Yuba River near mouth
Jack Slough at Highway 70 (?)
East Canal near Nicolaus, mouth
Sacramento River at Veteran's Bridge
Sacramento Slough, near mouth
Natomas East Main Drain, mouth
Sacramento River at Mile 44
Arcade Creek
Elder Creek
Elk Grove Creek
Sacramento River at Hood
Putah Creek
Cache Creek
Clear Lake tributaries (?)
Cache Slough

Table 1 (continued)
Suggested Locations for High Priority Nonpoint Source Monitoring

Wetlands discharges (TOC, nutrients)
Discharges of waters from rice cultivation areas
Others?

Delta

Port of Stockton Turning Basin (?)
Port of Stockton near Mormon Slough (?)
Smith Canal at Yosemite Lake (?)
Mosher Creek upstream of the city of Stockton
Sycamore Slough near Mokelumne River
Mokelumne River near its mouth
White Slough near its connection to the SJR
Potato Slough near its connection to the SJR
French Camp Slough near its connection to the SJR
Old River at several locations, including just downstream of Head of Old River and where DWR has its continuous monitoring stations in the South Delta
Paradise Cut near where it connects to Old River and upstream at a location that is to be selected
State and Federal Project pumps forebay or their discharge

Selected Delta island discharges to be specified
Others?

Tulare Basin

Kings River, Lower, at a location just downstream of the major agricultural inputs
Kern River just downstream of the major agricultural inputs
Others?

Klamath Basin

(Locations to be specified suggestion are needed.)

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* A "?" is used to designate those waterbodies that should be discussed with the Regional Board staff to determine if they should be on the "high priority list" of initial waterbodies to be monitored.

Some additional guidance can be provided for certain waterbodies with which the author is familiar. Cache Creek should be monitored at I-5, at the Capay Dam, and possibly upstream of Capay Valley agricultural activities. Gordon Slough, which is a tributary of Cache Creek, should also be monitored. Putah Creek should be monitored at Mace Blvd., and at an upstream location to be selected.

Waterbody upstream monitoring should be done on the Mud and Salt Slough watersheds at points A through M of the Grassland Bypass Project. Further, upstream monitoring should be done of the Merced, Stanislaus and Tuolumne Rivers for each of the major subwatersheds in these rivers' watersheds. Upstream monitoring of the San Joaquin River watershed at Lander Avenue should be conducted to determine the source of the nutrients and potentially other constituents that are found at the SJR at Lander location. Based on a recently conducted guided tour of this area, it appears that the local refuges may be the source of the high nutrients that are present in the SJR at Lander Avenue during the summer and fall. This will require monitoring of the discharges/releases from the State and Federal refuges that discharge to the SJR upstream of Lander Avenue.

The monitoring locations for each of the Table 1 tributary waterbodies should initially be near the mouth of the waterbody at a suitable location to avoid backwater from downstream waterbodies during their high flow and at a location near where stream gaging can be done. The monitoring near the mouths of Table 1 waterbodies should include installation of a gaging station to continuously measure the flow and therefore loads of the constituents of concern that are derived from agricultural sources to the mainstem of the Central Valley waterbodies. While normally the sampling stations of easy opportunity, such as where a public road crosses or intersects the waterbody, are used, each of the proposed waterbody mouths and upstream locations should be critically evaluated to be sure that the factors that could influence the water quality characteristics at the proposed monitoring location are understood.

Since a number of the waterbodies that receive nonpoint source runoff/discharges also receive NPDES-permitted, point source discharges of municipal and industrial wastewaters and stormwater, and since the agricultural community is concerned about the impacts of the point source wastewater discharges and stormwater runoff from urban areas as being a source of pollutants, it will be necessary to clearly distinguish between the urban loads and the agricultural and other nonpoint source loads in a waterbody. Therefore, it is recommended that measurements be made of the concentrations/loads of the constituents upstream of a municipality, as well as immediately downstream of it, for waterbodies that are being evaluated with respect to agricultural and other NPS impacts.

While the initial focus of this monitoring program is primarily devoted to detecting violations of Basin Plan WQOs at the mouths of Table 1 waterbodies that are caused by agriculturally derived constituents, it will be necessary to do upstream monitoring/evaluation of the potential impact of agriculturally derived potential pollutants at various locations in the Table 1 waterbodies' watersheds, including at the edge-of-the-field interface with State waters. It is recommended that the initial monitoring program be expanded to include detailed monitoring of each of the major subwatersheds where samples should be taken. The expanded monitoring program will lead to the definition of sources of constituents that are impairing water quality.

A review of some of the issues that should be addressed, as part of selecting sampling site(s) for monitoring of water quality should involve the following:

- Developing a clear, succinct definition of the purpose of the sampling.
- Developing a clear, succinct statement of how the data generated from the monitoring program will be used. Specifically, how will the data be used in a regulatory context? What constitutes an exceedance of a regulatory requirement?
- Tentative selection of one or more sampling locations which are designed to provide data that can be used to achieve the objective of the monitoring program.
- A site-specific evaluation of the proposed sampling location(s) to be sure that taking a sample at that location(s) is representative of the water that is present at that point at the

time of sampling. Of particular concern is whether the water at the sampling point under various stream flow regimes and seasons is representative of the water passing that point.

- Identification of all nearby upstream sources of constituents that can influence the water quality at the point of sampling. Determine whether the upstream sources of potential pollutants are thoroughly mixed with the waters passing the sampling point.
- Gaining an understanding of the agricultural practices and other land uses that are conducted in the watershed upstream of the sampling point.
- Gaining an understanding of the plumbing system involving sources of water and the movement of water through the watershed that ultimately gets to the sampling location. It is important to consider this situation over the seasonal and annual cycle, and the year-to-year variability in the plumbing and hydrology of the watershed upstream of the sampling point.
- Critically reviewing the data available on the characteristics of the water at the sampling location, based on information provided by previous studies conducted at that location or at other locations with similar upstream land use and hydrology.
- Becoming familiar with downstream waters' designated beneficial uses, applicable water quality objectives and existing water quality problems.

In order to achieve near-term, cost-effective control of water quality beneficial use impairment associated with nonpoint source runoff/discharges, it will be necessary to gain the cooperation of the "stakeholders" in a waterbody's watershed. Extensive efforts should be made to achieve a cooperative effort in developing the water quality monitoring program, evaluation of the beneficial use impairment associated with the "exceedance" of water quality standards (objectives), and formulation and implementation of the management program to control the impacts of constituents in nonpoint source runoff/discharges. The current, largely adversarial approach should be abandoned in favor of a "work together" approach to developing a sustainable agriculture that is conducted in a technically valid, cost-effective manner that is protective of the Clean Water Act designated beneficial uses of the receiving waters for the runoff/discharges from agriculture and other lands.

This cooperative approach starts with developing the monitoring program which becomes the first phase of the NPS water quality management program. An essential component of a technically valid NPS water quality monitoring/evaluation program is a good understanding of the "plumbing" and "hydrology" in a waterbody's watershed upstream of the proposed sampling location. The "plumbing" information of the upstream watershed is the flow path of the water that enters the upstream watershed and flow path routes that can transport water and associated constituents to the monitoring locations. The hydrological information covers the actual flow paths that the water follows in moving through the sampling location watershed, the variability of flow paths as well as the factors that control the water flow path at any time. This understanding will be greatly enhanced if the full cooperation of the land owners/users and irrigation districts is obtained.

An issue of particular concern is the location of upstream watershed land runoff/ discharge points that are not well mixed under all or some stream flow conditions. Site-specific studies need to be conducted to establish, under the range of stream flow conditions that occur at the proposed sampling locations, the physical and chemical homogeneity of the waters at the sampling location. Of particular concern is an assessment of the need for an integrated cross-sectional flow sampling such as that used by the USGS, or whether a single grab sample taken at about mid-depth and about mid-channel is representative of the waters passing the sampling location under various flow and upstream discharge regimes.

While it would be desirable to select representative agricultural activity/stormwater runoff/tailwater discharge situations for the waterbodies listed in Table 1, at this time there is insufficient understanding of basic issues governing how agricultural activities impact runoff of chemical constituents and pathogen-indicator organisms to be able to reliably select representative locations without some field studies. The initial-phase monitoring program should be directed toward developing this information so that follow-on studies can be conducted with an emphasis on defining representative situations.

Ultimately, the edge-of-the-field studies that will need to be conducted to define the impacts of agriculturally derived constituents that impact the beneficial uses of the State's waters should result in the development of constituent export coefficients, where the amount of constituent exported per rainfall runoff event or discharge event is related to the area and use of the land from which the constituent is derived. This approach has been successfully applied to describe the amount of nitrogen and phosphorus derived from various types of land use by Rast and Lee (1983). The export coefficient approach is an important tool in characterizing nonpoint source runoff/discharges. A key aspect of export coefficient development is an understanding of the factors influencing the amount of the constituent released from a particular type of agricultural practice/land use, under various climatological, hydrological and geomorphological conditions. This approach has recently been applied to pesticide runoff from urban and agricultural lands in Orange County, California (Lee, *et al.*, 2001) and the city of Stockton (Lee and Jones-Lee, 2002a), as well as BOD in stormwater runoff from the city of Stockton (Lee and Jones-Lee, 2002b).

In order to develop a credible monitoring program to assess nonpoint source runoff/discharges of potential pollutants from agriculture and other sources, there is need to have a good understanding of how the data that will be generated in the monitoring program will be used in a regulatory context for controlling the impairment of the designated beneficial uses of the waters impacted by nonpoint source runoff/discharges. This understanding should be present before the monitoring program is conducted, and thereby help to define the objective of the program, through obtaining the data and other information needed to interpret and reliably utilize the water quality data in a water quality management program.

Selection of Monitoring Parameters. There are two approaches for selecting the monitoring parameters. One involves monitoring all of the parameters that could be present in the runoff (see Table 2), and the other involves guided monitoring for a few selected parameters based on the general characteristics of the land use in the monitored area and the past and current use of chemicals and materials containing pathogens, such as manure or biosolids (domestic wastewater sludge). One of the primary reasons for a cooperative approach to developing the monitoring program is the selection of the monitoring parameters. A cooperative approach can greatly aid in selecting monitoring parameters for those constituents which are part of agricultural practices in a waterbody's watershed. Lee and Jones-Lee (2002c) have recently discussed the chemical

Table 2
Candidate Monitoring Parameters

Field Measurements

pH
dissolved oxygen
temperature
Secchi depth
estimated flow and water velocity at time of measurement
time of sample collection
weather conditions, including air temperature, wind velocity, cloud cover and precipitation, at time of sampling and for the previous 24 hours
presence of floating algal scum
unusual color, such as that associated with wetlands releases
general extent (estimated percent) of area near monitoring location that is covered by floating macrophytes (hyacinth, duck weed), emergent aquatic plants and/or attached algae.

Laboratory Measurements

In general, the analytical methods for the following parameters are those listed in Standard Methods, APHA, *et al*. (1998) or those listed by the US EPA (2000a). Note: some of the specific methods for a particular parameter in Standard Methods are not suitable for these measurements. Further, the method should have adequate sensitivity to reliably determine the constituent of concern at concentrations below those that represent regulatory limits, such as WQOs. The specific analytical methods used should be approved by the CVRWQCB.

total phosphorus, with a quantitation limit of 10 µg/L P
soluble orthophosphate with a quantitation limit of 5 µg/L P
ammonia, with a quantitation limit of 0.1 mg/L N
organic nitrogen, with a quantitation limit of 0.5 mg/L N
nitrate plus nitrite, with a quantitation limit of 0.1 mg/L N
electrical conductivity at 20 or 25 degrees C
planktonic algal chlorophyll-*a*, using acetone extraction
planktonic algal pheophytin-*a*
turbidity
color (true and apparent)
BOD_{10}
total suspended solids (TSS)
total dissolved solids (TDS)
alkalinity
total organic carbon (TOC)
dissolved organic carbon (DOC)
UV_{254}
boron
bromide
selenium
mercury, with a quantitation limit of about 1 ng/L
heavy metals, such as copper, zinc, cadmium, lead, nickel, chromium, iron, manganese (all heavy metals should be measured in the total and dissolved forms using “clean” sampling techniques)
molybdenum
arsenic
barium
scans for OP pesticides, carbamate pesticides, organochlorine pesticides, and chlorinated hydrocarbon herbicides, using most sensitive methods readily available
scan fish tissue for organochlorine pesticides, PCBs, dioxins, and mercury each fall

Table 2 (continued)

(for the OCls, use sufficient sensitivity to detect the OCls at OEHHA fish screening values for protection of human health)
chemicals such as pesticides, soil amendments, etc. added to agricultural lands
tastes and odors?
biological measurements
- dominant types of algae and zooplankton
- sediment organism assemblages
  - dominant benthic/epibenthic macro-organisms
- three species aquatic life toxicity, including assessing total toxic units and TUa due to OP pesticides, with and without PBO addition
- sediment toxicity using *Hyalella*
- *E. coli,* (contact recreation),
- total coliforms (shellfish)?,
- fecal coliforms (local health department)?

bulk parameters to be measured quarterly
- calcium
- magnesium
- sodium
- chloride
- sulfate

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parameters or characteristics that are causing or could cause waterbodies in the San Joaquin River watershed to be placed on the 303(d) list of impaired waterbodies for which a TMDL must be developed. At this time there are 15 parameters on their list. These parameters have been included in Table 2 as parameters for which monitoring should be conducted.

Monitoring should be conducted for all chemicals that are known to have been used and are being used on the lands within the watershed upstream of the monitoring station. This monitoring should include all insecticides, herbicides, fungicides, metals, soil conditioners, etc., that have been used in agricultural practices in a watershed. If there is a question about whether a chemical/product/material has been used in a watershed, the constituent should be monitored.

All NPS runoff/discharges should be monitored for total suspended solids (TSS), turbidity, total dissolved solids (TDS) or electrical conductivity, total organic carbon/dissolved organic carbon (TOC/DOC), organic N, ammonia, nitrite-nitrate, total phosphorus and soluble orthophosphate. The US EPA standard three-species aquatic organism toxicity test should be conducted. If toxicity is found, a dilution series with and without piperonyl butoxide (PBO) addition should be conducted in order to assess the amount of the toxicity that is due to OP pesticides, versus other pesticides.

Also, selenium and boron should be monitored until it has been demonstrated that they are not present in the runoff/discharges in a waterbody's watershed at potentially significant concentrations. Since several of the organochlorine "legacy" pesticides (DDT group, dieldrin, chlordane, and toxaphene) have been widely used in the Central Valley on agricultural lands, and there are problems of excessive bioaccumulation of these compounds in fish in several Central Valley waterbodies, including the Sacramento River, the San Joaquin River and the Delta, there is need to monitor fish from each waterbody each fall to determine if excessive OCl pesticide residues compared to OEHHA human health screening values are present in them. Since fish taken downstream of agricultural lands have been found to contain excessive PCBs, the fish monitoring should include PCBs as well.

Parameters can be removed from the list presented in Table 2 for certain tributaries, based on information that shows that the parameter is not likely an important constituent that has the potential to impact water quality at and downstream of a sampling location. Without this information, all of the parameters should be monitored until it has been demonstrated that the parameter is not present at concentrations that will adversely impact State of California waterbodies. It may also be possible to reduce the monitoring parameters listed, at certain locations, where other programs are already conducting monitoring. As an example, is the CVRWQCB (2002b) Surface Water Ambient Monitoring Program (SWAMP). This program has proposed to monitor several of the locations and parameters listed in Tables 1 and 2. To the extent that the monitoring is being done by another program that will generate data of the same quantity and quality as the recommended NPS monitoring for that location, the NPS funds be can be used at other locations and for other parameters.

E. Archibald, on behalf of the California Urban Water Agency (CUWA) has provided information on the parameters that CUWA feels should be monitored in Central Valley NPS runoff/discharges that are a potential threat to domestic water supply water quality. A copy of Archibald's discussion of these issues is presented in Appendix D. CUWA lists as constituents of concern to drinking water suppliers, *"…DBP precursors (TOC, DOC, UVA254, SUVA, THMFP, bromide); pathogens and their surrogates* (Giardia, Cryptosporidium, *total coliforms*, E. coli); *dissolved minerals (TDS), chloride); nutrients; and in the Sacramento basin, rice pesticides."* Many of these parameters are included in Table 2 as NPS recommended monitoring parameters. It is recommended that the pathogen monitoring recommended by CUWA be conducted as follow-up monitoring wherever *E. coli* is found at elevated concentrations. It should be noted that a number of these pathogens, such as *Cryptosporidium*, are of concern because of contact recreation impacts. Follow-up monitoring for SUVA and THMFP should be conducted on those waters where a high TOC is found, to determine if the TOC has a high potential to form disinfection byproducts.

Because of the importance of the Delta islands' drainage/discharges as a source of TOC and some other constituents, such as pesticides, nutrients, and salts, for waters exported from the Delta that are used for domestic water supply purposes, it will be important to gain an understanding of the role of Delta island discharges/drainage as a contributor of TOC to the Delta. Harader (pers. comm. 2002) has recommended that flow measurements of Delta island discharges to Delta waters be made so that the loads of potential pollutants discharged from these islands can be assessed.

In order to enhance agricultural production, a variety of chemicals and/or materials are added to agricultural lands. Many of these agricultural chemicals have the potential to be present in stormwater runoff and irrigation tailwater/drainwater and be adverse to the beneficial uses of the receiving waters for runoff/discharges from agricultural lands. The regulation of pesticides (which include fungicides, miticides and herbicides as well as soil conditioners such as some heavy metals etc.), with respect to causing violations of water quality objectives in receiving waters from runoff/discharges, should be based on an understanding of the amounts and timing of application, and the potential for transport from the area where application occurs in sufficient concentrations to cause impairment of beneficial uses of the receiving waters for the agricultural land runoff/discharges. While pesticides are registered by federal (US EPA Office of Pesticide Programs) and equivalent state level programs (in CA the Department of Pesticide Regulation - DPR), this registration fails to evaluate the potential for stormwater runoff and irrigation water discharges to transport the highly toxic "registered" pesticides approved for application to agricultural lands/crops to offsite waters at sufficient concentrations to be adverse to the aquatic life and other beneficial uses of the receiving waters for the runoff.

Another significant problem with current federal and state pesticide registration is the failure of the US EPA OPP and DPR to require that pesticide manufacturers develop reliable analytical methods for pesticides in runoff/discharges from areas to which they are applied that could be present at toxic levels in offsite waters.

An issue of particular concern in the monitoring of toxic chemicals applied to agricultural lands, such as pesticides, including herbicides, fungicides, etc., is the substitution of replacement pesticides such as pyrethroid pesticides for the OP pesticides. Some of the pyrethroid pesticides have an even greater toxicity to aquatic life than the OP pesticides. Further, analytical methods for measuring the pyrethroid pesticides at critical concentrations for aquatic life do not exist. This requires that a different approach involving site-specific studies be used to evaluate the presence of pyrethroid pesticides and other pesticides used on agricultural lands in receiving waters at potentially significant concentrations.

As described by Jones-Lee and Lee (2000) a proactive approach toward evaluating the potential impacts of these chemicals on receiving water water quality should be used, so that aquatic life toxicity monitoring of runoff/discharges from areas where these chemicals are applied can be conducted under conditions that are likely to represent the greatest concentrations/loads of the chemicals in runoff/discharge waters to waters of the State. The proactive approach for monitoring/evaluation will require that information be available on the chemicals used and when they are applied. In addition, since aquatic life toxicity measurements do not assess low levels of aquatic life toxicity which occur below those that can be measured by the standard aquatic life toxicity test, information will be needed on analytical methods that can be used to determine their concentrations at potentially critical levels with respect to aquatic life toxicity.

The cost of reliable monitoring programs could be greatly reduced if a program could be implemented that would provide information on when an agricultural chemical is applied to a particular agricultural situation so that a guided monitoring program could be conducted in a proactive approach of the type described by Jones-Lee and Lee (2000) to determine if runoff/discharges from the areas where the agricultural chemicals are applied cause water quality problems/water quality beneficial use impairment in the receiving waters. A few representative evaluations of this type would lead to an evaluation of the potential for water quality impacts associated with the labeled use of the pesticide. Without adopting this proactive approach to identify chemicals used on agricultural lands that should be monitored, a much more comprehensive/expensive monitoring program for chemicals applied to agricultural lands will have to be used.

Prioritization of Funding. Ideally, sufficient funding will be available to fund a comprehensive NPS water quality monitoring/evaluation program for the Central Valley. However, the funding potentially available, compared to needs, will require prioritization of the number of locations and parameters monitored.

It is suggested that a public process be used to determine the monitoring locations and the parameters to the extent allowed with funding available, where an advisory panel representing the stakeholders (CVRWQCB staff, agricultural interests, environmental groups and the public) develop the recommended NPS monitoring program. The highest priority should be given to initially monitoring near the mouth of constructed agricultural drains, tributaries of the mainstem rivers (San Joaquin River, Sacramento River, Stanislaus River, Tuolumne River and Feather River) and flows that are dominated by agricultural stormwater runoff/discharges. In addition, mainstem rivers should be monitored at several locations to determine if the composition of these rivers differs from that estimated based on tributary inputs between monitoring locations. It may be possible to utilize data from existing monitoring programs developed for other purposes to enable monitoring of other waterbodies that are not being monitored in this program, provided that the other monitoring programs meet the same QA/QC and other requirements of the NPS monitoring program that is being developed.

As information is developed from the initial monitoring NPS program, the initial monitoring program can be shifted to upstream in a watershed to determine if upstream water quality problems occur that are not detected at the tributary mouth, and/or in cases where there is need to define the origin of the pollutants that are found at the monitored tributary mouth.

Since there are a number of potentially significant pollutants in runoff/discharges from irrigated agriculture and managed wetlands areas for which there are no regulatory limits (water quality objectives) that are unregulated or are regulated by narrative objectives, there is need to provide guidance on levels of constituents that are found in mouths of the NPS-monitored tributaries that trip the need for additional monitoring/evaluation. It is suggested that the CVRWQCB Basin Plan objectives be one of the triggers for additional monitoring. Also, constituents listed in Table 3 that exceed the listed concentrations should be triggers for additional NPS monitoring.

The proposed trigger concentrations in Table 3 are listed with highest recommended priority first. A review of water quality problems downstream of the NPS monitoring location should be used to establish changes in priority. It is important to understand that the concentrations listed in Table 3 are not regulatory limits. The exceedance of a trigger concentration should lead to upstream monitoring to define the sources of the constituents that are causing the exceedance of the trigger concentrations. The exceedance of trigger concentrations should also be used to evaluate the potential for the exceedance to cause water quality impairments downstream of the monitoring locations. Of particular concern is an assessment of the impairment of downstream waterbodies which are regulated by CVRWQCB Basin Plan narrative objectives such as the aquatic plant nutrients (N and P compounds) that are regulated as "biostimulatory substances." Also of concern is the potential for TOC and nutrients to impair the use of a waterbody for domestic water supply purposes. Additional information on these issues is provided in a subsequent section of this report.

Table 3
Suggested Water Quality Trigger Concentrations

Constituent	**Recommended Trigger Concentrations (mg/L)**
Aquatic life toxicity	TUa for four/five day fish larva and zooplankton
Pesticides for which there are adequate analytical methods	0.1 x LC_{50} (four day) for fish larva and zooplankton based on US EPA OPP Ecosystem Database
TDS (EC) at 20 ºC	500
TOC	3
High pH and low DO associated with diel aquatic plant photosynthesis	Applicable Basin Plan Objectives
Total N (NO_3^-, NO_2^-, NH_3, NH_4, Org N)	0.5
Total P	0.05
TSS	100
Turbidity (NTU)	100
Secchi Depth (meters)	2
OCls* in edible fish tissue	Exceedance of OEHHA guidelines for fish consumption
E. coli	MPN 200 per 100 mL
BOD_5	20

* Group A pesticides (dieldrin, chlordane, toxaphene), DDT (including DDE, DDD), PCBs and dioxins/furans

As indicated in this report, the monitoring must eventually move upstream to evaluate whether there are upstream water quality problems that are not detected by monitoring at the mouths of the NPS-monitored tributaries. This should involve monitoring at various locations upstream of the tributary mouth and of each of the major sub-watersheds to the NPS-monitored tributary.

Monitoring Frequency and Duration. The monitoring program should consist of monthly sampling at each of the sampling sites, coupled with event-based sampling. The event-based sampling should be designed to collect samples during rainfall runoff events, as well as at times when there are tailwater and/or subsurface drain discharges. Particular attention will need to be given to monitoring during the initial tailwater discharges for the growing season. In addition, information on the use of chemicals on agricultural lands should be obtained as to the chemicals used, when application occurs and the amount applied per acre. This information should guide special-purpose sampling, which would be conducted the next time after application when there are water releases/discharges from the treated areas.

This initial monitoring program should be conducted for a minimum of three years and needs to be repeated every few years (i.e., 5 years) to address year-to-year variability and changes in agricultural chemicals' use in each of the studied watersheds.

Standard QA/QC Program. It is recommended that the US EPA standard QA/QC procedures be followed for replicate and spiked samples. In addition, split samples and known standard samples which are not identified as splits should be sent to the laboratory.

Recently, Azimi-Gaylon, *et al.* (2002) published "Quality Assurance for Effective Monitoring of Pesticides in the San Joaquin River Basin, California." This paper provides guidance on the development of a quality assurance project plan (QAPP) for water quality monitoring. While it is directed toward pesticide monitoring, the guidance is equally applicable to all water quality parameters. It is presented in Appendix E.

Data Management and Evaluation. The monitoring program should be an "active" monitoring program, where a panel of experts would review the data as soon as they are available and make recommendations and modifications to the monitoring program as needed.

Phase II: Evaluation of Water Quality-Beneficial Use Impacts

Phase I of this nonpoint source water quality monitoring/evaluation program is designed to determine the nonpoint source potential water quality/use impairments that exist in Central Valley waterbodies that are potentially impacted by irrigated agriculture and other diffuse sources of chemical constituents and pathogen-indicator organisms that can impact the beneficial uses of waterbodies that receive the stormwater runoff, tailwater and/or subsurface drain water discharges. Phase II of this water quality monitoring/evaluation program is devoted to evaluating whether the potential water quality use impairments exist, as indicated by exceedance of worst-case-based water quality chemical-specific criteria/objectives. The Evaluation Monitoring (EM) approach, as described by Jones-Lee and Lee (1998), should be used as the basic framework for the problem definition part of the monitoring program. The EM approach focuses on determining water quality impairments. For additional information on the issues discussed below, consult other sections of this report.

As discussed in this report, the US EPA national water quality criteria are designed to be protective of aquatic life and domestic water supply beneficial uses under essentially all conditions. As a result, these criteria can, in many situations, be overprotective of the beneficial uses, which can lead to unnecessary constituent control programs beyond those needed to protect the beneficial uses in a technically valid, cost-effective manner. This is especially true for constituents present in agriculturally derived runoff/discharges that tend to be associated with particulate matter in the runoff. These forms of potential pollutants are, in general, in nontoxic, non-available forms in the water column. In order to use the funds available for water quality management in a technically valid, cost-effective manner, it is essential to properly evaluate whether the exceedance of the worst-case-based water quality objective represents a real, significant beneficial use impairment of the receiving waters for the agricultural runoff/discharge. In addition to considering water quality impacts in the immediate receiving waters for the runoff/discharge, consideration should also be given to downstream impacts.

The primary adjustment of the water quality criteria/objectives involves the evaluation of site-specific conditions that can cause a worst-case most toxic/available form of a potential pollutant to become less toxic/available in the waterbody receiving the agricultural runoff/ discharges. This adjustment involves the consideration of aquatic chemistry/toxicology/biology and the hydrology/hydraulics/hydrodynamics of the runoff/discharges and the receiving waters. As discussed in this report, the US EPA (1994) provides information on some aspects of justified site-specific adjustment of the national criteria for site-specific conditions. The Agency is developing additional methodology for site-specific adjustment of national criteria, such as the use of TOC complexation to adjust the copper criterion.

The US EPA encourages site-specific adjustment of the national criteria/objectives to account for detoxification and other conditions that make the national criteria, and state standards numerically equal to these criteria, overprotective. The Clean Water Act requires that failure to make these adjustments results in the dischargers of potential pollutant(s) having to control the discharges/releases to the worst-case conditions. There is, therefore, considerable economic incentive to reliably evaluate the real, significant water quality use impacts of the agricultural discharges/runoff.

To proceed with the site-specific evaluation of appropriate WQOs, it will be necessary to appoint a team of experts representing the component disciplines who can work with the dischargers, regulatory agencies, environmental groups and the public to develop a cooperative program for developing and conducting the studies needed to support the site-specific adjustment of the worst-case-based water quality criteria/objectives. For each of the initially assessed violations of WQOs potentially caused by agriculturally derived constituents, a study to confirm that agriculture in the waterbodies' watershed is a major source of the constituents of concern needs to be conducted. If the water quality objective violation is confirmed, then, or at the same time, studies should be conducted of the receiving waters to determine the magnitude of the beneficial use impairment that can be attributed to agricultural runoff/discharges. Also, the Phase III monitoring/evaluation program should begin to be developed.

The Phase III program is initiated at this time to begin to explore the potential for controlling the agriculturally derived potential pollutants. If it is possible to readily control the sources of the agriculturally derived constituents, then implementing control programs eliminates the cost of doing the studies to make the site-specific adjustment of the WQO.

It is not possible to specify the locations of the Phase II study sites since they will be dependent on the Phase I results. They should be selected in a collaborative effort by the expert panel guiding these studies.

Phase III: Management Program Development and Implementation

The focus of the Phase III monitoring is on evaluating the effectiveness of control programs for constituents that are present in nonpoint source discharges/runoff that are suspected – and, if Phase II has been conducted, confirmed - to be having an adverse impact on the beneficial uses of the receiving waters for the nonpoint source runoff/discharge. As discussed in other sections of this report, the best management practice (BMP) evaluation requires a comprehensive site-specific monitoring program to determine if the control programs are effective in improving/protecting the designated beneficial uses of the receiving waters for the runoff/discharge. The monitoring should include water column and sediments upstream, near, and downstream of the receiving waters where the control program is conducted. Because of the variability in situations of this type, several reference areas with similar characteristics, in which there is no control program conducted, should also be monitored with much the same pattern as for the areas where the control program is implemented. The guidance provided in the other sections of this report should be followed in developing the BMP evaluation, including carrying out the BMP evaluation over multiple years to address the year-to-year variability.

Biostimulation Studies. Since one of the issues that will become important in managing the excessive fertilization of waterbodies in the Central Valley is an evaluation of the potential for the control of algae in the watersheds through limiting the phosphorus concentrations in the waters in which the algae develop, it is of interest to assess potential benefits of removing phosphorus from the water on reducing the algal growth in the water. This approach appears promising to control the excessive fertilization in some parts of the Central Valley waterbody watersheds, such as the Grassland area, associated with Mud and Salt Sloughs. As a special-purpose study at selected locations within each of the watersheds where excessive nutrients are present, at about monthly intervals, a biostimulation algal productivity study should be conducted. In general, the approach to be followed is set forth in Standard Methods, APHA, *et al.* (1998), Section 8111, pp. 8-42, Biostimulation (Algal Productivity).

Field studies should be conducted of certain waterbodies to address special problem areas. One of these is associated with agricultural runoff that contributes nutrients to the State's waters. At about monthly intervals, diel (day/night) measurements should be conducted during late spring, summer and early fall over one day for DO, pH and other parameters needed to conduct the "Flowing Water Productivity Measured by Oxygen Method," as set forth on pages 10-37 of Standard Methods, APHA, *et al.* (1998). Generally, this will require measurements of DO and pH every 2 to 3 hours at representative monitoring stations in each of the upstream watersheds. Samples for chemical analysis of the water for many of the parameters listed above should also be taken at early morning and late night.

Filtered samples of the water to be tested are treated with aluminum sulfate (alum) to remove phosphorus by coprecipitation. It is suggested that sufficient alum be added to reduce the soluble orthophosphate of the sample by 25, 50, and 75 percent of the original value. (In general, the procedures in Standard Methods section 8111 F Inoculum and 8111 G Test Conditions and Procedures should be followed.) To each sample an inoculum of *Selenastrum capricornutum* is added. After about one week, the algal biomass in the sample is measured using one of the procedures set forth in Standard Methods, such as chlorophyll.

Since alum additions to a water sample may also remove essential trace elements, a duplicate set of experiments should be conducted where phosphorus is added back, in the amount removed by alum treatment, to determine if essential trace elements/compounds were also removed. If the alum-treated, phosphorus-added samples do not develop about the same algal biomass, then the trace element cocktail specified in Standard Methods should be added to the alum-treated samples and the untreated sample to determine if the alum removed an essential trace element that is present in the cocktail.

Background Information for Recommended Monitoring Program

Organizing a Water Quality Monitoring Program

There have been a number of reviews that provide guidance on how water quality monitoring programs should be developed/evaluated. These include the NRC (1990), Managing Troubled Waters, and the Lee and Jones-Lee (1992), "Guidance for Conducting Water Quality Studies." As discussed by Lee and Jones-Lee (1992), the development of a comprehensive water quality monitoring program involves consideration of each of the following:

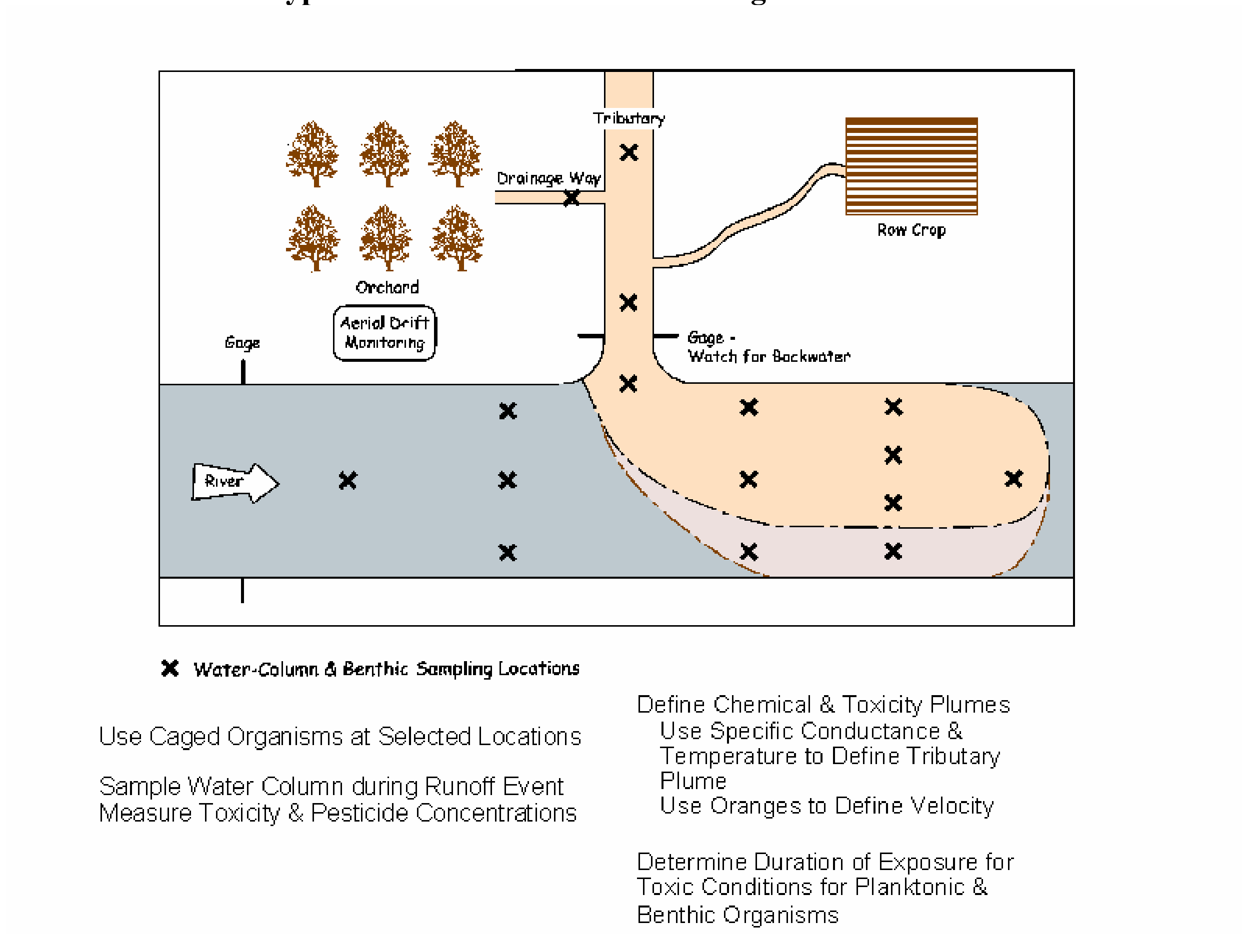
- Clearly establish the objectives of the monitoring program.
- Understand the nature of "water quality," water quality concerns, beneficial uses, and their assessment for the waterbodies of concern.
- Select the parameters to be measured and justify potential significance of each parameter selected.
- Examine previous studies to understand variability in each area of the waterbody to be monitored.
- List factors that can influence results of the monitoring program and how they may influence the results.
- Determine the level of confidence at which the objective is to be achieved.
- For each area of the waterbodies to be monitored, determine the number and location of samples to be collected.
- If no data are available from previous studies or if existing data are inadequate to define variability and other characteristics needed to establish a reliable monitoring program, conduct a pilot study of representative areas to define the characteristics of the area that are needed to develop a reliable water quality monitoring program.
- If the purpose of the monitoring program is to determine changes in water quality characteristics, select the magnitude of change that is to be detected and design the monitoring program accordingly.
- Select sampling techniques and methods of analysis to meet the objectives and level of confidence desired.
- Verify that analytical methods are appropriate for each area of the waterbody and at various seasons and flow regimes.
- Conduct studies to evaluate precision of sampling and analytical procedures and technique, reliability of preservation, and variability of the system.
- Critically examine the relationship between present and past studies.
- Determine how the data will be analyzed, with respect to compliance with Basin Plan objectives, using existing data or synthetic data that is expected to be representative of the site.
- Screen/evaluate data as they are collected.
- Analyze, interpret and store data, and report on the results of the analysis and interpretation.

Lee and Jones-Lee (1992) provide a discussion of each of the above bulleted items. Information in each of these areas as it is pertinent to the nonpoint source monitoring program and comprehensive agricultural waiver monitoring program is presented below.

First Step: Clearly Define the Objectives of the Monitoring Program

Both the NRC's (1990) and Lee and Jones-Lee's (1992) water quality monitoring program guidance reports state that one of the most important steps in developing a credible monitoring program to assess the impact of constituents derived from a particular source on the beneficial uses of receiving waters is an explicit statement of the objectives of the monitoring program. Figure 1 presents a typical situation in which there is need to determine the impact of stormwater runoff-associated diazinon on receiving water water quality/beneficial uses. This figure depicts an orchard, which, during the dormant season (winter), will receive diazinon treatment. Presented below is a discussion of many of the issues that need to be considered in properly evaluating the water quality impacts of diazinon runoff from the dormant-spray-treated areas. The same issues need to be considered for the development of monitoring programs associated with all pesticide and potentially toxic chemical applications to agricultural areas.

Figure 1
Typical Diazinon Runoff Monitoring Situation



Following the application of diazinon, rainfall events will transport some of the diazinon to a nearby watercourse. Further, at the time of application, airborne drift of the dormant spray will carry diazinon, in some cases, for many miles from where it was applied. In establishing a monitoring program for this situation, there is need to address a number of issues related to defining the objectives of the monitoring program. Majewski and Capel (1995) have reviewed the issue of atmospheric transport of pesticides. At this time, the USGS is conducting studies on behalf of the CVRWQCB on atmospheric loadings of OP pesticides to the ground surface in the San Joaquin River watershed. This information will help in understanding the significance of long-range atmospheric loadings of OP pesticides to the ground surface in some parts of the Central Valley. There is need, however, for studies to better define the atmospheric loadings to nearby lands that can occur from aerial drift from the areas where the pesticides are applied.

The objectives of the water quality monitoring program typically include:

- How much (mass per storm) diazinon is transported per unit time from the area where applied?
- What are the regulatory requirements for diazinon control, and are these exceeded?
    - Does the concentration of diazinon exceed a water quality standard at a particular location/compliance point? At any location?
    - What is the allowed frequency of exceedance/violation?
    - What are the consequences/penalties for excessive exceedances/violations?
- What is the potential toxicity (diazinon concentration - duration of exposure) to:
    - Water column organisms?
    - Benthic organisms?
- What is the area, distance and duration of potential toxicity in runoff from the treated area?
- What is the measured toxicity in the runoff/discharge event at various locations in the discharge plume?
    - What is the maximum magnitude and duration of exposure and areal extent of measured toxic conditions?
- What is the impact of diazinon discharge on the beneficial uses of receiving waters?
    - What impacts are there on the numbers, types and characteristics of receiving water aquatic life?
        - Is this significantly detrimental to the beneficial uses of the waterbody, with particular reference to higher trophic organisms?
          (Water fleas vs largemouth bass)
- What factors influence the water quality impacts of the diazinon runoff/discharge, such as rainfall intensity, duration, frequency; sprayed area characteristics, diazinon application characteristics, water quality runoff best management practices (BMPs) in place, etc.?
    - Particular concern for high intensity, large storms
    - Will the monitoring program adequately characterize these factors?
- How well do existing BMPs mitigate the impacts of the diazinon runoff for each of the water quality monitoring objectives?
    - What are the factors that influence the performance of the BMP?
        - Have these been adequately evaluated for the particular locations of concern?
    - How many storms during a year and how many years must a BMP be evaluated to reliably conclude that it is an effective mitigation measure under the range of climatological and other factors that influence its performance?
- Is diazinon use monitoring a reliable indicator of potential water quality impacts of diazinon runoff from areas where it is applied?
    - Does reduced diazinon use result in improved water quality?

  - If other pesticides are used as alternatives for diazinon, what is their impact on water quality?
- Are there adequate funds and methodology to properly evaluate the potential water quality impacts of alternative pesticides?

In developing this monitoring program, it is important to consider both wet-year and dry-year situations. Of particular importance is how the monitoring program would change under the wet-year periods, such as those that have occurred for the past few years, versus the dry years, such as occurred in the late 1980s and early 1990s.

Each of the above water quality monitoring objectives/issues for assessing the stormwater runoff of areas where diazinon has been applied as a dormant spray has specific monitoring requirements that need to be considered in developing a comprehensive water quality monitoring program. A similar set of questions/issues can be raised with respect to the variety of potentially toxic pollutants discussed below that are being discharged to the State's waters from irrigated agriculture in the Central Valley.

Agricultural Waiver Monitoring Objectives. The agricultural waiver policy and the CVRWQCB and staff have identified a number of objectives that need to be met in developing a water quality monitoring program to evaluate the impact of irrigated agricultural stormwater runoff and water releases on receiving water beneficial uses. These include violations of Basin Plan water quality objectives (WQOs), which also include California Toxics Rule (CTR) (US EPA, 2000b) criteria. Of particular concern is whether the amount of sediment derived from irrigated agriculture, especially during stormwater runoff, exceeds the Basin Plan requirements for limiting increased turbidity in waterbodies. Further of concern is whether the runoff/discharge contains constituents that cause measured toxicity or that occur in sufficient concentrations in the discharge/runoff to be potentially toxic to aquatic and terrestrial life. These issues are discussed further below.

While not explicitly stated in the agricultural waiver policy, an issue that should be addressed is whether there is potential toxicity to humans due to excessive bioaccumulation in edible fish and other aquatic life tissue or through the impairment of drinking water quality. An example of this type of situation is the "legacy" pesticides, such as DDT, that were used in the past on much of the agricultural lands in the Central Valley, where runoff from some of these lands still contains DDT and its transformation products at concentrations which bioaccumulate to excessive levels in edible fish tissue. This issue has been recently reviewed by Lee and Jones Lee (2002d). The CVRWQCB staff/Board, through their Resolution No. 5-01-236, have made it clear that they want *field* level information on specific substances from specific types of fields. While this issue is not being addressed in the spring 2002 proposed Phase I of the agricultural waiver monitoring program, a comprehensive monitoring program, such as that proposed herein, should provide this information.

Model Monitoring Program

This section presents an example of a monitoring program for a situation where a particular orchard or other agricultural area is being used as a demonstration area for evaluation of whether the use of a particular chemical (such as a pesticide) in the area is the cause of water quality objective violations/impacts in the near-field and far-field waters receiving the runoff/discharges from the area where the chemical is applied. The same issues would apply to an evaluation of a particular BMP to control diazinon or other pesticides applied as an orchard dormant spray in stormwater runoff that leads to aquatic life toxicity in the receiving waters for the runoff from the orchard.

Develop an Understanding of the Hydrology of the Area and Potential Upstream Contributions of Potential Pollutants during Stormwater Runoff Events. An initial step in developing a monitoring program to evaluate the potential water quality problems caused by the use of a chemical on agricultural lands is to develop an understanding of the hydrology (i.e., water movement) under stormwater runoff and irrigation releases/discharges. Because of the complex irrigation water flow paths that occur in many parts of the Central Valley, it is important to understand the "plumbing" of the areas upstream of the sampling point as well as how the flow through this plumbing system changes during the irrigation season and annually. All points where runoff from the test area can discharge to a particular receiving water should be identified. If possible, the receiving water stream should be gaged just upstream of the test area and either at the point of runoff from the treated area or just downstream of this point. An estimate should be made of the expected amount of runoff that will occur from the fields under various antecedent moisture conditions, rainfall intensity and duration. A recording rain gage should be installed in the area where the study is being conducted.

A survey of upstream land use and chemical applications should be conducted to be certain that there are no major unexpected contributors of the potential pollutant in stormwater runoff or wastewater discharges. The location selected should be one where the runoff from the test area would be expected to contribute to or cause violations of a water quality standard and/or aquatic life toxicity (for diazinon, *Ceriodaphnia* toxicity) in the receiving waters for the runoff. At least one – and preferably three – years of study should be conducted in order to gain insight into the amount of potential pollutant export that occurs from the test area under various climatological conditions and other factors that influence export.

While the focus of the water quality evaluation program is on stormwater runoff from agricultural areas where a chemical is applied, it will be important to also assess the aerial drift that occurs associated with the application of the chemical. A monitoring program for aerial drift under the range of conditions that could affect drift should be conducted through the use of rainfall and dry fallout collectors. These collectors should be positioned around the study area at various distances.

Importance of Aquatic Chemistry in Water Quality Objective Violation and Water Quality Impact Evaluation. The development of technically valid, reliable assessments of water quality objective violations and water quality impacts on beneficial uses requires the proper incorporation of aquatic chemistry into the evaluations. Contrary to the simplistic approach that is often used by those who are not familiar with aquatic chemistry, it is not a list of the chemical concentrations found in a water sample. Such a list is a presentation of chemical characteristics, not chemistry.

Chemistry involves the study of the transport and reactions of the chemical constituents of concern. It is devoted to assessing the advective transport, mixing, diffusion and dispersion, as well as the chemical kinetics and thermodynamics of the chemical reactions that govern the chemical species of concern in a particular situation. Figure 2 presents the aquatic chemistry wheel that was developed by Lee, *et al*. (1982a,b). For each chemical, such as a heavy metal with multiple oxidation states, there are a variety of chemical reactions, represented by the spokes in the wheel, that lead to products at the rim. It is the products at the rim that determine whether a particular chemical will be transported from an area where it is applied at sufficient concentrations to impact the beneficial uses of the receiving waters for the runoff/discharges.

Through proper application of aquatic chemistry, considerable insight can be gained into the expected impacts of chemical constituents on receiving water quality, as well as the expected performance of BMPs under various runoff/discharge conditions. For example, the properties of diazinon are such that it has low tendency to sorb (attach) onto surfaces. This means that BMPs that are based on sorption for removal will not be effective unless very large sorption areas are provided and extended periods of time are available for sorption to take place. It is for this reason that retention basins, vegetative strips and related BMPs (including setback areas) will not be effective in controlling diazinon runoff from treated areas, especially under high flow conditions. However, the aquatic chemistry of some of the pyrethroid pesticides is such that providing sorption surfaces within the area of application can greatly minimize stormwater runoff of the pesticide.

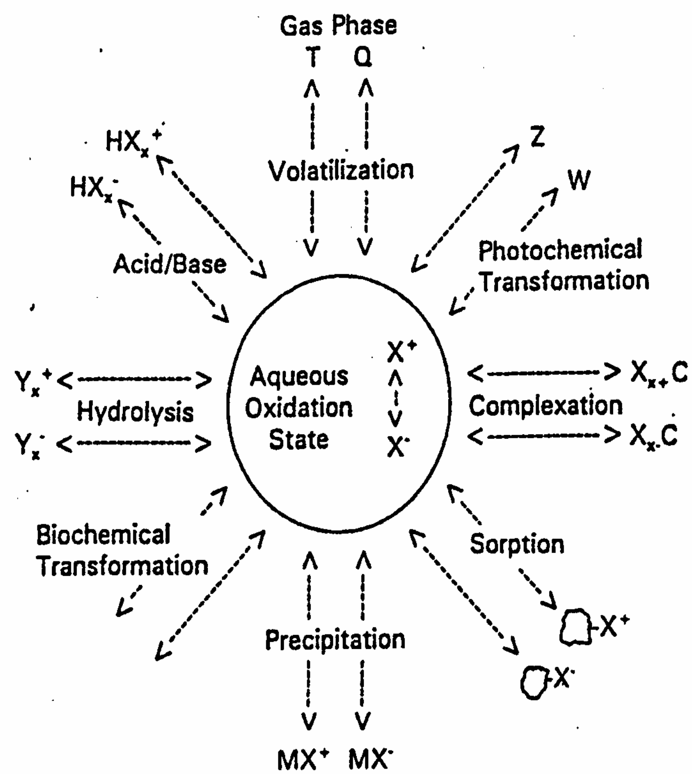
Accounting for Variability

Since the measurements of irrigated agricultural runoff/discharge-derived constituent concentrations at any particular time and location have a certain amount of variability associated with them, every monitoring program should evaluate the magnitude of the variability about any particular measurement, as well as for measurements made of different systems or at different times. This then introduces the need to evaluate the variability for each system monitored, and then establish, as part of the monitoring program goals, the amount and type of monitoring that is needed to achieve a certain prescribed degree of reliability of the measured concentrations of potential pollutants and associated water quality impacts associated with a particular discharge/runoff. Addressing these issues should involve standard statistical techniques, where, *a priori*, a degree of reliability in detecting concentrations and water quality impacts is established.

One of the issues that is particularly important in interpreting water quality monitoring data is the reliability of the sampling and sample analysis programs. Lee and Jones (1979) and Lee and Jones-Lee (1992) have found that it is helpful to develop information on how variable a particular analytical result is for a particular sampling event. In order to develop this information, it is often useful to repetitively sample a location at one time. For example, 10 samples are taken immediately after each other and analyzed as discrete samples. Also, a large sample is taken at the same time and split into 10 sub-samples and analyzed. This approach provides insight into the overall sampling and analysis variability, as well as the variability of the analytical procedure. This approach should be done at a variety of locations in the nonpoint source and agricultural waiver monitoring programs, during the winter under high flow conditions and during the summer under low flow conditions.

Figure 2

Aquatic Chemistry of Chemical Constituents



- Distribution among Species Depends on Kinetics & Thermodynamics of Reactions in the Particular Aquatic System
- Each Chemical Species Has Its Own Toxicity Characteristics
  - Many Forms Are Non-Toxic

A frequent problem that is encountered in water quality studies is that those who organize and control the funding for the studies do not require that the laboratory doing the analyses use adequate sensitivity (detection limits or reporting limits) to detect the constituent of concern at concentrations that are potentially significant in impacting water quality. It is essential, if the data are to be of any value in assessing water quality impacts of a discharge/runoff or of an existing waterbody, that the analytical methods used have adequate sensitivity to detect the constituents of concern at potentially critical levels.

If there are not adequate analytical methods to measure the constituents at the critical levels, then the discussion of the data should reflect this situation so that the reviewers understand that there could be a water quality problem associated with a particular constituent that potentially would not have been detected in the study. There are, however, modifications of most analytical methods which will enable measurements to be made at critical levels. A possible exception to this is the measurement of the organochlorine pesticides and PCBs in water. Unless extraordinary modifications of the standard methods are used, the measurement of DDT, chlordane, dieldrin, etc., will not detect the constituents at their critical levels for their potential to bioaccumulate to excessive levels.

However, this problem is readily addressed through measuring the concentrations of these same chemicals in fish tissue from fish that are resident of the region. The bioaccumulation of these chemicals in fish leads to a readily measurable concentration. It is this bioaccumulation that is of concern with respect to the water quality significance of these chemicals and, therefore, their measurement in fish is a more reliable method of assessing potential water quality problems than trying to measure the concentrations in ambient waters. For effluents, a procedure involving incubation of fish in a flow-through system of the effluent can be used to detect excessive concentrations.

The spring 2002 proposed CVRWQCB (2002a) Phase I agricultural waiver monitoring program is based on monthly sampling. This sampling approach is not reliable to detect the high variability that can occur in the concentrations of constituents in irrigated agricultural runoff/discharges. It was suggested by a representative of the agricultural community at a CVRWQCB meeting devoted to agricultural waiver monitoring that, if monitoring for a particular constituent at a particular location for 12 months did not show a water quality problem, then there would be no need for further monitoring of that constituent at that particular location. The problem with that approach is that for many of the chemicals of concern associated with agricultural use, the application and the runoff are highly episodic, where high concentrations of the potential pollutant occur in the runoff water/receiving waters for only short periods of time. Routine monthly sampling of the type that is proposed by the CVRWQCB staff during the Phase I agricultural waiver monitoring can readily miss highly significant water quality impacts of agriculturally derived constituents, such as pesticides. Short-term releases of pesticides that are not detected by routine monitoring can cause significant adverse impacts on the beneficial uses of receiving waters for the runoff. A single highly toxic pulse, lasting only a few days, can have a disastrous impact on the fisheries-related beneficial uses if it causes adverse impacts to larval fish or larval fish food. Such situations may not be detected by the spring 2002 proposed Phase I agricultural waiver monitoring program.

In order to reliably monitor stormwater runoff-associated constituents and their potential impacts, it is necessary to base the monitoring program on when the constituents of potential concern are applied to the agricultural areas and during stormwater runoff events or other times when there would be expected transport of the constituent of concern from the areas where it was applied. This episodic monitoring requires a significantly different approach and resources than that being proposed by the CVRWQCB staff in their spring 2002 proposed Phase I Water Quality Monitoring Program for Discharges from Irrigated Lands.

The appropriate approach to take in developing a reliable monitoring program for runoff/discharges from irrigated lands, or for that matter, any type of land use, is to first define the constituents that are potentially present in the runoff/discharges that could occur at sufficient concentrations to impair the beneficial uses of the receiving waters for the runoff. Next it is necessary to gain an understanding of when, where and how various chemicals, or sources of potential pollutants, use/apply/release the constituents of concern. Further, there is need to understand, for each constituent defined as a potential pollutant, how that constituent potentially impacts the beneficial uses of a downstream waterbody. With this information, it will be possible to develop a reliable water quality monitoring program to assess whether irrigated agriculture runoff/discharges adversely impact the beneficial uses of the State's waters. Without this critical review and implementation of this approach, the water quality monitoring program can be of limited value in reliably achieving the objectives of the nonpoint source monitoring program and agricultural waiver monitoring program, since it has not been properly designed to meet the objectives of these programs.

Another significant problem with the spring 2002 proposed CVRWQCB irrigated agriculture Phase I water quality monitoring program is that many of the monitoring stations represent agriculturally dominated waterbody discharge points near where the constructed or natural drain/creek discharges to the State's mainstem waters. This sampling does not provide the upstream information on specific sources or practices that can cause excessive concentrations of the constituents at the monitoring point. It is inappropriate to assume that there are no upstream water quality problems caused by irrigated agricultural runoff/discharges just because monitoring at the drain discharge point did not detect a problem. Since upstream tributaries can be important fish and other aquatic life reproduction/development areas, and since chemicals used in one part of a watershed can cause localized water quality impacts, it is important to evaluate whether waters from other tributaries which may not have the chemical at critical concentrations or at any concentration are diluting the concentrations at the downstream monitoring point sufficiently so that the interpretation of the data at that location leads to an erroneous conclusion that there are no upstream water quality problems due to the use of that chemical in a part of the watershed.

Rather than the approach using monitoring points only at the *drain*/*basin* levels, there is need to greatly expand the monitoring within a *drain/basin* to define the concentrations of constituents at selected locations within the watershed where there is likely a potential problem based on known chemical use, hydrology and/or waterbody habitat characteristics. This type of information can then be used to focus in subsequent years' monitoring on specific sources/practices within a particular *drain/basin* that are leading to the water quality problems that are occurring downstream.

Further as discussed above in the "Background" to the development of the NPS monitoring plan, it will be necessary to evaluate the adequacy of the implementation of the Plan's management measures. Also, it will be desirable, through the agricultural waiver monitoring program to evaluate the efficacy of a particular BMP or group of BMPs in controlling the water quality impacts of runoff/discharges from irrigated agriculture. For example, if it is desired to determine whether a BMP significantly affects the total amounts of diazinon exported from a particular plot of land during a stormwater runoff event to a 95-percent degree of confidence, then it becomes necessary to monitor a sufficient number of stormwater runoff events for both the untreated and BMP-treated runoff from particular areas to account for the inherent variability associated with such runoff and monitoring. Since the storm-to-storm variability in runoff of chemical constituents from a particular area is high, normally a large number of storms will need to be monitored, for both the untreated and BMP-treated systems over a number of years, to reliably assess whether the BMP is effective in controlling the transport of diazinon from a particular area to the desired degree. Accounting for this variability has to be built into the monitoring program, or else the results of the monitoring program could readily prove to be inconclusive because a sufficient number of studies have not been conducted (or samples collected) to reliably detect a change in diazinon export or impacts as a function of BMP implementation.

One of the issues that need to be addressed is the number of samples that need to be taken during runoff events to adequately describe the maximum concentration in the runoff, as well as the worst-case load and overall load from the stormwater runoff event. The worst-case potential pollutant load relates to the load conditions that lead to the greatest concentration of the potential pollutant in the receiving waters. The worst-case load will be highly dependent on precipitation intensity and duration during a rainfall event. There will be times during a rainfall runoff event when the concentrations in the receiving waters (and, therefore, their potential to cause toxicity) will be the greatest. This may not be related to any significant extent to the overall load transported from the evaluation area for a particular storm. One of the issues that need to be considered as part of any evaluation of potential impacts of irrigated agricultural runoff/discharges is the relationship between the worst-case load of the constituent of concern and the overall load during a period of time.

Trend Analysis. One of the objectives of water quality monitoring is an assessment of trends. While this terminology is often used as part of discussing a justification for a monitoring program, rarely are monitoring programs established that have any potential for reliably detecting trends in water quality data, especially associated with stormwater runoff from agricultural and/or urban areas. In order to reliably assess a trend in the data over time or as a function of the implementation of control technology for discharges, it is necessary to have a sufficient database at any one time to be able to reliably detect a change in concentration at another time. A sample collected once each month from an agricultural drain, for almost all parameters will show high variability. This variability will need to be considered in determining how many samples are needed to detect a change in concentration with a certain degree of reliability.

Considerable attention has been given recently in urban stormwater runoff water quality monitoring to the monitoring frequency and duration to be able to detect a statistically significant change in the concentration associated with a runoff management program. The key issue that needs to be evaluated is the probability (statistical power) of detecting a specific change in concentration with a certain statistical confidence (see NRC, 1990). It has been found (Suverkropp, 1998) that, for certain key parameters such as copper and organophosphate pesticides (diazinon, chlorpyrifos) in urban stormwater runoff, which involve monitoring several runoff events per year, 20 or more years of monitoring would be needed to detect a 15 to 30 percent reduction in the concentration of the constituents in the stormwater runoff. Similar situations would be expected for detecting trends/changes in stormwater runoff from irrigated agriculture.

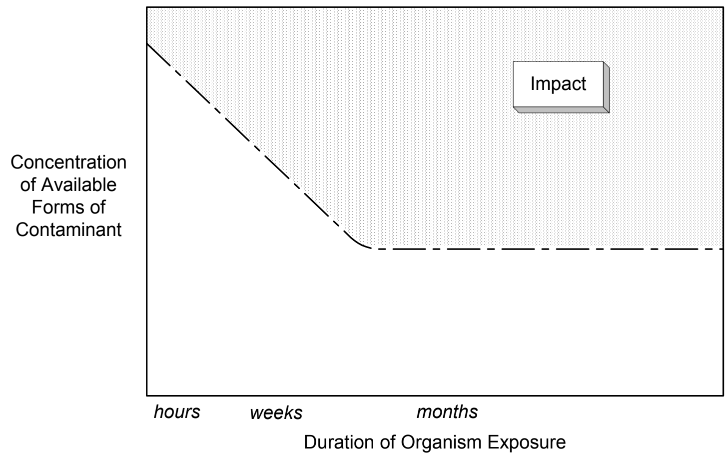
A common mistake that is made in "water quality" trend analysis is to assume that trends in the concentration of a chemical directly relate to trends in changes in the water quality (the impact of that chemical on the beneficial uses). It is indeed rare (if ever) that a chemical concentration measured at one time or over time is directly related to the water quality impacts of the chemical. As discussed herein, there are a variety of factors that relate chemical concentrations to water quality impacts (see Lee and Jones-Lee, 1999).

One of the purposes of the proposed agricultural waiver monitoring program is to detect violations of water quality objectives, including aquatic life toxicity in the receiving waters caused by pesticide runoff/discharges. As shown in Figure 3 (Lee, *et al*., 1982a,b), toxicity/impact has a concentration/duration-of-exposure component that must be considered in evaluating the reliability of the monitoring program to detect aquatic life toxicity in the receiving waters for the runoff.

Some individuals in the stormwater runoff water quality management field use what is called an "event mean concentration" to estimate total loads of chemical constituents. While this approach is appropriate for estimating total loads, it is not appropriate to evaluate water quality impacts of the loads, since it is not the average concentration over a runoff event that determines toxicity or many other impacts. For those monitoring programs where there is interest in evaluating the water quality impacts of those loads, a critical evaluation needs to be made as to the concentration/duration-of-exposure in the receiving waters which would have the greatest impact on their beneficial uses.

Another common mistake that is made in trend analysis, as well as other analysis, of water quality data is to attempt to use the median or mean concentration of a constituent over time as a reliable indicator of water quality. The median or mean concentration is not a reliable indicator of the potential impacts of a constituent on the water quality/beneficial uses of waterbodies. Erroneous conclusions can readily be developed from using median/mean concentrations to compare sites within a waterbody's watershed, or over time, as in a trend analysis. As discussed above, for potentially toxic constituents, the concentrations of available (toxic) forms and duration of exposure of potentially sensitive organisms must be analyzed to properly detect changes in water quality between locations or over time. The monitoring program that is established for aquatic life toxicity must generate data needed for this type of analysis if it is to be reliable in assessing the impacts of potentially toxic constituents, such as pesticides in agricultural runoff, on aquatic life.

Figure 3
Concentrations of Toxicant, Duration of Exposure Impact Relationship



ISSUES:

- What Is Impact of Toxicant on Numbers, Types & Characteristics of Desirable Aquatic Life?
  - Direct & Higher-Trophic-Level Impacts
  - Impacts on Zooplankton That Are Essential, Non-Replaceable Food for Larval Fish
  - Consider both Acute & Chronic Impacts
- Does This Impact Represent a Significant, Adverse Impact on Beneficial Uses of Waterbody Fisheries & Other Aquatic & Terrestrial Life of Importance to the Public?

Review of Existing Data

Before finalizing a monitoring program, a systematic effort should be made to collect and carefully review all existing data pertaining to the area of the study. The data collected in previous studies, even though inadequate to achieve the objectives of the present study, can still be of significant value to present and future studies to help plan these studies. For example, the existing data can help define the general concentration range of specific parameters expected, the variability of parameters in the area and with water depth in the system, and the general characteristics of the system. Such information can be a useful guide for determining the proper number, depth and location of the samples. In reviewing the results of previous studies, it is important to also examine the details of how the studies were conducted, analytical methods used and pertinent prevailing characteristics. Such examination can yield useful information on planning the current studies. As discussed in this report, however, the use of poor or inadequate sampling or analytical techniques in previous studies does not provide justification for their continued use; continued use of inappropriate approaches does not render data that are more "comparable" with previously collected data.

List Factors that Can Influence Results of the Study

Water quality characteristics in particular waterbody types tend to behave according to certain fairly well-defined principles of physics, chemistry and biology. While the details of many of the processes may not be fully understood, there is considerable knowledge about them and how they influence the manifestation of "water quality" which should be used to develop a more reliable/efficient monitoring program. Understanding these processes should allow a better assessment to be made of the significance of changes in concentration and distribution of contaminants between sampling dates, and whether changes in concentrations measured are related to a natural driving force or result from man's activities and are hence potentially controllable.

For each sampling point, an estimate should be made of the expected range of concentrations of the parameters being measured and, most importantly, the factors influencing these concentrations. This information should be used to guide the development of the monitoring program, to be certain that it covers the conditions that are likely to be encountered in the study.

Verify that Analytical Methods are Appropriate

It would be ideal if the analytical methods used were certain to quantify the forms of the contaminants that are of importance to water quality and if they were equally appropriate for all types of waters. Unfortunately, this is rarely the case. Far too often methods selected for making the various chemical and biological/toxicological measurements associated with a study program are simply and arbitrarily chosen from compendia of "standard methods" such as those of the US EPA, APHA *et al.* (American Public Health Association, American Water Works Association, and Water Environment Federation), or ASTM (American Society for Testing and Materials) and presumed to be suitable for the situation under investigation because they are "standard methods." The authors have termed this the "Standard Method syndrome" (Lee, 1969; Lee and Jones, 1983a). However, the fact that an analytical procedure or methodology is appropriate for some situations or types of water and hence included in a compendium of methods, does not make it necessarily suitable for any particular situation or purpose. Further, even if a chemical analytical procedure selected were demonstrated to be reliable for the type of water involved, it may or may not measure forms of the contaminant that are of water quality significance.

An example of problems with using "standardized" analytical methods without evaluating whether the method is subject to interferences present in a sample is the situation that was recently reported by the US EPA in the analysis of arsenic in groundwaters located near the Lava Cap Mine Superfund site, Nevada City, CA. This situation is described in a US EPA (2002a) Region 9 Lava Cap Mine newsletter, November, 2002. This newsletter is devoted to discussing arsenic contamination of domestic water supply wells in the Lava Cap Mine area. An excerpt from this newsletter is presented below.

> *"**Uncertainties in well water analysis***
>
> *"EPA used its own Region 9 laboratory to analyze the May 2002 samples, rather than the contract lab used for previous rounds of sampling. This raises the question of whether the results are due to the change in laboratories rather than a change in the water. To answer this question, EPA investigated whether the apparent results were caused by different techniques used in the different labs.*

"The results of this analysis are now in. EPA's Region 9 laboratory recently determined that high concentrations of calcium in some samples interfered with the analysis, adding several parts per billion to the sampling results. It therefore appears that the arsenic levels in the affected wells are not rising as the original results had indicated. The laboratory will re-analyze these samples to confirm this conclusion (standard operating procedure requires the laboratory to keep water samples on hand following the initial analysis for exactly this reason). EPA will be sending letters to the affected well owners to provide the results of the corrected analysis."

In summary, the US EPA Region 9 laboratory has found that the analysis of arsenic in a number of domestic water supply wells in the Lava Cap Mine area has been in error, due to interference by calcium, which caused the arsenic concentrations to appear to be elevated above the water quality standard (drinking water MCL). The reason that this was found was that the analyses by a commercial laboratory, also using a "standardized" procedure (which was not subject to the calcium interference), had found arsenic levels in a number of these wells below the drinking water MCL. Ordinarily, errors of this type go unnoticed, because there is no basis for a comparison to other analyses on the same sample. The US EPA Region 9 laboratory that conducted these analyses followed standard US EPA QA/QC and QAPP procedures.

It is the experience of the senior author (G. F. Lee) that problems of this type frequently occur where those conducting the studies do not properly evaluate whether the analytical results are reliable. It is recommended that, if the analytical results are near a critical value, further studies need to be done to evaluate the reliability of the analytical procedures that are used, through independent analysis.

Similarly, while a toxicity assessment approach (toxicity test) may be appropriate for some situations, it may not provide a reliable assessment of the toxicity or other impact under the conditions of exposure, concentration and chemical form that exist at the site under investigation. Therefore, a water quality monitoring program must incorporate an appropriate evaluation of the applicability of the analytical methods selected to make various chemical and biological measurements in the study program.

Some investigators select an analytical technique simply because that technique had been used in a previous study; the belief is that even if the method is not reliable, use of the method will allow a comparison to be made with the previously collected data. The fallacy of that approach is obvious; if the method is unreliable, the use of data generated by it will render unreliable assessments. Using one method to obtain results comparable to those of another investigator does not relieve the investigator of the responsibility of evaluating the reliability of the method in the system under investigation.

Even if a previously conducted study included an evaluation of the reliability of the analytical procedure, the procedure still may not be reliable for the present study. One reason for this is that the water analyzed in the previous studies may have had insignificant amounts of chemicals that would interfere in the analysis, while another water could have a different amount or type of interference. Therefore, even though the same analytical procedure was conducted on both waters, the results may not be comparable, owing to the amounts or types of interference present.

Those familiar with the development and use of chemical analytical methods for waters, wastewaters, sediments, and sludges know that the presence of chemical interferences is a fairly common problem that causes "standard methods" to provide unreliable information on the concentration of the water quality characteristic(s) being investigated. Such interferences, when known, are often noted in standard methods compendia such as APHA, *et al.* Further, Standard Methods for the Examination of Water and Wastewater (APHA, *et al*., latest edition) as well as other compendia of "standard methods" incorporate methods deletions and changes with almost every edition. Changes in methods are often associated with the identification and elimination of chemical interferences that cause the method to yield unreliable results when applied to some waters.

Contract commercial and in-house laboratories typically mechanically process samples using some "standard method" without any regard, or sufficient regard, to whether the use of the methods on the specific sample analyzed produces reliable data for the parameters in the water being investigated. Many regulatory agencies require that US EPA-approved analytical methods be used to generate water analysis data associated with NPDES permits. While those methods produce satisfactory results for many waters and wastes, it is inappropriate to assume that they are reliable for any particular sample.

In general, compendia of standard methods from various agencies or organizations should be used only as a guide to analytical procedures that have been found to have applicability to a variety of waters. The investigator is responsible for conducting the evaluation necessary to be certain that the analytical method is applicable to the particular waters under investigation. It is important to involve analytical chemists familiar with properly conducting water quality studies in helping to develop the monitoring program. Such involvement can significantly improve the reliability of the data generated through the study program.

In addition to selecting the sampling techniques and analytical methods, the investigator should also select with care and consideration the methods that will be used for the preservation and storage of the samples. As prescribed for the analytical methods, the investigator should determine whether the methods selected are adequate for the particular study. It should not be assumed that the US EPA sample preservation and storage methods prescribed for NPDES permit-associated samples are applicable to the investigator's situation.

Adequate Funding

Once the objectives of the monitoring program are clearly defined and the general characteristics of the site to be evaluated are known, then an assessment has to be made as to the number, types, locations, frequency, etc., of sampling that is to be conducted to achieve the desired objectives. This is the first phase of establishing the budget for the monitoring program. It is important that this approach be followed and not the traditional approach of establishing a budget and then developing a monitoring program to fit the budget. That approach is a primary cause of the failure of most water quality monitoring programs to provide definitive information on the water quality characteristics of the system being monitored. So long as program administrators are led to believe that the *ad hoc* monitoring program, which is budget-driven, provides reliable information, water quality monitoring programs will continue to yield limited results compared to those needed to achieve the objectives of the study. Programs of this type are largely chemical constituent monitoring programs that provide limited information on water quality/beneficial use impairment. Those responsible for developing true water quality monitoring/evaluation programs should work with the program administrators in defining the monitoring program goals and then informing the program administrators what it will cost to achieve those goals with an adequate degree of reliability.

If insufficient funds are available to achieve the goals with a desired degree of reliability, then, rather than cutting back on the monitoring program to match the funds available while maintaining the original program goals, the monitoring program goals should be redefined to match the funds available considering the variability of the system being monitored. This approach leads to an iterative monitoring program development, where the monitoring program goals and the funding available are properly matched.

Baggett's (2002) announcement of the State Board making available $1 million to support agricultural waiver monitoring will cover part of the first phase of this program. Much larger funding levels will ultimately be needed to achieve the requirements that the State Water Board and the CVRWQCB have defined as the goals of the agricultural waiver monitoring program.

Evaluating Water Quality Impacts of Agricultural Runoff/Discharges

One of the most important aspects of developing a credible water quality monitoring program is an evaluation of the approaches that will be used to determine whether there are significant water quality impacts caused by the constituents in irrigated agriculture stormwater runoff and water discharges. This is an important component of developing the proposed NPS and the agricultural waiver monitoring program. This information is essential to evaluating whether WDRs are needed for irrigated agricultural runoff/discharges. The development of a comprehensive, reliable water quality evaluation program with respect to exceedances of regulatory requirements and/or impacts on beneficial uses requires that a clear understanding of how the data will be used be available at the time of monitoring program development, and the monitoring program be developed accordingly to support this use. Far too often there is a disconnect between those who develop water quality monitoring programs and those who use the data generated in such a program to make regulatory decisions.

In the case of the agricultural waiver monitoring, the CVRWQCB staff, with possible guidance by the Board, needs to consider how they are going to use the data generated from the monitoring program to determine whether agricultural waivers of WDRs should be continued. An assessment should be made in the near future of the type of information that the Board needs by December 31, 2002, to determine whether WDRs should be issued to all or to some agricultural dischargers or whether the waiver from WDRs can be extended for all, or some, agricultural discharges/runoff. It is suggested that, because of the importance of this issue in helping to guide the development of the water quality monitoring program, the staff and Board develop a set of realistic synthetic data of the type that is likely to be generated at Central Valley representative monitoring points for the constituents of concern. This synthetic data then would be used in a mock decision-making process on the continuation of agricultural waivers for discharges from certain types of irrigated agricultural activities.

The development of realistic synthetic data can readily be based on what is already known. For example, for virtually all waterbodies in the Sacramento River and San Joaquin River watersheds where diazinon/chlorpyrifos is used to any substantial extent, the concentrations of diazinon/chlorpyrifos in the State's waters will at some time and place be sufficiently high to cause aquatic life toxicity. This arises from the fact that under current agricultural practices, it is virtually impossible to use diazinon/chlorpyrifos as a dormant spray without causing runoff waters to be toxic as measured in toxicity tests and/or to be potentially toxic based on the concentrations found relative to the CA Department of Fish and Game recommended water quality criteria. Those familiar with the organophosphate (OP) pesticide toxicity problem in the Central Valley question the need to conduct additional aquatic life toxicity and/or diazinon/chlorpyrifos measurements as proposed in the staff's draft plan, since there will be exceedances of the narrative objective for toxicity and/or the Department of Fish and Game's recommended criteria in the State's waters near where diazinon is used as a dormant spray in an orchard. As structured now, such exceedances are a violation of the CVRWQCB's agricultural waiver policy of not causing toxicity in the State's waters.

An issue that needs to be addressed by the staff and Board is what will be done with the monitoring data on aquatic life toxicity/diazinon/chlorpyrifos with respect to the agricultural waiver continuance/termination next December. Clearly, if any substantial amount of diazinon is used in an agricultural drain or agriculturally dominated-waterbody watershed as a dormant spray, and the monitoring program does not detect it in runoff waters, the monitoring program is deficient and needs to be improved. If it is found that the climate during the particular year is such that there is no major runoff event following application of diazinon to orchards in a particular agricultural drain watershed, there is little doubt that the next year or sometime in the future with continued use there will be climatological conditions that lead to measured aquatic life toxicity and/or exceedance of water quality criteria/objectives that are currently being used to determine excessive concentrations of diazinon and chlorpyrifos in the State's waters.

The issue of the reliability of the monitoring program to detect aquatic life toxicity needs to be examined relative to how the data will be used by the Board. It appears that at this time there is already sufficient information for the Board to determine that any substantial amount of use of diazinon/chlorpyrifos in an agricultural drain watershed will cause an impairment of the beneficial uses as defined by current regulatory approaches. This issue is currently being addressed through the diazinon/chlorpyrifos TMDLs for the Sacramento and San Joaquin River watersheds.

For those constituents for which there are Basin Plan objectives, the exceedance of these objectives by any amount more than once every three years is by definition an impairment of the beneficial use of a waterbody. However, for the constituents of major concern in irrigated agricultural stormwater runoff and surface water or agricultural drain discharges in the Central Valley, there are few applicable chemical-specific numeric water quality objectives. A review of this issue for the constituents of potential concern is presented below.

pH. The CVRWQCB Basin Plan establishes a water quality objective (standard) for pH as follows:

> *"The pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses. In determining compliance with the water quality objective for pH, appropriate averaging periods may be applied provided that beneficial uses will be fully protected."*

The pH limitation of 8.5 is more stringent than that listed by the US EPA in its "Gold Book" Water Quality Criteria of 1986 (US EPA, 1987). The Gold Book lists the maximum pH as 9.0. It is known that highly fertile (eutrophic) waterbodies with large algal or other aquatic plant populations frequently have pH above 9.0 during late afternoon, and still have outstanding warm-water fisheries. This does not mean that if the pH did not go above 9.0, the fisheries would not be better; however, as discussed by Lee and Jones (1991), the fish productivity of a waterbody is directly related to algal productivity.

The reason that the pH increases above 8.5 or 9.0 is may be due to algal or other aquatic plant photosynthesis in the waterbody, where in late afternoon, due to the removal of CO_2 in photosynthesis, the pH is increased, while in early morning, due to overnight respiration of the algae, other aquatic plants, bacteria, as well as other organisms, the pH is decreased to the minimum for the day. There is a substantial diel pH cycle in many fertile waterbodies, where the night-to-day change in pH can be several units. It is directly attributable to the fertility (available nutrient concentrations that lead to planktonic algae, attached algae or macrophytes) of the waterbody.

Many of the Central Valley agricultural drains can be expected to have exceedances of pH 8.5 during the spring, summer and early fall months, due to algal photosynthesis. However, the early morning pH could be less than 8.5. It is possible that the violations of the 8.5 maximum pH that would occur in late afternoon could be addressed through appropriate averaging of the daily pH.

The magnitude of the diel pH change in a waterbody is dependent on the intensity of photosynthesis, which, in turn, is related to the planktonic and attached algae, as well as higher aquatic plants (such as macrophytes), sunlight intensity, duration of sunlight, season of the year and the alkalinity of the waterbody. Alkalinity is the sum of the hydroxide, bicarbonate and two times the carbonate concentration, which, when combined with pH, determines the buffer capacity of the waterbody and, therefore, its ability to resist pH change from addition of acid or base to the waterbody or from photosynthesis. Alkalinity in many areas is related to hardness, since it is derived from the weathering of limestone (calcium carbonate).

In much of the Central Valley, especially on the eastern side, the hardness and alkalinity of the waters are low, with the result that they have limited buffer capacity. This limited buffer capacity would allow agricultural drains and agriculturally dominated waterbodies, as well as effluent-dominated waterbodies, to experience substantial diel pH changes as a function of photosynthesis. Since agricultural drains and agriculturally dominated waterbodies would tend to be high in nutrients during the irrigation season, it can be expected that there will be frequent violations of the CVRWQCB Basin Plan objective limiting the pH to 8.5. This exceedance of the pH value is related to the nutrients discharged to the agricultural drains and agriculturally dominated waterbodies from agricultural activities, as well as any urban or industrial/ commercial wastewater discharges to the waterbody.

The Regional Board is considering recommending a basin plan amendment to remove the words, "*Changes in normal ambient pH levels shall not exceed 0.5 in fresh waters with designated COLD or WARM beneficial uses.*" The allowable pH range 6.5 to 8.5 would remain the same. NPDES dischargers are not required to correct background exceedances of the water quality objective. However, NPDES discharges are required to stay in the pH range.

The CVRWQCB staff and board may wish to determine how they are going to address exceedance of the pH WQO with respect to implementation of further agricultural waivers from WDRs covering irrigation return water discharges. Strict enforcement of the current pH 8.5 water quality objective will require nutrient control programs from irrigated agriculture tailwater releases.

While the focus of the proposed Basin Plan amendment for pH is domestic wastewater effluent-dominated waterbodies, agriculturally dominated waterbodies and agricultural drains may also have elevated pH above 8.5 due to algal photosynthesis. The Regional Board staff have been allowing a NPDES-permitted discharger that faces the problem of elevated pH above 8.5 that is due to algal photosynthesis to demonstrate that algal growth is the cause of the elevated pH and thereby be exempt from having to come into compliance with respect to the pH water quality objective downstream of the discharge due to algal photosynthesis. A similar approach may be needed for agriculturally dominated waterbodies.

Color. The Basin Plan objective for color is, *"Water shall be free of discoloration that causes nuisance or adversely affects beneficial uses."* The California Department of Health Services drinking water limit for color is 15 units. Since DHS drinking water MCLs are incorporated as CVRWQCB Basin Plan objectives, color in excess of 15 units in a waterbody that has a domestic water supply beneficial use designation (MUN) is a violation of the Basin Plan. Many waterbodies in the Central Valley, either directly or through the Tributary Rule, carry a domestic water supply beneficial use designation.

There are a variety of factors that could influence color concentrations. Color measurement is not a well-defined assessment of a specific parameter. It is an overall characteristic of water, where the measurement measures a number of water characteristics which are summed together as a "color" response. The individual components that make up the color response, including turbidity, light-scattering, different types of colored materials, can vary with season, location and flow regime. A key issue of concern is the drainage from wetland or vegetated areas, which is often high in color. Appreciable color can be associated with agricultural drains. Further, during elevated flow, the increased inorganic turbidity is measured to some extent as a color response, through light scattering.

While any agricultural stormwater runoff and irrigation water releases that contain color, or for that matter, odor (discussed in the next section) above the DHS MCL is a violation of a Basin Plan objective, for many situations in the Central Valley, this violation does not represent an impairment of the beneficial uses of the State's waters, since the regions where the color and/or odor occurs are not now being used for domestic water supply purposes, and these constituents do not cause downstream water quality use impairments in waterbodies that are used for domestic water supply purposes. Under these conditions, the exceedance of the water quality objective for color or odor is an administrative exceedance. The Board may wish to develop an approach for addressing situations of this type.

Tastes and Odors. The CVRWQCB Basin Plan objective for tastes and odors is,

> *"Water shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to domestic or municipal water supplies or to fish flesh or other edible products of aquatic origin, or that cause nuisance, or otherwise adversely affect beneficial uses."*

The DHS (2001) drinking water standard for odor is 3 threshold odor units (TON). As discussed above with color, agricultural drain waters may contain sufficient odorous compounds to cause a violation of the CVRWQCB water quality objective for MUN-designated water for odor (3 TON); however, this may not be a significant adverse impact on the beneficial uses of those waters or downstream waters. A site-specific investigation will be needed to evaluate this situation.

Salinity/Total Dissolved Solids (TDS). The total dissolved solids, total salts, salinity and electrical conductivity are all related parameters for measuring the total salt content of waters. One of the purposes of irrigated agriculture tailwater releases is to prevent salt buildup in the fields, which would be damaging to the crops. These salts, however, can be damaging to downstream water users, including agriculture, aquatic life and domestic water supply as well as ground waters. The CVRWQCB (2000) provides some information on water quality goals for the use of water in agriculture.

The CVRWQCB's water quality objective for salinity applies to a particular waterbody, such as the Sacramento River, San Joaquin River, etc. The California DHS has a secondary drinking water MCL for TDS of 500 mg/L as a recommended value, with an upper range of 1000 mg/L, and allowing short-term excursions to 1500 mg/L. The CVRWQCB (Oppenheimer and Grober, 2002) has adopted a TDS (electrical conductivity) objective for the San Joaquin River at Vernalis of a 30-day running average of 1000 μS/cm for September 1 through March 31, and 700 μS/cm for April 1 through August 31. The more stringent objective relates to the impact of TDS on irrigated agriculture. Typically, TDS is equal to the electrical conductivity in μS/cm (μmhos/cm) times 0.6 to 0.8. Since the San Joaquin River at Vernalis at times violates this objective, a TMDL is being developed to control salt discharges in the San Joaquin River watershed.

The type of salt components is an important parameter that needs to be evaluated. Of particular concern is the ratio of sodium to the calcium and magnesium content of the water.

High-sodium waters tend to adversely impact the ability of soil to accept water. The agronomy field has developed the sodium adsorption ratio (SAR) which is the ratio of the equivalence of sodium to the equivalence of calcium plus magnesium. This issue is reviewed in the US Department of Agriculture (USDA, 1969) Handbook 60, which has been updated by Tanji (1990). Waters with a high SAR tend to cause crop production problems.

An issue of concern with respect to the discharge of salts in the Sacramento and San Joaquin River watersheds and within the Delta is the impact of salts on the use of water for domestic water supply purposes. There are about 22 million people that use exported Delta water for domestic water supply within the State. Increases in the total salt content of Delta and its tributary waters are a potential impairment to those water utilities that want to recharge domestic wastewaters to the groundwater basins of the area. The Metropolitan Water District of Southern California and other water utilities in Southern California are particularly sensitive to increases in salt in Delta waters. The salts in the Delta water coupled with the normal increase in salt of several hundred mg/L when waters pass through a city can limit the amount of groundwater recharge because the total salts can exceed the Southern California Regional Board's 500 mg/L Basin Plan objective for groundwater recharge.

An issue of concern in implementing the control of salt runoff/discharges from irrigated lands is the potential to cause increased groundwater pollution by salts. As discussed in a subsequent section, it will be important in implementing the control of salt discharges from irrigated lands to be certain that the control practices do not lead to increased groundwater pollution by salts. Letey (1994) has presented a review of managing groundwater quality associated with irrigated agricultural practices. He points out that, while it is possible through appropriate irrigated agricultural practices to minimize groundwater pollution by salts, it is not possible to prevent it and maintain soil productivity. As discussed below, the issue of groundwater pollution by salts and nitrate associated with irrigated agriculture is an issue that the Board will need to address as part of evaluating the results of the agricultural waiver monitoring program.

In evaluating the reliability of assessing the total salt content of a waterbody, it is often useful to compare the total estimated electrical conductivity of the water to the measured electrical conductivity. Electrical conductivity of most fresh waters is made up primarily by the sodium, calcium, magnesium, sulfate, nitrate and chloride content. Standard Methods (APHA, *et al.*, 1998) provides a table of equivalent electrical conductivities which can be used to convert the concentrations of the dominant cations and anions to their equivalent electrical conductivity. If there is a major discrepancy between the sum of the equivalent electrical conductivities and the measured value, then there is need to do additional work to determine the source of the discrepancy/error.

Another useful check on the reliability of salinity measurements is an assessment of the charge balance. The total equivalence of cations should equal the total equivalence of anions. If it does not, then there are problems with the analysis that need to be investigated.

Another factor to consider is the effect of temperature on electrical conductivity. Typically the electrical conductivity of a sample changes from 2 to 3 percent per degree C.

While many conductivity meters have built-in temperature compensation, this temperature compensation assumes that the water has a certain composition which, for most cases, is adequate, but there may be situations where it is not adequate. It is important to report the temperature at which the measurements are made (i.e., 20 or 25ºC) and/or are corrected to.

Total Suspended Solids (TSS) and Turbidity (NTU). NTU is a nephelometric turbidity unit. The TSS and NTU are related parameters, in that the measurement of total suspended solids in a sample is somewhat related to the light scattering as reported in NTU. As a rough approximation, 1 mg/L of TSS in the form of finely divided silica of a certain type is equivalent to about 1 NTU. There are large variations in this relationship, depending on the characteristics of the suspended solids and how the NTU measurements are made. NTU is a standardized parameter for measuring light scattering that does not necessarily measure a definitive property. There are different turbidity measurement techniques which yield different NTU results on the same sample, which are all reported as "NTU" without reference to the technique used for measurement.

The CVRWQCB limits sediment, settleable materials and suspended materials so that they "*…do not cause a nuisance or adversely affect beneficial uses*."

The CVRWQCB Basin Plan limitations for turbidity are,

"Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases in turbidity attributable to controllable water quality factors shall not exceed the following limits:

- *Where natural turbidity is between 0 and 5 Nephelometric Turbidity Units (NTUs), increases shall not exceed 1 NTU.*
- *Where natural turbidity is between 5 and 50 NTUs, increases shall not exceed 20 percent.*
- *Where natural turbidity is between 50 and 100 NTUs, increases shall not exceed 10 NTUs.*
- *Where natural turbidity is greater than 100 NTUs, increases shall not exceed 10 percent."*

In order to evaluate whether there is a violation of the turbidity requirements, it is necessary that sampling be conducted prior to and during the stormwater runoff event. Without that sampling pattern, it will be difficult to properly assess whether the percent increase in turbidity allowed in the CVRWQCB Basin Plan has occurred.

One of the impacts of turbidity on water quality is with respect to its adverse impact on the use of turbid waters for domestic water supply. Waters with substantial turbidity require additional cost for treatment to remove the turbidity at the treatment works.

Some agricultural tailwater and especially stormwater runoff will have sufficient turbidity to cause receiving waters for the runoff/discharges to violate the CVRWQCB water quality objective. It is important to note that turbidity and this objective were specifically delineated in the CVRWQCB Resolution No. 5-01-236 as issues of concern in evaluating the need for WDRs on irrigated agriculture discharges/runoff. It is expected that enforcement of the Basin Plan turbidity objectives will require substantial efforts to control turbidity in stormwater runoff from irrigated agriculture for discharges in the headwaters of Sacramento and San Joaquin River tributaries. Eventually this situation will be applicable to the downstream waters as headwater areas begin to effectively control erosion/turbidity discharges to the State's waters.

Bryan and Rasmussen (2002) have developed a draft report in support of an amendment to the water quality control plan for the Sacramento River and San Joaquin River basins for pH and turbidity at Deer Creek in El Dorado and Sacramento Counties. This report supports a Basin Plan Amendment to develop a site-specific turbidity objective for Deer Creek of a daily average of 2 NTU, with a daily maximum of 5 NTU, where natural turbidity is between 0 and 5 NTU. The change is principally that of, instead of restricting the daily average to 1 NTU, it is now allowed to be increased to 2 NTU. According to Briggs (pers. comm., 2002), the Regional Board staff is considering recommending a basin wide basin plan amendment to modify the 0-5 NTU range.

A factor influencing the magnitude of algal growth/biomass in a waterbody is the turbidity of the waterbody. There are a number of waterbodies in the Central Valley, such as the San Joaquin River, where algal growth is limited by light penetration, which is controlled by turbidity from upstream erosion of the River and tributary channels and adjacent lands. As erosion control is more effectively practiced in a watershed, it can be expected that this would lead to increased algal growth, increased photosynthesis and increased diel pH changes. This in turn could lead to increased need to control algal nutrients (nitrogen and phosphorus compounds) in irrigated agriculture stormwater runoff and tailwater and drain water discharges. As discussed by Lee and Jones-Lee (2002b), this issue may become important in the San Joaquin River watershed as it relates to the low DO in the Stockton Deep Water Ship Channel.

One of the issues of concern with respect to excessive suspended sediment is the potential for it to have an adverse impact on aquatic life habitat. High suspended sediment loads can, in quiescent areas, settle and significantly adversely impact the characteristics of a spawning bed and/or the growth of fish food organisms.

Sampling of suspended sediment in a stream is rarely done correctly. In order to reliably sample suspended sediment concentrations, it is necessary to use isokinetic sampling. Under isokinetic sampling, it is necessary to match the intake velocity into the sampling device to the velocity of the water. Failure to achieve this match will result in either oversampling suspended sediments, or undersampling, depending on the direction of the difference between the sampling device intake velocity and the surrounding water velocity. Since the velocity of water in the water column is often a function of depth, this means that the velocity of the intake for the sampling device has to be adjusted as a function of depth if it is desired to properly sample the suspended solid load/concentration in the water column. The USGS has developed samplers of this type; however, they are rarely used in conventional water quality monitoring by others.

Based on information provided by Dileanis (pers. comm., 2002) of the USGS, information on USGS sediment sampling techniques is provided at the following URL:

http://water.usgs.gov/owq/FieldManual/

He indicates that the USGS D-77 sampler is used on the San Joaquin River unless the water velocities are lower than the minimum required for isokinetic sampling (1.5 ft/sec). Under those conditions, the USGS uses a weighted bottle sample, which integrates through the water column. Information on acquisition of the D-77 sampler is available from http://fisp.wes.army.mil/ (click on catalog index and find D-77).

A rule of thumb that is used in sediment transport studies is that 90 percent of all sediment transport occurs in about 10 percent of the flow. The highest sediment loads are associated with the very high flows. This is related to the high erosion that occurs with these flows and the sediment carrying capacity of the waterbody.

Another significant problem in trying to assess sediment load is that, in most situations, much of the sediment load moves as bed load near the bottom of the waterbody. It is virtually impossible, without special construction at the sampling site, to reliably assess bed load of suspended sediments.

Measurements should be made of the Secchi depth at the point of sampling. Secchi depth is measured using a 20 cm diameter weighted metal or plastic plate connected to a marked, metered line. The Secchi disk has alternating black and white quadrants. It is lowered into the water column until it is not possible to distinguish between the black and white quadrants, and the depth of the water where this occurs is one measurement of Secchi depth. It is continued to be lowered below this depth, and then raised to where the black and white quadrants are just visible. The depth is again recorded, and the average of the two readings is the Secchi depth. Secchi depth values can be related to the planktonic algal chlorophyll in the absence of inorganic turbidity. Lee, *et al*. (1995) have developed relationships which relate planktonic algal chlorophyll to Secchi depth. If the Secchi depth is less than the Lee, *et al*., relationship, then the sample contains non-algal particulates which cause light scattering/adsorption.

Nitrate. The California DHS drinking water MCL for nitrate is 45 mg/L as NO_3 (10 mg/L as N). This primary drinking water standard is based on protecting children from methemoglobanemia (blue babies). Some waters in the San Joaquin River watershed, especially from westside tributaries of the San Joaquin River and constructed agricultural drains, contain nitrate at several mg/L N. Further, some of the irrigated agriculture tile drain waters contain nitrate above the drinking water MCL.

While not a water quality criteria/standard at this time, the US EPA (2001a) and Grubbs (2001) have indicated that states must, by 2004, have developed or be well on their way to developing chemical-specific numeric nutrient (nitrogen and phosphorus) criteria which would protect the beneficial uses of waterbodies from excessive fertilization/growth of algae and water weeds. At this time, the CVRWQCB's Basin Plan objective for controlling excessive fertilization of waterbodies is a narrative objective:

> *"**Biostimulatory Substances***
> *Water shall not contain biostimulatory substances which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses."*

Nutrients have been specified in both CVRWQCB Resolution No. 5-01-236 and by the staff in their December 2001 and February 2002 draft agricultural waiver monitoring programs as parameters that are to be monitored. The actual chemical species that are to be monitored have not thus far been defined. The authors (Lee and Jones-Lee) have been involved in excessive fertilization (eutrophication) investigation and management programs, for the senior author, for over 40 years. Based on this experience, they recommend that the soluble orthophosphate with a detection limit of 5 μg/L P, total P, total Kjeldahl nitrogen (ammonia plus organic nitrogen), ammonia and nitrate plus nitrite should all be measured. The Kjeldahl nitrogen should be measured with a detection limit of 0.5 mg/L N, ammonia at 0.1 mg/L N, and nitrate/nitrite at 0.1 mg/L N.

Nitrite. The California Department of Health Services has a primary drinking water MCL for nitrite of 1 mg/L as N, with a further constraint that the nitrate plus nitrite shall not be greater than 10 mg/L N. This is applicable to CBRWQCB water center that have a designated beneficial use as MUN. The conversion factor between nitrite as NO_2 and nitrite as N is 3.3. The concentrations of nitrite found in most Central Valley surface waters are typically less than 1 mg/L N. There are exceptions to this downstream of significant inputs of ammonia to a waterbody, where during the winter months, nitrite can build up in the waterbody associated with slow nitrification reactions under cold water conditions. Nitrite is another parameter contributing to nitrogen concentrations, which could be judged to be excessive compared to those that have been found to cause excessive growths of algae.

While not listed as a US EPA water quality criterion or as a CVRWQCB water quality objective, nitrite is well-known to be highly toxic to some forms of fish at about 0.1 mg/L N (Lewis and Morris, 1986; Solbe, 1981). Nitrite can be present in waters above this level during cold weather conditions, associated with the nitrification of ammonia. At this time there is insufficient data to determine whether this is a problem in any Central Valley agricultural drains and/or agriculturally dominated waterbodies. Since normally water quality monitoring programs involve the measurement of the sum of the nitrite plus nitrate, in order to investigate whether there is potentially a nitrite aquatic life toxicity problem, it will be necessary to measure nitrite as a separate chemical species. This can be readily done with Standard Methods (APHA, *et al.*, 1998) procedures.

Ammonia. The California Department of Health Services does not have an ammonia drinking water MCL. The CVRWQCB also does not have an ammonia water quality objective. The US EPA (1999a) revised the ammonia national water quality criteria. The CVRWQCB is considering adopting the revised ammonia criteria into Basin Plan objectives with the revision of the Basin Plan that is currently being developed. The US EPA ammonia criteria depend on temperature and pH. At pH 8.0, the acute (one-hour average) criterion for ammonia, if salmonids are present is 5.62 mg/L N, and with salmonids absent it is 8.40 mg/L N. The acute criterion is not temperature dependent. The chronic (four-day average) criterion at pH 8.0 and temperatures of 16°C or greater, with early life stages of fish present is 2.2 mg/L N. It is unlikely that there would be sufficient releases of ammonia used as agricultural land fertilizer to cause agricultural tailwater to contain excessive ammonia compared to the US EPA water quality criteria. However, since ammonia is one of the forms of nitrogen that the US EPA proposes to consider as part of the chemical-specific nutrient criteria, ammonia should be monitored in agricultural drains/agriculturally dominated waterbodies to establish current levels.

Total Kjeldahl Nitrogen. Total Kjeldahl nitrogen (TKN) represents the organic nitrogen plus ammonia, and typically consists of dissolved and particulate plant and animal protein material. Neither California DHS, the US EPA nor the CVRWQCB have total Kjeldahl nitrogen concentration limits for drinking water or protection of aquatic life. Total Kjeldahl nitrogen, on the other hand, is part of the nitrogen compounds that will be regulated by the US EPA (2001a) through their nutrient criteria that are being developed. According to the US EPA (Grubbs, 2001) these criteria will consider the sum of the total Kjeldahl nitrogen, nitrite plus nitrate, in determining the excessive concentrations of nitrogen compounds in a waterbody. The US EPA's default national criteria being suggested are on the order of 0.1 mg/L N for the sum of these compounds. It is likely that many agricultural drains and some mainstem waterbodies such as the San Joaquin River and its westside tributaries, especially during times of significant algal growth, will contain total Kjeldahl nitrogen in excess of 0.1 mg/L N. Therefore, while TKN is currently not a regulated parameter, concentrations above the detection limit of 0.1 mg/L N would cause or contribute to non-compliance with the default nutrient criteria that the US EPA is suggesting may be required to be adopted by states as water quality standards (objectives), without site-specific investigations to justify another value.

In some waterbodies, such as the San Joaquin River just upstream of the Stockton Deep Water Ship Channel, the TKN is of importance due to the mineralization of the organic nitrogen to ammonia and the nitrification of the original ammonia plus the organic-N-derived ammonia to nitrate. The nitrification reactions consume large amounts of dissolved oxygen, leading to DO concentrations below the water quality objective. Lee and Jones-Lee (2002b) have provided information on this issue for the San Joaquin River Deep Water Ship Channel near Stockton.

Phosphorus. Neither the California DHS, the CVRWQCB nor the US EPA has established MCLs or water quality criteria/objectives for phosphorus in water. The US EPA (2001a), however, has adopted the approach of requiring that phosphorus concentrations in water be controlled in order to prevent excessive fertilization of waterbodies. The Agency is currently requiring that the states must, by 2004, have developed or be well on their way to developing chemical-specific numeric nutrient (phosphorus) criteria which would protect the beneficial uses of waterbodies from excessive fertilization/growth of algae and water weeds (US EPA, 2000c, 2001a; Grubbs, 2001).

The US EPA has suggested, in the absence of site-specific nutrient-based phosphorus criteria, that a default phosphorus criterion of about 0.01 mg/L P be used. The concentrations of total phosphorus in agricultural drains and agriculturally dominated waterbodies, as well as some mainstem waterbodies such as the Sacramento and San Joaquin Rivers, are, at times (and possibly all the time), above the US EPA's suggested recommended default nutrient criterion of 0.01 mg/L as P. While the US EPA proposed nutrient criteria are to be based on total phosphorus, Lee and Jones-Lee (2001a, 2002e) have discussed the fact that much of the particulate phosphorus derived from agricultural stormwater runoff is in a non-algal available form and therefore will not be contribute to excessive fertilization. They have also recommended the approach that agricultural interests may wish to consider in evaluating the potential water quality impacts of phosphorus runoff/discharges from agricultural lands.

Lee and Jones-Lee (2001a, 2002e) have concluded that the adoption of the US EPA default criterion for phosphorus will often lead to gross over-regulation of phosphorus in agricultural and urban stormwater runoff. They have recommended that agricultural interests work with the regulatory agency (in the Central Valley, the CVRWQCB) in developing site-specific phosphorus and nitrogen criteria that would protect the beneficial uses of Central Valley waters without unnecessary expenditures for nutrient control.

Boron. The CVRWQCB (1998) has established a water quality objective for boron in the San Joaquin River between the mouth of the Merced River and Vernalis. The magnitude of this objective depends on the season, and ranges from about 0.8 to 2.6 mg/L. Since the concentrations of boron in this part of the San Joaquin River exceed these values, the CVRWQCB (Oppenheimer and Grober, 2002) have established a TMDL for boron in the lower San Joaquin River. During the irrigation season (April to August) the boron numeric target at Vernalis is 0.8 mg/L, while from September to March, it is 1.0 mg/L.

The California Department of Health Services does not have a primary or secondary MCL for boron, nor does the California Toxics Rule (US EPA, 2000b) include a criterion for boron. The US EPA (1999b) National Recommended Water Quality Criteria-Correction references the US EPA (1987) "Gold Book" as a source of information on the critical concentrations of boron. The US EPA (1987) "Gold Book" lists the boron criterion as 750 ng/L for long-term irrigation of sensitive crops, and points out that some crops, such as citrus, are very sensitive to boron. Table 4 is derived from a Yolo County (1998, 1999) Planning and Public Works Department report. Examination of Table 4 shows that there are a number of crops that are grown in the Central Valley which have a high sensitivity to boron. Boron toxicity can lead to stunted plant growth and reduced crop yields.

Table 4
Boron Tolerance Limits for Local Agricultural Crops

Crop	Threshold at which production may begin to decrease (mg/L)	Tolerance Level
Grapes	0.5	Sensitive (under 1.0 pm)
Prunes	0.5	
Walnuts	0.5	
Beans	0.75	
Sunflower	0.75	
Wheat	0.75	
Barley	2.0	Semitolerant (1.0 to 2.0 ppm)
Corn	2.0	
Melons	2.0	
Oats	2.0	
Alfalfa Hay	4.0	Tolerant (2.0 to 4.0 ppm)
Sugar Beets	4.0	
Tomatoes	4.0	
Cotton	6.0	Very Tolerant (over 4.0 ppm)
Sorghum	6.0	
Asparagus	10.0	

Source: Yolo County (1998, 1999).

Total Coliforms and Fecal Coliforms. Increasing attention is being paid to the sanitary quality of the State's waters, particularly with regard to the use of the State's waters for contact recreation. While this issue has been largely ignored in the past, this situation is changing, primarily as a result of the US EPA's efforts to require that states update and enforce the sanitary quality indicator organism water quality standards. California, like many states, has been badly out-of-date with respect to incorporating more reliable information into protecting those who recreate in the State's waters (swimming, wading, fishing, boating, waterskiing, jet-boating, etc.).

Total coliforms are, at this time, not regulated in Central Valley waterbodies. The California Legislature, however, adopted a total coliform standard for contact recreation, which is applicable to marine waters. There are significant questions about the reliability of total coliforms as a measure of human health hazards associated with contact recreation, since a number of studies have shown that total coliforms and, for that matter, fecal coliforms are not reliable indicators of human health hazards associated with contact recreation (Cabelli, *et al*., 1982; Dufour, 1984; US EPA, 1986). It is expected that the total coliform concentrations in many Central Valley waterbodies, including agricultural drains, would be significantly elevated due to wild and domestic animals, including birds.

Until September 2002, the CVRWQCB (1998) Basin Plan has a water quality objective for fecal coliforms of 200 MPN per 100 ml, for the geometric mean of five samples taken over 30 days. Not more than 10 percent of the samples taken over 30 days shall exceed 400 fecal coliforms per 100 ml. Fecal coliforms would at times be expected in many Central Valley waterbodies, including agricultural drains, to be above 200 MPN per 100 ml. While fecal coliforms are currently being used by the State and Regional Water Quality Control Boards as a parameter for assessing pollution of waters by fecal material, which would be a hazard to contact recreation, it has been known since the mid-1980s (Cabelli, *et al*., 1982; Dufour, 1984; US EPA, 1986) that fecal coliforms are not a reliable assessment of potential human disease associated with contact recreation. The US EPA (1998) is requiring that states adopt a revised contact recreation criterion for fresh water based on the measurement of *E. coli*.

The California Department of Health Services (DHS, 2000) has been developing statewide water quality standards for contact recreation. These were first developed in initial draft form in November 1997, and updated in July 2000. While they have not been finalized/adopted, they provide information on contact recreation water quality standards that could be adopted by the CVRWQCB as part of a Basin Plan Amendment. In September 2002 the CVRWQCB adopted *E. coli* (126 E. coli/ 120 mL) as the basis for regulating the sanitary quality of Central Valley waterbodies. This new objective requires State Water Resources Control Board, Office of Administrative Law and the US EPA approval.

According to DHS (2000),

> ***"B.3 FRESH WATER***
> *The EPA evaluated health effects of microbiological contamination on recreational use of fresh waters (DuFour, 1984). Subsequently it published guidance on water quality for fresh water recreational uses (EPA, 1986).*

"EPA's guidance for fresh recreational waters is based upon an "Acceptable Swimming Associated Gastroenteritis Rate" of 8 cases/1000 swimmers at a steady state geometric mean indicator density of 33 enterococci per 100 ml or 126 E. coli per 100 ml. The rate of 8 cases of illness per 1000 swimmers is estimated to result from exposures to waters containing bacteria using the fecal coliform indicator group at the maximum geometric mean of 200 per 100 ml."

The US EPA (2002b) has recently released for public comment a draft Implementation Guidance for Ambient Water Quality Criteria for Bacteria. According to the announcement, the US EPA expects to finalize this guidance in December 2002. It will be important to consider this guidance in developing a monitoring program for bacterial water quality monitoring.

The US EPA's *E. coli* water quality standard does not adequately address acquiring enteric diseases caused by protozoan pathogens and viruses. Waters that meet the *E. coli* standard can still cause enteric and other diseases through contact recreation. An area of particular concern is the discharge of cattle fecal material, which can contain cryptosporidium, into Central Valley waterbodies. Cryptosporidium is a cyst-forming protozoan that caused over 400 people in Milwaukee to die due to its presence in their domestic water supply that had not been adequately treated to remove this organism. It is believed that the cryptosporidium that got into the Milwaukee water supply was derived from cattle (Lee and Jones-Lee, 1993).

An area of particular concern for irrigated agriculture stormwater runoff and tailwater discharges with respect to impacting the sanitary quality of Central Valley waters would be the use of animal manure and domestic wastewater biosolids (sewage sludge) as a source of fertilizer. Particular attention needs to be paid to whether such practices lead to sanitary quality problems in agricultural drains, agriculturally dominated waterbodies and Central Valley mainstem waterbodies.

Dissolved Oxygen. The CVRWQCB water quality objective for dissolved oxygen depends on the waterbody. It ranges from 5 to 7 mg/L. The basin plan also contains a number of specific dissolved oxygen water quality objectives that are applicable to certain waterbodies within the Central Valley. It should be consulted for further information on the DO WQO particular waterbody.

The San Joaquin River Deep Water Ship Channel near Stockton has had violations of the 5 or 6 mg/L DO water quality objective each summer/fall for over 40 years. These violations are due to city of Stockton wastewater discharges of carbonaceous BOD and ammonia to the San Joaquin River, as well as the development of algae in the San Joaquin River upstream of the Deep Water Ship Channel based on nutrients primarily derived from agricultural land runoff. The DO problem in the San Joaquin River Deep Water Ship Channel is aggravated by upstream diversion of water from the San Joaquin River which reduce the flow through the Deep Water Ship Channel. Also, the construction of the 35-foot deep channel has greatly reduced the ability of the San Joaquin River below the port of Stockton to assimilate oxygen demanding materials that lead to DO WQO violations in the channel. This matter is being addressed through a TMDL which will be developed by the CVRWQCB by June 2003. Additional information on this

TMDL and the DO situation in the Deep Water Ship Channel is provided by Lee and Jones-Lee (2002b).

One of the issues of particular concern to agricultural drains and agriculturally dominated waterbodies will be DO depletions during early morning hours below the water quality objective. However, by late afternoon the DO concentrations in agricultural drains can be above the objective, due to algal photosynthesis. The issue of daily averaging of the DO objective will need to be addressed by the CVRWQCB.

Another DO water quality objective violation issue that will likely need to be addressed in some agricultural drains is DO depletion below the WQO in the near-bottom waters. The sediment oxygen demand of agricultural drains during late summer can potentially be sufficiently high so that there is DO depletion below the WQO in the lower few feet of the drain. Such depletion can occur even though there may be only temporary daily thermal stratification in the water column. Where this occurs, it would be a violation of the Basin Plan requirements.

This situation arises from the growth of algae in the drain, which settle to the bottom, die and decompose, exerting an oxygen demand. It is analogous to the situation that occurs in eutrophic lakes, where the near-bottom waters often have significantly depressed DO concentrations due to sediment oxygen demand. While the US EPA (1987), as part of its "Gold Book" of water quality criteria, allows for DO depletion near the sediment water interface in eutrophic waterbodies, the CVRWQCB Basin Plan does not make provisions for this situation. This is an issue that the Board may need to address. Otherwise, controlling the low DO that occurs near the sediment water interface in an agricultural drain or agriculturally dominated waterbody could require substantial expenditures for control of algal nutrients discharged to the drain/waterbody from irrigated agriculture during the summer months.

Biochemical Oxygen Demand (BOD). The biochemical oxygen demand (BOD) of a water is a parameter that is included in the draft agricultural waiver monitoring program proposed by the CVRWQCB (2002a) staff. This parameter is a measure of the amount of oxygen that is needed to biochemically oxidize the organic compounds and ammonia in a water sample. It is composed of carbonaceous BOD and nitrogenous BOD. It is an important parameter for characterizing the total amount of oxygen that will be needed to prevent violation of the dissolved oxygen water quality objective downstream of where the measurements are made.

Oxygen is added to water through atmospheric aeration and photosynthesis. If the rate of supply of oxygen is less than the rate of BOD exertion, dissolved oxygen concentrations below the water quality objective can occur downstream of the sampling point. There are no water quality objectives for BOD. Excessive BOD is judged by depletion of DO below the water quality objective. Since BOD reactions typically require several weeks for completion, the characteristics of the downstream waters must be understood with respect to travel time, morphology, etc, to interpret the water quality significance of a BOD concentration found in a waterbody.

At this time, intensive studies are underway of agriculturally derived BOD in the San Joaquin River watershed. Lee and Jones-Lee (2000, 2002b) have summarized these studies. The situation is that of the agricultural discharge of nitrogen and phosphorus compounds leading to the growth of algae in the San Joaquin River tributaries and in the mainstem. These algae are transported into the Stockton Deep Water Ship Channel, where they die, decompose and thereby cause the DO to be depleted below the water quality objective. Studies of the San Joaquin River low-DO problem have shown that it is often more reliable to measure a 10-day BOD than a five-day BOD. Foe, *et al.* (2002) have reported that more reproducible results were found with 10-day BOD measurements rather than 5-day BOD measurements for San Joaquin River water. They found that the five-day BOD is 0.65 times the 10-day value. They also reported that the ultimate BOD of San Joaquin River water samples required 30 or more days.

Chlorophyll. Planktonic algal chlorophyll is a useful parameter for estimating the excessive fertilization of waterbodies. While there are no numeric regulatory limits for planktonic algal chlorophyll, generally, when the concentrations are much above 10 to 15 µg/L, the water is normally classified as eutrophic and on the edge of being excessively fertile. This could lead to the imposition of a narrative water quality objective for biostimulatory substances, discussed above. As discussed herein, excessively fertile waterbodies have a variety of water quality problems that cause an impairment of use of the waters for a variety of purposes, including domestic water supply, recreation, etc. The US EPA (2000d), in its National Water Quality Inventory, lists excessive fertility as one of the most significant causes of water quality impairment in the US. Work in the San Joaquin River watershed has shown that there is a fairly tight correlation between planktonic algal chlorophyll in the San Joaquin River and its tributaries and the BOD of the water samples (see Lee and Jones-Lee, 2002b).

Planktonic algal chlorophyll should be measured reliably with a detection limit of 5 µg/L. The chlorophyll extraction procedure using acetone should be used, rather than the one using methanol, since most investigators use the acetone extraction procedure (APHA, *et al*., 1998). In addition to measuring planktonic algal chlorophyll *a*, measurements should be made of pheophytin *a*. The sum of the chlorophyll *a* and pheophytin *a* is a measure of the total living and dead algae in the sample. In the San Joaquin River system this sum correlates fairly well to the BOD of the sample.

Biostimulatory Substances. Evaluation of the water quality significance of nutrient concentrations requires information on the aquatic plant populations at the monitoring site and downstream. The typical water quality monitoring program for nutrients (nitrogen and phosphorus compounds) generates concentration data for a particular location, as a function of time. The concentrations found are often dependent on the flow of the stream or river, the depth at which the samples are taken, the season of the year and a variety of other factors. The Central Valley Regional Water Quality Control Board Basin Plan has a narrative objective for nutrients, which is expressed in terms of "biostimulatory substances." This objective states,

> *"**Biostimulatory Substances***
> *Water shall not contain biostimulatory substances which promote aquatic growths in concentrations that cause nuisance or adversely affect beneficial uses."*

In order to assess whether nutrients at a certain concentration are violating the biostimulatory water quality objective, it is necessary to evaluate the impacts of the nutrients found at a particular location and time on the nutrient-related water quality of the waterbody near the sampling location and downstream. Based on the authors' experience, having worked on nutrient-related water quality issues over the past 40 years in a variety of locations in many parts of the world and the specific experience gained over the past 13 years working in the Central Valley, it is found that there are a number of nutrient-related water quality problems in Central Valley waterbodies that could lead to the determination of excessive biostimulatory substances. A summary of these situations has been presented by Lee and Jones-Lee (2002f).

Because of the fact that many of the impacts of nutrients on water quality are subjective, dependent on perspective and setting, it is important that the stakeholders concerned with water quality in a particular situation make the determination on whether the water quality at a particular location is significantly adversely impacted by the excessive growth of aquatic plants.

The basic approach for evaluating the potential impacts of a certain nutrient concentration at a sampling point on waters at that sampling point, as well as downstream, involves an understanding of the relationship between nutrient concentrations and eutrophication-related water quality. This relationship is dependent on the transport and transformation of the nutrients in the water, algal and other aquatic plant growth dynamics, and the impacts of algal and other aquatic plant biomass on the beneficial uses of the waterbody. The waterbody at the point of sampling and downstream needs to be examined with respect to determining the current eutrophication-related water quality. Consideration should be given to each of the potential impacts discussed by Lee and Jones-Lee (2002f).

Because of the US EPA's perceived difficulty in implementing narrative objectives such as the CVRWQCB's "biostimulatory" objective for controlling excessive fertilization, the US EPA is requiring that states adopt chemical-specific nutrient criteria/standards to regulate excessive fertilization. While nitrogen criteria are not yet developed, from the default criteria that the US EPA (2000c) is suggesting as potential values that could be applied to waterbodies in the Central Valley (about 0.1 mg/L N, including the sum of ammonia, organic nitrogen and nitrite/nitrate), these waterbodies could be found to contain excessive concentrations of nitrate and other nitrogen compounds, which could lead to excessive fertilization associated with the growth of algae and/or contribute to excessive nutrient concentrations in agricultural drains, agriculturally dominated waterbodies and downstream waterbodies. The US EPA has suggested that an alternative for developing default nutrient criteria could be the 25th percentile of the existing concentrations of total N and total P. Adopting this approach would mean that 75 percent of the waterbodies in a region would be in violation of the default criteria. Lee and Jones-Lee (2002e) have discussed the unreliability of the US EPA's proposed approach for developing the default nutrient criteria. As discussed below, the US EPA encourages the development of site-specific nutrient criteria, which consider the relationship between nutrient concentrations in a waterbody and the impairment of the beneficial uses of the waterbody due to excessive fertilization.

When the nitrogen-based nutrient criteria are adopted into the Basin Plan as a chemical-specific nutrient objective, many waterbodies in the Central Valley will likely be found to contain excessive nitrogen (especially nitrate), compared to the objective value. This will be especially true for nutrient criteria based on default values, as opposed to site-specific development. The excessive nitrogen in many Central Valley waterbodies will in many instances be primarily derived from irrigated agricultural stormwater runoff and tailwater/drain water discharges. Adoption of nutrient criteria, however, will not likely occur for five to 10 years. Until then, the regulation of nutrients, including nitrate, in stormwater runoff from irrigated agricultural fields with respect to causing excessive fertilization in receiving waters will continue to be based on the current Basin Plan narrative "biostimulatory" objective.

Lee and Jones-Lee (2001a, 2002e) suggest that the potentially regulated community and the regulatory agencies work together to develop appropriate, site-specific nutrient criteria. Failure to do so could result in the US EPA imposing extremely restrictive nutrient concentrations as the water quality objectives in California. Both urban and agricultural interests could face massive expenditures for nutrient control as part of the 303(d) listing that could evolve from the default criteria and the follow-on TMDLs that would have to be adopted to meet these criteria as water quality objectives.

The US EPA Region 9 has organized a Regional Technical Assistance Group (RTAG) in which each of the Regional Boards, including Central Valley Board, are working with the US EPA to develop nutrient criteria. This RTAG has determined that site specific criteria are needed since the US EPA's default criteria are inappropriate. As of yet, the regional boards have not adopted an approach for developing site specific criteria for nitrogen and phosphorous compounds as they may impact the fertility of a waterbody.

Temperature. The current CVRWQCB Basin Plan objective for temperature is,

> *"The natural receiving water temperature of intrastate waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Water Board that such alteration in temperature does not adversely affect beneficial uses. At no time or place shall the temperature of COLD or WARM intrastate waters be increased more than 5ºF above natural receiving water temperature. Temperature changes due to controllable factors shall be limited for the water bodies specified as described in Table III-4. To the extent of any conflict with the above, the more stringent objective applies."*

Several waterbodies in the Central Valley have specific temperature objectives that need to be met. It is unclear at this time whether agricultural drain or agriculturally dominated waterbody discharges to mainstem waterbodies would be in violation of an existing temperature requirement in the drain or cause violations of the temperature requirements for the receiving waters for the agricultural drain/agriculturally dominated waterbody.

The temperature of the near-surface waters of an agricultural drain or agriculturally dominated waterbody will show a diel change, with the highest temperatures in late afternoon. Further, there may be some thermal stratification, especially under conditions of low wind and slow water movement, which would cause the temperature in the near-surface waters in late afternoon to be higher than near the bottom. A key issue that needs to be addressed by the Board for temperature, as well as other parameters that show diel changes (such as pH), is whether any averaging of the parameter for time of day or depth in the water column will be practiced in assessing whether the agricultural drain or agriculturally dominated waterbody is violating a Basin Plan objective.

Pesticides, Herbicides and Other Potentially Toxic Agricultural Chemicals Kuivila (2000) has reported that there are over 150 pesticides used in the Central Valley which are a potential threat to cause aquatic life toxicity in stormwater runoff/agricultural discharge waters. Few of these currently used pesticides/agricultural chemicals have been evaluated with respect to their potential to cause impairment to the beneficial uses of the receiving waters for stormwater runoff and irrigation water releases. As discussed by Jones-Lee and Lee (2000a), the current US EPA Office of Pesticide Programs and the California Department of Pesticide Regulation registration of pesticides for use in agricultural or urban areas does not require that an evaluation be made of whether use of the pesticides in accord with the label could result in the pesticide being transported from the area of use to nearby watercourses in stormwater runoff or irrigation water releases. As it stands now, highly toxic pesticides are registered for use on agricultural lands, which are also highly mobile – i.e., would be expected to be present in stormwater runoff from these areas. In order to address this issue, Jones-Lee and Lee (2000a) developed a "proactive" approach for identifying the potential water quality impacts of pesticides and other agricultural chemicals that are in use today that have not been properly evaluated with respect to water quality impacts in the receiving waters for the stormwater runoff and irrigation water releases.

In addition to currently used organic pesticides, some agricultural areas are being treated with heavy-metal pesticides such as copper and zinc which will be present in stormwater runoff and irrigation water releases from areas of treatment and are a threat to cause aquatic life toxicity in the State's waters. At this time, there is limited information available as to whether the treatment of agricultural lands with heavy metals results in violations of water quality criteria/standards in the receiving waters for stormwater runoff and water releases from the treated areas.

The CVRWQCB (1998) Basin Plan objective for pesticides, which includes herbicides, is,

*"**Pesticides***

- *No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses.*
- *Discharges shall not result in pesticide concentrations in bottom sediments or aquatic life that adversely affect beneficial uses.*
- *Total identifiable persistent chlorinated hydrocarbon pesticides shall not be present in the water column at concentrations detectable within the accuracy of analytical methods approved by the Environmental Protection Agency or the Executive Officer.*
- *Pesticide concentrations shall not exceed those allowable by applicable antidegradation policies (see State Water Resources Control Board Resolution No. 68-16 and 40 C.F.R. Section 131.12.).*
- *Pesticide concentrations shall not exceed the lowest levels technically and economically achievable.*

- *Waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of pesticides in excess of the Maximum Contaminant Levels set forth in California Code of Regulations, Title 22, Division 4, Chapter 15.*
- *Waters designated for use as domestic or municipal supply (MUN) shall not contain concentrations of thiobencarb in excess of 1.0 µg/L.*

Where more than one objective may be applicable, the most stringent objective applies."

The California Department of Health Services (DHS, 2000) has primary MCLs for certain herbicides, such as 3 µg/L for atrazine. Atrazine is used on some crops for weed control. OEHHA (2001) has a California public health goal for atrazine of 0.15 µg/L and public health goals for a number of other pesticides and herbicides. The DHS MCLs are regulatory limits in the CVRWQCB Basin Plan. The OEHHA goals are not. They, however, are a guide to potentially "safe" (nontoxic) levels of chemicals.

The CVRWQCB has a toxicity limitation requirement which states that,

"All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal or aquatic life. This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Compliance with this objective will be determined by analyses of indicator organisms, species diversity, population density, growth anomalies, and biotoxicity tests of appropriate duration or other methods as specified by the Regional Water Board."

The experience that has been gained with the aquatic life toxicity due to the organophosphate pesticides diazinon and chlorpyrifos is relevant to evaluating whether agricultural drains or agriculturally dominated waterbodies comply with the Basin Plan objective for control of toxicity. It was found in the early 1990s that many of the waters in the Central Valley were at times toxic to certain forms of aquatic life (*Ceriodaphnia dubia*/water flea – a standard US EPA test organism) due to the runoff of these pesticides from agriculture and urban areas where they have been applied. This toxicity was determined to be a violation of the Basin Plan objective for control of aquatic life toxicity. This violation triggered a 303(d) listing of a number of waterbodies in the Central Valley for aquatic life toxicity due to diazinon and chlorpyrifos. At this time,20 waterbodies are listed on the 303(d) list for diazinon-caused impairment. Of those 20, 12 are also listed for chlorpyrifos. The 303(d) listing, in turn, has led to the current CVRWQCB requirements of developing TMDLs to control diazinon and/or chlorpyrifos concentrations in Central Valley waterbodies.

Since toxicity tests do not adequately measure the toxicity that can occur under acute and chronic exposure conditions, it is necessary to develop a chemical-specific numeric target concentration that can be used to evaluate whether low levels of toxicity could be occurring in a waterbody below those that are measured in toxicity testing. The US EPA's approach for developing water quality criteria for potentially toxic substances involves estimating the "safe" concentration of the substance which should not cause toxicity to about 95 percent of aquatic life forms. This "safe" concentration (water quality criterion) is considerably less than the concentration that causes toxicity in a standard toxicity test.

Since there were neither US EPA water quality criteria nor CVRWQCB water quality objectives for diazinon, the California Department of Fish and Game (Siepmann and Finlayson, 2000), using US EPA water quality criteria development approaches, developed recommended water quality criteria for diazinon of 50 ng/L (four-day average) and chlorpyrifos of 14 ng/L (four-day average). Strauss (2000) of the US EPA Region 9 has indicated that the DFG water quality criteria for diazinon and chlorpyrifos are suitable TMDL goals for the control of these chemicals. The concentration of diazinon that will kill about half of the *Ceriodaphnia* in a four-day test is on the order of 450 ng/L. The lowest level of diazinon toxicity that can be measured in a US EPA standard toxicity test (Lewis, *et al*., 1994) is about 200 ng/L. It is evident that concentrations of diazinon well below those that can cause toxicity in a standard toxicity test are projected to be toxic to aquatic life based on US EPA water quality criteria development approaches.

Based on the US EPA (2002c) Office of Pesticide Programs Ecotoxicity Database, similar types of situations will exist for a number of other pesticides, including herbicides, that are used in agriculture, where the stormwater runoff from irrigated agricultural fields and/or agricultural tailwater discharges would be found to be toxic in the standard toxicity test. Through forensic toxicity studies, the origin of the toxicity and identification of the pesticide responsible can be determined. For those pesticides/herbicides for which there are chemically-based, numeric water quality criteria, exceedance of the criterion value would be used to evaluate whether there is a potential for aquatic life toxicity in a waterbody.

To address toxicity and agricultural drains or agriculturally dominated waterbodies, it will likely require measurement of aquatic life toxicity using US EPA standard three-species tests, as well as making specific chemical concentration measurements for pesticides/herbicides for which water quality criteria/objectives exist. In addition, potential inference on the toxicity of measured pesticides for which no water quality criteria/objectives exist can be obtained from a review of the US EPA (2002c) OPP Ecotoxicity Database, through the use of standard acute/chronic toxicity ratios for pesticides. This database provides the toxicity data that was provided to the US EPA OPP as part of registering the pesticides for use.

As discussed above, a reliable monitoring program for control of aquatic life toxicity due to pesticides should focus on measuring aquatic life toxicity and chemical concentrations in the runoff/discharge waters from areas where the pesticide has been recently applied. This proactive approach (Jones-Lee and Lee, 2000a) is a much more reliable approach to detecting/controlling pesticide-caused toxicity in waterbodies than the approach that is proposed to be used in the initial phase of the agricultural waiver monitoring program, where toxicity testing is to be conducted at the mouths of agricultural drains and agriculturally dominated waterbodies. As discussed above, there could readily be toxicity upstream in the State's waters that is not detected by this approach.

Organochlorine Pesticides. A group of pesticides of potential concern because of their former use in agricultural and urban areas, are the organochlorine pesticides, such as DDT, chlordane, toxaphene, dieldrin, etc. These "legacy" pesticides, called Group A pesticides, are regulated as potential carcinogens and have not been legally used in the US since the 1970s, when they were banned from further use. Group A pesticides include aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including lindane), endosulfan and toxaphene. These compounds are extremely persistent and are still being found in soils and water in runoff from some of the areas where they have been applied, at concentrations which are a threat to human health through drinking water and, more importantly, through bioaccumulation in fish to excessive levels, compared to those that are considered to be safe for consumption of the fish.

The SWRCB has been conducting the Toxic Substances Monitoring (TSM) program for a number of years (SWRCB, 2001b; SWRCB/TSM, 2002). This program has included collecting fish taken from various Central Valley waterbodies and analyzing them for Group A pesticides and PCBs. PCBs, while similar in chemical structure to the Group A pesticides, were not pesticides, but industrial chemicals. Based on the SWRCB (1998) 303(d) list of waterbodies, the American River (Lower), Colusa Drain, Delta Waterways, Feather River (Lower), Kings River (Lower), Merced River (Lower), Natomas Main Drain, San Joaquin River, Stanislaus River (Lower), Tuolumne River (Lower) and Stockton Deep Water Ship Channel have been found to contain fish with excessive concentrations of one or more Group A pesticides and/or PCBs. In addition, subsequent sampling of fish in the Sacramento River has shown that some fish in this river contain Group A pesticides, DDT and PCBs. Fish in Orestimba Creek have been found to contain excessive concentrations of DDE, a transformation product of DDT. Further, fish in the Smith Canal in the city of Stockton and the San Joaquin River at Vernalis have been found to contain excessive PCBs. Lee and Jones-Lee (2002d) have recently completed a review of the occurrence of the excessive bioaccumulation of the legacy pesticides and PCBs in Central Valley waterbodies.

Because of the widespread occurrence of excessive concentrations of the organochlorine pesticides in Central Valley waterbody fish, there is need, as part of the NPS quality monitoring program and the agricultural waiver monitoring program, to monitor fish in agricultural drains and agriculturally dominated waterbodies, to determine if they have excessive concentrations of Group A pesticides and PCBs. The approach of monitoring fish, rather than water, is a more reliable approach for detecting water quality problems caused by Group A pesticides because it is difficult to achieve the necessary detection limits for water monitoring to detect these compounds at concentrations above US EPA water quality criteria as set forth in the CTR. It is relatively easy to measure the pesticides and PCBs in fish tissue at potentially significant concentrations. In addition to measuring the organochlorine pesticides, PCBs, dioxins and furans (see below) in fish tissue, the lipid content of this tissue should also be determined since the amount of these chemicals that is taken up by fish is often related to the lipid content of the fish tissue. This information can be used to develop a site-specific biota sediment accumulation factor (US EPA, 2000e), which can serve as a guide to the degree of sediment cleanup needed to prevent excessive bioaccumulation of organochlorine pesticides and PCBs in fish.

If one or more Group A pesticides are found in agricultural drain or agriculturally dominated waterbody fish, then upstream monitoring of fish and stormwater runoff and tailwater releases for the Group A pesticides found at excessive concentrations in fish from the agriculturally dominated waterbody should be conducted through forensic studies to define the source(s) of the pesticides that are discharging sufficient concentrations to lead to excessive bioaccumulation in edible fish tissue. The excessive bioaccumulation of the Group A "legacy" pesticides and PCBs likely involves transfer of these chemicals that are associated with sediments from the sediments to lower forms of aquatic life (such as benthic invertebrates), which are ingested by higher forms of aquatic life (such as fish).

The US EPA (2000e) has recently discussed the need for sediment bioaccumulation testing procedures to evaluate whether chemicals like the "legacy" pesticides and PCBs, which tend to strongly sorb to particulates (sediments), are bioavailable to lead to excessive bioaccumulation in higher trophic level (edible) fish. The US EPA (1994a) has developed a standard benthic organism bioavailability test involving the use of *Lumbriculus variegatus* (oligochaete-worm). This procedure should be used to evaluate whether sediments in an agricultural drain or agriculturally dominated waterbody that has been found to contain fish with excessive concentrations of Group A pesticides and/or PCBs are a potential source of the pesticides/PCBs that are bioaccumulating to excessive levels in fish. All sediment testing should include measurements of total organic carbon (TOC), since the Group A pesticides and PCBs' bioavailability is often related to the TOC in the sediments. Sediments with higher TOC tend to make Group A pesticides and PCBs less bioavailable.

Dioxins and Furans. The dioxins and furans represent a group of organochlorine compounds that are formed during combustion and are present in highway and street stormwater runoff. Further, burning of plant materials has been found to produce dioxins and furans. They have also been found as contaminants in certain manufacturing processes and some agricultural chemicals. Some of the dioxins and furans have a high potential to cause cancer at low concentrations and are among some of the most hazardous chemicals known. Dioxins and furans tend to accumulate in fish to levels that are hazardous to those who use the fish as food. There is limited information on the concentrations of dioxins and furans in stormwater runoff and fish in the Central Valley, although excessive concentrations of dioxins have been found in fish taken from the Stockton Deep Water Ship Channel. Further, studies in other areas have shown that in areas such as the San Francisco Bay, dioxins and furans bioaccumulate to excessive levels in fish.

Dioxins and furans have been found to be formed during low-temperature combustion. Since some irrigated agricultural practices involve burning of materials on agricultural lands, it is possible that such burning could lead to dioxin formation. Fish in agricultural drains and agriculturally dominated waterbodies should be examined for the presence of dioxins and furans in their edible tissue. If these chemicals are found at potentially hazardous levels, then a procedure similar to that described above for determining the source of organochlorine pesticides in an agricultural drain or agriculturally dominated waterbody should be conducted.

Unknown-Caused Toxicity. Monitoring of toxicity in Central Valley waterbodies has resulted in the placement of 14 waterbodies in the Central Valley on the SWRCB 303(d) list of impaired waterbodies due to the presence of aquatic life toxicity due to unknown causes. The toxicity monitoring of agricultural drains and agriculturally dominated waterbodies should be conducted in such a way as to determine, on undiluted samples, whether there is aquatic life toxicity to the

US EPA three standard test species, fathead minnow larvae (fish), *Ceriodaphnia dubia* (zooplankton), and *Selenastrum capricornutum* (algae). If toxicity is found, then a toxicity dilution series of the same sample should be conducted to determine the magnitude of the toxicity (toxic units) and, through toxicity identification evaluations (TIEs), its cause and whether all of it can be accounted for by known toxicants in the sample. If there is a difference between the total toxicity and the toxicity that is expected based on the chemical concentrations of known toxicants and their respective potential toxicity, then the sample contains "unknown-caused" toxicity. This is the approach that has been used to determine that there are 14 waterbodies in the Central Valley that have unknown-caused toxicity for which TMDLs must be developed to control this toxicity.

An example of unknown-caused toxicity associated with agricultural activities occurs in the Grassland Bypass Area (SFEI, 2002). Testing of Grassland Bypass waters for aquatic life toxicity over the past several years has shown unknown-caused toxicity to fathead minnow larvae and *Selenastrum*. In general, these waters were not toxic to the zooplankton *Daphnia magna*. Attempts to conduct TIEs to identify the cause of this toxicity were unsuccessful.

There are basically two approaches to controlling unknown-caused toxicity. One of these is to use a more comprehensive/sophisticated TIE procedure for toxicity identification. Once the toxicant has been identified, then its use within the watershed can potentially be determined and controlled. The other approach is through the use of forensic studies based on toxicity measurements made at various locations in the waterbody, where the specific location(s) from which the toxicity is derived is identified. Once the source of the toxicity is known, then it is usually straightforward to determine its cause, through an assessment of the types of chemicals used in the area.

The staff of the University of California, Davis, Aquatic Toxicology Laboratory (ATL), working with several CVRWQCB staff (Valerie Connor, Chris Foe), have been leaders in developing and using aquatic life toxicity tests in Central Valley waterbodies (Fong, *et al.*, 2000; UC Davis ATL,1999; Deanovic, *et al.*, 1998) Those working in this area should check with UC Davis ATL for the latest information/guidance in conducting toxicity tests.

Sediment Toxicity. Increasing attention is being given to regulating the toxicity of aquatic sediments. The US EPA and the SWRCB are developing sediment quality guidelines that can be used for this purpose. Within a few years, dischargers of constituents that cause sediments to become toxic to aquatic life could become responsible for controlling the input of these constituents from land runoff/irrigation water discharges. Examples of constituents that can cause sediment toxicity include aquatic plant nutrients that develop into algae or other aquatic plants which die and become part of the sediments, organic nitrogen present in the plant materials as well as particulate organic nitrogen discharged in land runoff that accumulates in sediments and, through sediment mineralization processes, produces ammonia which causes sediments to be toxic. Also of concern are the pesticides, such as the pyrethroid-based pesticides, that tend to sorb to particulates, and therefore accumulate in aquatic sediments. While, ordinarily, sorbed potential toxicants tend to be nontoxic, Weston (2002) has recently reported on the fact that there is a potential for pyrethroid-based pesticides that are being used as replacements for diazinon and chlorpyrifos, which are sorbed to particulates, to be toxic to aquatic life.

Agricultural drain and agriculturally dominated waterbody sediments should be tested for aquatic life toxicity using the US EPA (1994a) standard sediment test organism *Hyalella azteca* (amphipod). If toxicity is found, then sediment-based TIEs and/or sediment toxicity forensic studies should be used to determine the cause of the toxicity and its origin.

Lee and Jones-Lee (2002g) have recently discussed the approach that should be used to evaluate the water quality significance of chemical constituents in aquatic sediments. Their recommended approach involves the use of a non-numeric best professional judgment triad weight of evidence integration of aquatic life toxicity/bioaccumulation, aquatic organism assemblage, and appropriate chemical information to determine whether a chemical or group of chemicals present in sediments at elevated concentrations is impairing the beneficial uses of the waters overlying the sediments.

Overall Toxicity Issues. In summary, there are a variety of chemicals associated with irrigated agriculture that can be present in agricultural stormwater runoff and tailwater discharges that can lead to aquatic life toxicity in agricultural drains and downstream waters. The NPS and the agricultural waiver monitoring program should include comprehensive water column aquatic life toxicity evaluation as one of the primary measurements that are made to protect the beneficial uses of the states' waters from potentially toxic constituents used on agricultural lands. Further, as funds become available, toxicity measurements of agriculture drain and agriculturally-dominated waterbody sediments should be conducted.

Total Organic Carbon. The Delta provides a domestic water supply for about 22 million people in California. Water utilities that use Delta waters experience excessive concentrations of total organic carbon (TOC) compared to US EPA regulatory limits. This TOC is of concern because, through water disinfection, elevated concentrations of trihalomethanes (THMs) are formed which represent a human health risk to cause cancer in those who consume the water for domestic purposes. This situation could lead to the listing of the Delta and many of its tributaries as 303(d) "impaired" waterbodies because of excessive TOC. If this occurs, TMDLs will need to be developed to control the excessive TOC which will include controlling TOC export from agricultural and urban areas in stormwater runoff and irrigation water releases.

As with the other constituents of concern discussed herein, an evaluation of the presence of TOC in stormwater runoff irrigation release waters, relative to the US EPA regulatory limits for domestic water supplies of 3 mg/L TOC, should be conducted. Woodard (2000) has reviewed the TOC and dissolved organic carbon (DOC) data that have been collected over the years in the tributaries to the Delta and within the Delta. These data point to the San Joaquin River upstream of Mossdale being an important source of organic carbon for the Delta, and that an appreciable part of this organic carbon is in the form of algae and algal remains (detritus). At this time the role of irrigated agriculture as a source of TOC and DOC is not well understood. There is need, therefore, to monitor agricultural drains and agriculturally dominated waterbodies to evaluate irrigated agriculture runoff/discharges as a source of TOC/DOC that causes Delta waters to contain excessive concentrations compared to those that can lead to excessive THM formation in domestic water supplies.

Heavy Metals. The CVRWQCB spring 2002 draft agricultural waiver monitoring program includes the measurement of several heavy metals, including copper, chromium, lead, nickel and zinc. Many of these metals are of concern because of their potential toxicity to aquatic life at low concentrations. Some heavy metals, such as copper, are used as pesticides in irrigated agriculture. The US EPA (1995, 1999b, 2000b) established water quality criteria for heavy metals that are potentially toxic to aquatic life, based on their dissolved forms. The particulate forms of these heavy metals are nontoxic in the water column; however, particulate forms should also be measured, since they can accumulate in sediments and potentially lead to sediment toxicity.

If sediment toxicity is found using the *Hyalella* toxicity testing discussed above, then the concentrations of acid volatile sulfides present in the sediments should also be measured as a TIE procedure to determine if any of these heavy metals in the sediments could potentially be a cause of this toxicity (see Lee and Jones-Lee, 1994). If the molar sum of the acid volatile sulfides exceeds the simultaneously extracted molar sum of the non-iron heavy metals, then the sulfides in the sediments will detoxify all heavy metals due to precipitation reactions. If, however, there are more heavy metals than sulfides, then there is a potential for one or more of the heavy metals to be present in a toxic form.

Selenium. Elevated concentrations of selenium have been found in discharges from agricultural lands in some of the upper parts of the San Joaquin River watershed. The CVRWQCB (1998) has established a water quality objective for selenium for several waterbodies in the San Joaquin River watershed. Currently the CVRWQCB has developed a TMDL to control selenium discharges to the San Joaquin River. It is possible that the current selenium discharge limit will be revised so that even more stringent control of selenium in agricultural runoff/discharges will be needed. All agricultural runoff/discharges should be monitored for total selenium to determine whether selenium is present in the stormwater runoff/irrigation water discharges at concentrations that are near the current selenium water quality objective of 5 µg/L.

Mercury. Fish taken from many areas of the Central Valley have been found to contain excessive concentrations of mercury in edible tissue. Mercury can convert to methylmercury, which then bioaccumulates in fish tissue. Methylmercury is highly toxic to fetuses and young children, causing neurological damage. Some areas of the Central Valley, especially areas where mercury and gold mining has occurred, are already on the 303(d) list of "impaired" waterbodies because of excessive bioaccumulation of mercury. These include Marsh Creek Reservoir, Cache Creek, Dunn Creek, Lower Feather River, Harley Gulch, Humbug Creek, James Creek, Marsh Creek, Panoche Creek, Sacramento River, Sacramento Slough, San Carlos Creek, Sulfur Creek and the Delta. The Delta has had a human health advisory for fish consumption for mercury since 1971.

Domagalski (2001) has reviewed the occurrence of mercury and methylmercury in water and sediments in the Sacramento River basin. From the information available, mercury is derived from former mercury mining, from its use in recovery of gold, and from natural sources.

Foe (pers. comm., 2001) has indicated that excessive mercury is also being found in fish taken from the San Joaquin River and its watershed.

There are other areas that could be added to the updated 303(d) list of "impaired" waterbodies due to excessive bioaccumulation of mercury in fish. It is possible that, as further studies are done, many areas not now considered significant sources of mercury outside of former mining areas will need to develop programs to control mercury runoff from these areas. This could include agricultural lands where there has been no history of mercury use, yet mercury is being found in stormwater runoff at concentrations which are a threat to bioaccumulate to excessive levels in fish.

The CA DHS has established a mercury drinking water MCL of 0.002 mg/L. The CVRWQCB does not have a water quality objective for mercury; however, the US EPA (1987) developed a water quality criterion for total recoverable mercury of 12 ng/L. The US EPA (2000b), as part of developing the California Toxics Rule, subsequently raised this criterion to 50 ng/L. The US EPA (Woods, 2000) has indicated, however, that this change does not represent a change in the level of significance of mercury in water, but a change related to how the Agency determines critical concentrations of mercury. Woods (2000) has indicated that the mercury criterion will likely be lowered to about 5 ng/L total recoverable mercury within a few years. This concentration represents a "worst case" situation for bioaccumulation of mercury in fish tissue.

To date, the US EPA has been regulating mercury in water based on water concentrations of total recoverable mercury. This approach has proven to be unreliable, since there are a wide variety of factors that influence the conversion of total mercury in water and/or sediments to methylmercury in water and fish tissue. The US EPA (1999c,d; 2001b,c) is recommending a change in the approach for regulating mercury, which would be based on fish tissue residues. The US EPA (2001c) states,

> *"To assess health risks, EPA developed a reference dose that is a scientifically justifiable maximum level of exposure to protect public health from all toxic effects. EPA based the methylmercury criterion on a new reference dose that protects all exposed populations. EPA also updated the exposure assessment and relative source contribution following the recently published 2000 Human Health Methodology. The resulting criterion of 0.3 mg methylmercury/kg in fish tissue should not be exceeded to protect the health of consumers of noncommercial freshwater/estuarine fish."*

This is a more reliable approach for regulating mercury, since it focuses on tissue residues, rather than water concentrations. Since water quality objectives are based on water concentrations, there will be need to develop a waterbody-specific translation factor between methylmercury in water and methylmercury in fish tissue for waterbodies where excessive concentrations of mercury are found in fish tissue.

Woods (2001) has indicated that the US EPA is also developing guidance for implementing the methylmercury tissue-based criterion. A draft of this guidance was scheduled to be available in 2002; however, recent events have caused the US EPA to shift the personnel working in this area to other activities related to terrorism.

While, ordinarily, agricultural lands would not be considered as likely sources of mercury that would bioaccumulate to accessible levels in edible fish, at this time, the full range of sources that lead to excessive mercury and edible fish tissue are poorly understood. Mercury is being found in runoffs from lands above US EPA recommended criterion values where there have been no known pervious uses. It is suggested that to be certain that there are no mercury sources in agricultural drains and agriculturally-dominated bodies, that fish from these drains be analyzed for mercury. This only needs to be done once in the fall for several years to determine if there are significant sources of mercury upstream of the fish sampling locations.

Bioassessment

Bioassessment of the numbers and types of benthic macroinvertebrates, as well as fish populations is an important water quality assessment tool that can be used to determine whether constituents present in a waterbody are adversely affecting the aquatic-life-related beneficial uses. The California Department of Fish and Game (Harrington and Born, 1999) and the US EPA (Barbour, *et al*., 1999) have reported on bioassessment methodology that can be used to assess whether discharges from irrigated agriculture are adversely affecting the biological characteristics of the waterbody. According to Rowan (pers. comm., 2002), the CVRWQCB bioassessment sampling follows the US EPA low gradient Rapid Bioassessment Protocol.

One of the primary objectives of bioassessment is to determine whether the numbers and types of aquatic life present at a particular location are those that should be there if there were not adverse impacts of chemical constituents. Habitat characterization has proven to be valuable by ascertaining whether the organism habitat characteristics are the same upstream and downstream of the discharge point. If they are, then it can be inferred that the numbers and types of organisms downstream of the discharge should be the same as those upstream. Lee and Jones (1982) utilized aquatic habitat assessment technologies to determine whether wastewater discharges are causing significant adverse impacts on the numbers, types and characteristics of desirable forms of aquatic life in a stream downstream of the discharge. Similar approaches could be used with respect to irrigated agricultural runoff/discharges.

Kennedy, *et al.* (2001) have provided guidance on some of the problems of counting organisms in a benthic organism biological assessment. As they point out, one of the problems in biological assessments is the clumping of organisms. They provide statistical guidance on how to address this problem.

Hall and Killen (2002) have recently reported on a study of the benthic communities and physical habitat in agricultural streams on the west side of the San Joaquin River. The purpose of this effort was to determine if the pesticide-caused aquatic toxicity pulses that occur each winter with stormwater runoff from agricultural areas impact the number and types of benthic macroinvertebrates present in several SJR west side tributaries the following spring. Their report provides useful information on the problems of trying to use benthic organism assemblage information in assessing the impact of toxic pollutants on water quality. Benthic organism assemblage information monitoring should be done to determine if the number and types of organisms present that are potentially affected by toxicants in stormwater runoff are impacted during and immediately after the runoff event.

Groundwater Quality

Baggett (2002) specifically mentions evaluating the agricultural waiver requirements in terms of whether agricultural practices are leading to groundwater pollution. It is known that irrigated agriculture pollutes groundwaters with salts, nitrate and some other constituents. With increasing emphasis on controlling the concentrations of these constituents in stormwater runoff and tailwater releases, there likely will be a tendency to increase groundwater pollution by irrigated agriculture. While groundwater pollution by irrigated agriculture in the Central Valley has been well-known to be occurring for at least 30 years, efforts to control it have not been successful, largely as a result of the fact that, thus far, the regulatory agencies have been unable to develop early warning monitoring of when groundwater pollution is occurring under areas influenced by irrigated agriculture.

Letey (1994) has pointed out that groundwater pollution by irrigated agriculture is an inevitable consequence of irrigated agriculture in the Central Valley. Without sufficient infiltration of the irrigation water and surface water runoff/discharges, the concentrations of salts will build up to such an extent as to cause the soil to become nonproductive. As part of practicing irrigated agriculture, it is essential that there be transport of salts from the root zone through the vadose zone and into the groundwater system and the flushing of salts from the surface soils to surface watercourses.

There is need for proactive monitoring of irrigated agricultural areas for the potential to cause significant groundwater pollution. The current monitoring approach of measuring an increase in constituents in groundwater is not a reliable approach for protecting groundwaters from pollution by irrigated agriculture, since the groundwaters have to be polluted before action is taken. There is need to develop and implement vadose zone monitoring under irrigated agricultural areas, where the concentrations of constituents in the vadose waters are measured, and a prediction is then made as to whether these concentrations are sufficient to significantly impair the designated beneficial uses of the groundwaters under the areas devoted to irrigated agriculture. Vadose zone monitoring using an array of vacuum cup lysimeters is an approach that could serve as a early warning system for significant pollution of groundwaters.

Vadose zone monitoring should be conducted with a sufficient array of vacuum cup lysimeters to have a high probability of detecting major fluxes of salts, nitrate and other potential pollutants in the vadose zone. These fluxes will typically occur associated with a wetted front movement of waters through the vadose zone. It is important not to try to predict movement of salts, nitrate, pesticides, etc., within the vadose zone based on the annual average moisture content of the vadose zone. The movement of constituents through the vadose zone is not governed by the average moisture content of the vadose zone, but by wetted fronts that occur over short periods of time associated with irrigation water application and/or rainfall infiltration events.

In order to properly sample the concentrations of constituents in the vadose zone, it is necessary to operate the vacuum cup lysimeters in such a way as to maintain the vacuum on the lysimeter probe just under soil moisture tension, as measured by tensiometers. Further, it is necessary to conduct frequent sampling of the wetted front associated with an infiltration event, in order to reliably obtain samples of the infiltrating water. This approach was developed in connection with the studies by George, *et al.* (1986). It was found that, associated with some infiltration events, several hundred mg/L of nitrate-nitrogen were present in the vadose zone sampled water. These high concentrations moved through the vadose zone over a short period of time.

In estimating the impact of the slug of constituents associated with the wetted front transport of pollutants, it is necessary to make an estimate of the depth to which the upper part of the water table mixes with the infiltrating water. A number of investigators have used a two-foot depth in order to assess what the groundwater concentrations might be when the percolate that has passed through the vadose zone enters the water table. In those situations where the infiltrating water has sufficient salts so that it has a density greater than that of the groundwaters underlying it, the percolated water will sink upon entering the water table. Under these conditions, the mixing of the percolate with the groundwater will be somewhat different than if the percolated water had essentially the same density as the groundwater.

QA/QC Issues

It is important that the standard US EPA QA/QC or equivalent procedures be followed in sampling, sample handling and analysis. It is also important to understand that following such procedures does not necessarily produce reliable data. As discussed above, there can readily be interferences in standard approved analytical procedures, which cause the results to be unreliable. The QA/QC procedures used by the US EPA do not necessarily detect the presence of interferences.

According to Chilcott (pers. comm., 2002), the CVRWQCB SWAMP is developing a QAPP. She indicated that the final version will not likely be available before October 2002. This program should be a useful guide to QA/QC procedures for the Phase II agricultural waiver monitoring program.

Recently, Azimi-Gaylon, *et al.* (2002) published "Quality Assurance for Effective Monitoring of Pesticides in the San Joaquin River Basin, California." This paper provides guidance on the development of a quality assurance project plan (QAPP) for water quality monitoring. While it is directed toward pesticide monitoring, the guidance is equally applicable to all water quality parameters. It is presented in Appendix E.

It is important that those who are knowledgeable about the data interpretation review the data that is posted in the computer database to be sure that it makes sense and it is correctly stored. The approach that some parts of the US Geological Survey (USGS) use of requiring that the principal investigator on a particular project be responsible for reviewing all data entered into the USGS data storage system is an appropriate one to follow. The investigator for a project is probably best able to spot unreliable data.

Evaluation of the Water Quality Significance of a Water Quality Objective Violation

A key component of developing a technically valid, cost-effective water quality management program is an evaluation of the water quality significance of exceedance of a water quality criterion/standard/objective. In 1972, the US Congress (1972), as part of developing what has become the Clean Water Act, mandated that the US EPA develop water quality criteria that would be protective of the nation's waters. At the same time the National Academies of Science and Engineering (NAS/NAE, 1973) developed the "Blue Book" of water quality criteria. These criteria were developed by a consensus process of experts in the field. They were designed to be protective of the nation's waters under all conditions.

In 1976, the US EPA (1976) adopted the "Red Book" of water quality criteria, which were based on the National Academies' Blue Book of water quality criteria. This led to what has become known as the worst-case-based water quality criteria. By "worst-case," it is meant that these criteria will be protective of essentially all aquatic life in any waterbody. The senior author of this report was an invited peer reviewer to the National Academies of Science and Engineering for the Blue Book of water quality criteria. In developing these criteria, it was understood that these criteria would be overprotective for many situations, due to the site-specific conditions that affect how a chemical constituent impacts the beneficial uses of waters. Of particular concern is the aquatic chemistry of the constituent, discussed above.

In the early 1980s, the US EPA (1987) initiated an update of the Red Book of water quality criteria, which was ultimately released in 1987 as the "Gold Book" of water quality criteria. In accord with the requirements of the Clean Water Act (US Congress, 1987), these criteria were designed to be protective of aquatic life in all waterbodies. It has been understood since the early 1970s that criteria designed to be protective of aquatic life in all waterbodies – i.e., worst-case-based water quality criteria and standards based on these criteria – would, in many waterbodies, for certain constituents (especially heavy metals, certain organics, etc.), be overprotective. This overprotection could lead to greater expenditures for potential pollutant control from its sources than is necessary to protect the aquatic life or other designated beneficial uses of a waterbody. The National Academies recognized this problem for heavy metals and did not adopt chemical-specific numeric criteria for potentially toxic heavy metals, such as copper, zinc, lead, cadmium and nickel. This developed because of the fact that it was well-known in the early 1970s that heavy metals exist in a variety of chemical forms only some of which are toxic/available. Instead of adopting a numeric value, the National Academies adopted a toxicity testing procedure to directly measure toxicity, as opposed to trying to estimate toxicity based on the chemical composition of the water.

In the early 1980s, the US EPA abandoned the toxicity testing approach and opted for the bureaucratically simpler (but often technically invalid) approach of using worst-case-based numeric water quality criteria for the heavy metals. The Agency also began to develop at that time guidance on how to adjust the worst-case-based criteria for site-specific conditions. In 1994, the Agency issued its second edition of the Water Quality Standards Handbook (US EPA, 1994b), which provides guidance on how to adjust the worst-case-based criteria/standards to protect the designated beneficial uses of waterbodies without unnecessary expenditures for constituent control. The basic issue in adjusting the worst-case-based (protective in all situations) criteria into site-specific criteria is an adjustment for the aquatic chemistry of the potential pollutant. Unfortunately, as implemented at the federal and state level, those responsible often do not have sufficient aquatic chemistry understanding to make this adjustment in a cost-effective manner, continuing to lead to overregulation. The basic problem is that the Agency's funding has been inadequate to properly address this issue since the early 1970s.

The current US EPA (2002d) administration has recently announced that the US EPA water quality criteria development approach is under review. This review could lead to changes in the US EPA water quality criteria and their implementation as state water quality standards that would tend to minimize the overregulation that occurs now, especially when the US EPA criteria are used without modification as state standards for agricultural and urban stormwater runoff. It should be noted, however, that, in addition to overregulation of some of the regulated constituents, there is significant under-regulation of unregulated constituents (i.e., those without water quality criteria) and the additive impacts of the regulated constituents.

Exceedance of a WQO. As typically implemented today, the US EPA water quality criteria are mechanically used as state water quality standards (objectives), where an exceedance is considered a violation subject to initiation of a control program to eliminate the exceedance. Based on how the US EPA water quality criteria have been developed, Lee and Jones-Lee (1996) discussed how these criteria should be used in regulatory programs. Basically, an exceedance of a criterion/standard should be considered as an indication that there may be significant water quality problems in the waters where the exceedance occurs. It should not be assumed that the exceedance represents an impairment of the designated beneficial uses of the waterbody. Far too often, exceedances of the US EPA water quality criteria and state standards based on these criteria represent "administrative exceedances," reflecting the worst-case nature of the criteria/standards. Basically, since the early 1980s the US EPA has focused its water pollution control programs on chemical concentration control rather than chemical impact control. This has led and will continue to lead to overregulation of many constituents, especially in stormwater runoff from urban and rural areas.

Jones-Lee and Lee (1998) have developed the Evaluation Monitoring approach that is specifically designed to determine whether the exceedance of a worst-case-based criterion/standard is an administrative exceedance or is likely causing a significant adverse impact to the beneficial uses of the waterbody. Evaluation Monitoring focuses monitoring resources on determining whether the discharge of a constituent(s) to a waterbody is adverse to the beneficial uses of the waterbody. For example, rather than measuring copper in the discharge and then trying to extrapolate to copper-caused toxicity in the receiving waters as is typically done today, the Evaluation Monitoring approach measures aquatic life toxicity. If toxicity is found, then studies are conducted to determine its cause and its water quality significance. This is a much more valid approach to protecting the beneficial uses of a waterbody without unnecessary expenditures for constituent control.

The Evaluation Monitoring approach requires the expenditure of funds beyond those that are typically made available for water quality monitoring/evaluation. Since the US public, at the federal and state level, does not provide the water quality regulatory agencies with adequate funding to make this evaluation, the burden of cost for conducting Evaluation Monitoring has to be borne by the discharger. The current regulatory program at the federal and state levels allows dischargers the opportunity to demonstrate, using scientifically defensible approaches such as Evaluation Monitoring, that the exceedance of a water quality criterion/standard/objective does not represent a significant adverse impact on the beneficial uses of a waterbody. If the discharger is unwilling to fund studies of this type, then the regulatory program defaults to the worst-case approach, where the exceedance of a water quality objective by any amount more than once every three years is a violation that must be corrected. This then leads to the 303(d) listing of the waterbody and eventually the need to develop a TMDL to control excessive concentrations of the constituents of concern at their sources.

With respect to the agricultural waiver monitoring, there can be little doubt that concentrations of a variety of potential pollutants will be found in excess of CVRWQCB Basin Plan objectives. If the constituents that violate the WQO are not already being addressed through a TMDL, then a 303(d) listing will occur, and TMDLs will ensue. The agricultural community, however, should be given the opportunity to conduct the studies to demonstrate, using scientifically defensible approaches that are acceptable to federal and state regulatory agencies and the public, that the water quality objective that is being violated is overprotective in the agriculturally dominated waterbodies and downstream thereof. If, however, the agricultural community is unwilling or unable to conduct these studies, under the current regulatory requirements it will need to develop control programs to eliminate the violations of the WQO in agricultural drains and agriculturally dominated waterbodies, as well as any downstream impacts arising from stormwater runoff or tailwater/drain water discharges to the State's waters.

One of the most significant problems with the current US EPA regulatory program, which leads to technically invalid approaches for regulating constituents in stormwater runoff and wastewater discharges, is the Agency's continued use of the independent applicability policy (see Lee and Jones-Lee, 1995). This policy, which was adopted without public review, requires that chemical-specific numeric water quality standards be met, even though biological or other testing shows that the chemical-specific standard is overprotective. For example, it has been repeatedly demonstrated that urban area street and highway stormwater runoff contains a variety of heavy metals (such as copper, zinc, lead) at concentrations above worst-case-based water quality objectives. However, toxicity testing using a suite of sensitive organisms in a variety of locations, has demonstrated that the heavy metals in urban area street and highway runoff are in nontoxic, non-available forms. This applies to the total as well as the dissolved forms of these metals. The dissolved forms of copper have been found to be complexed with organics and are nontoxic. Under the independent applicability policy, the public agencies responsible for urban area and highway stormwater runoff management through the NPDES permit must go to the expense of changing the water quality standard (objective) using US EPA (1994b) guidance in order to eliminate the violation of the standard. Such studies can cost several hundred thousand dollars. Since the purpose of water quality standards is often the protection of aquatic life, it should be possible to focus the regulatory program on aquatic-life-related issues, rather than chemical-concentration issues. This focus would rely heavily on aquatic life toxicity and bioaccumulation testing as the basis for evaluating whether potentially toxic constituents are present in a waterbody at concentrations which could cause aquatic life toxicity or excessive bioaccumulation.

Aquatic Life Toxicity. Finding aquatic life toxicity in a standard toxicity test of the types that are used does not necessarily mean that this toxicity is significantly adverse to either the ecosystem or the water quality-related beneficial uses. It does mean, however, that there is a potential for ecological and/or water quality impacts due to the laboratory measured toxicity that needs to be evaluated. In the current regulatory framework, however, where the US EPA interprets the Clean Water Act congressional mandate to include full protection of the nation's water quality/beneficial uses, any toxicity found under standardized conditions must be regulated as though the toxicity were significantly adverse to the aquatic life-related beneficial uses of the waterbody, either directly to higher trophic level organisms, or through the food web, as well as adverse to the ecosystem's functioning, unless it is appropriately demonstrated that these impacts are not occurring.

This "worst-case" approach is in accord with the US EPA's approach for implementing the 1972 amendments to the federal water pollution control regulations ("Clean Water Act," US Congress, 1972, 1987). In many respects, the Clean Water Act is implemented in such a way so that if there is a significant question about a potential water quality impact, it is assumed that the impact will occur unless it is demonstrated otherwise. The US EPA has made it clear that those interested in continuing to use/discharge chemicals to the nation's waters have the opportunity to use good science to demonstrate that a discharge may take place, including toxic discharges, provided it is shown that these discharges are not adverse to beneficial uses, which includes protection of ecosystem functioning.

The evaluation of the potential significance of toxicity or other impacts associated with stormwater runoff events or discharges from agricultural sources requires a comprehensive field study that reliably evaluates the hydrology and hydraulics of the discharge/runoff situation as it mixes with the receiving waters, and the concentrations of chemicals, both conservative (non-reactive) and reactive chemicals that are potentially toxic to aquatic life in the receiving waters for the discharge/runoff. There are basically three focal points for any impact evaluation: the sediment-associated organisms (associated with a particular area of the waterbody's sediments), the planktonic organisms (moving with the water, with only limited locomotion ability) and the nektonic organisms (free-swimming). For the sediment-associated organisms, consideration must be given to the epibenthic organism impacts as well as those that are present within the sediments.

For each type of organism, there is need to assess the duration of exposure and the integrated magnitude of exposure to the toxicant(s). This assessment frequently requires considerable understanding of the movement of water and the associated constituents that are of concern. While generally for planktonic organisms and dissolved constituents, it is fairly straightforward (with appropriate sampling) to determine the exposure situation, for constituents associated with particulates where the particulate-bound fraction is toxic, the issue of the movement of the particulates also has to be evaluated. This is typically a much more complex issue than for dissolved constituents.

The current overall regulatory requirements for controlling aquatic life toxicity due to pesticides and other potentially toxic constituents is to protect the water quality-related designated beneficial uses of the waterbody. As it relates to aquatic life resources, this is typically understood to mean the numbers, types and characteristics of desirable forms of aquatic life in the potentially impacted waterbody. For many situations where the toxicant is toxic to a variety of types of aquatic life at low concentrations (such as some heavy metals to zooplankton, fish larvae, etc.), there is a fairly well defined relationship between measured toxicity and impacts on a number of forms of aquatic life in the receiving waters. However, for the organophosphate pesticides such as diazinon and chlorpyrifos where the toxicity is only manifested to a limited number of types of zooplankton and benthic organisms, there are important questions regarding how to translate the laboratory measured toxic pulses of diazinon associated with stormwater runoff from recently treated areas to adverse impacts on the designated beneficial uses of the receiving waters. This situation may justify conducting field studies to determine whether the toxic pulses of diazinon in stormwater runoff from dormant-sprayed orchards are significantly adverse to higher trophic level organisms such as fish larvae.

In those situations where potentially significant aquatic life toxicity is found to zooplankton, there is need to evaluate the potential water quality/ecological significance of this toxicity. A distinction should be made between ecological significance of the toxicity – as it may impact the function of the ecosystem that exists or could exist in the waters under consideration – and the water quality significance of the toxicity – as it may impact the designated beneficial uses of the waterbody of concern to the public.

With respect to ecological significance, it is well understood that there can be appreciable toxicity to certain forms of aquatic life which can eliminate a species or so without adversely impacting the ecosystem's functioning. Similarly, from a water quality/beneficial use impact assessment situation, there can be toxicity to certain forms of aquatic life, especially lower trophic level forms, without impairing the beneficial uses of the waterbody from the public's perspective. For example, in many situations, toxicity to algae would not be considered significantly adverse to the beneficial uses of a waterbody if the algae are already present there at concentrations which are impairing the beneficial uses. Further, toxicity to mosquito larvae without toxicity to essential larval game fish food could be considered beneficial. Similarly, toxicity to rough fish populations, such as carp, may be considered acceptable if it does not also affect certain game fish species, such as trout or bass. The issue, therefore, in evaluating the impact of toxicity on a waterbody's ecosystem or its water quality-related beneficial uses, is one of understanding the range of organism types and magnitude of toxicity and its persistence that occurs in association with a particular situation.

The elimination of all toxicity in the State's waters due to diazinon runoff from dormant-sprayed orchards will almost certainly mean that diazinon cannot be used as a dormant spray. This situation arises from the fact that the properties of diazinon under its current formulation/ application are such that the likelihood of developing an affordable BMP that will control diazinon runoff from dormant-sprayed orchards, that have received a recent application of diazinon when a major rainfall runoff event occurs, is small. Since diazinon's use in some instances is cost-effective in controlling certain types of orchard insects and since alternative pesticides to diazinon may be at least as adverse, if not more adverse, to the beneficial uses of waterbodies, consideration should be given to conducting the studies necessary to determine whether the laboratory-based *Ceriodaphnia* toxicity represents a significant adverse impact on desirable higher trophic forms of aquatic life such as game fish larvae, endangered species, etc.

Although pyrethroid-based pesticides are being used as an alternative to diazinon, problems are being encountered with pest resistance to pyrethroid pesticides. It will, therefore, be important to reliably evaluate the water quality significance of diazinon in stormwater runoff from dormant-sprayed orchards. Such an evaluation should include determining alternative approaches for application of diazinon to minimize runoff.

It should not be necessary to conduct studies at each and every location where there is significant stormwater runoff from a dormant-sprayed orchard or other area of diazinon application. A few well-chosen representative locations should be adequate to determine whether diazinon in stormwater runoff from dormant-sprayed orchards is significantly adverse to the beneficial uses of waterbodies. In the early 1990s Kuivila and Foe (1995) found that diazinon applied as a dormant spray in Sacramento River watershed orchards produced a toxic pulse that persisted for more than a week down the Sacramento River and through the Delta. This toxic pulse was of sufficient magnitude, duration and extent to be considered potentially significantly adverse to the beneficial uses of the Sacramento River and the Delta.

More recently, however, associated with reduced use of diazinon, the magnitude of the toxic pulse associated with stormwater runoff events following application of diazinon as a dormant spray appears to be significantly less. Further work needs to be done to confirm that the worst-case toxic pulse associated with the use of diazinon as a dormant spray in the Sacramento and Feather River watersheds is of limited duration, extent and impact.

Lee and Taylor (1999), and Lee, *et al*. (2000, 2001) conducted a fate/persistence study of OP pesticide-caused aquatic life toxicity for stormwater runoff events in 1998-2000 into the Upper Newport Bay in Orange County, California and its watershed. This study involved monitoring San Diego Creek as it enters Upper Newport Bay, which is the primary tributary of the Bay, during a stormwater runoff event. Upper Newport Bay is a marine bay with typical salinities on the order of 30 ppt. Stormwater inputs to the Bay generally occur as a freshwater lens floating on the marine waters of the Bay. The Bay has a three- to four-foot tide and about a ten-day, tidally-controlled hydraulic residence time. The freshwater input from San Diego Creek mixes to a limited extent with the Bay waters to form the freshwater lens with a salinity greater than that of freshwater, but considerably less than that of the Bay waters. Based on the total *Mysidopsis* toxicity due to chlorpyrifos of about 10 TUa (toxic units, acute), any time the salinity of the Bay waters during a runoff event is greater than about 3 ppt, the waters would be expected to be nontoxic to *Mysidopsis*, since insufficient toxic freshwater has mixed into the Bay waters to create toxic exposure conditions. *Mysidopsis* is a marine zooplankton that is highly sensitive to chlorpyrifos toxicity.

The Bay monitoring program consisted of evaluating the net advective down-Bay transport of the freshwaters in the Bay to assess the average downstream velocity. At about 6- to 10-hour intervals, samples of Bay waters near the surface, near mid-depth and near the bottom were taken. Temperature, salinity, OP pesticides and, for some samples, *Mysidopsis* toxicity were measured. Based on the results of this testing, it was found that the chlorpyrifos-caused toxicity persisted for about a day after the stormwater runoff event had ceased. There was measured toxicity and a chemical-concentration-based potential for toxicity near the mouth of where San Diego Creek entered the Bay in the freshwater lens. These studies, therefore, concluded that, in order for toxicity to be significantly adverse to the Bay ecosystem and to the Bay's water quality/aquatic life-related beneficial uses, it would be necessary for a marine zooplankter that normally lives in 30-ppt marine waters to migrate into the freshwater lens near the mouth of the Bay and to receive a toxic exposure during about a one-day time period. Lee and Taylor, through the use of modeling of the Bay's characteristics under various magnitude stormwater runoff events, concluded that there would be several storms per year where there would be a potential for toxicity to *Mysidopsis* due to chlorpyrifos.

The freshwater zooplankters that come into the Bay from San Diego Creek watershed are killed in the Bay by the salinity, so the OP pesticide-caused toxicity to them is not an issue in the freshwater part of the Bay because of the salinity-controlled toxicity. In order for the chlorpyrifos-caused toxic pulses to be significantly adverse to the beneficial uses of the Bay, not only must the marine zooplankter receive a toxic exposure, but also these zooplankter(s) must be of critical ecological importance to the Bay's ecosystem and/or be of significance to higher trophic level marine aquatic life that inhabits the Bay, such as being an essential, non-replaceable food source for desirable forms of fish or other higher trophic level aquatic life. Lee and Taylor (1999, 2001) and Lee, *et al*. (2000, 2001) concluded that, while these conditions could occur, the likelihood of their occurring is small and, therefore, under the conditions of OP pesticide-caused aquatic life toxicity entering Upper Newport Bay, it is unlikely that the stormwater runoff-associated toxicity causes significant impairment to the beneficial uses of the Bay or its ecosystem.

It should be noted that toxicity that occurred under laboratory conditions after several days of exposure would not be of concern in Upper Newport Bay, since the potential for aquatic organisms to receive that type of exposure in a rainfall runoff event is remote due to the tidal mixing of Bay waters with the freshwater input.

Intensive fate/persistence studies of the type conducted by Lee and Taylor are difficult to carry out and expensive, but they are necessary to evaluate whether toxicity measured under laboratory conditions is likely to occur in the field to a sufficient extent to be adverse to aquatic life. They are also essential to being able to justify the continued use of a pesticide like diazinon or chlorpyrifos, which can be readily transported from the area of use to the State's waters in stormwater runoff events. Without these studies, under the Clean Water Act requirements the pesticide-caused toxicity will have to be regulated under the Basin Plan requirements of "no toxicants in the waters in toxic amounts." This is interpreted to mean that there cannot be an exceedance of the acute and chronic water quality criteria/objectives.

Lee and Taylor (1999) and Lee, *et al*. (2000) have pointed out that the laboratory measured toxicity of diazinon and chlorpyrifos that occurs in the freshwater tributaries of Upper Newport Bay is not a reliable assessment of a potential water quality impact of these pesticides to aquatic life in the Upper Newport Bay tributary streams. These streams are nontoxic between stormwater runoff events. The maximum travel time for zooplankters during a stormwater runoff event between the headwaters of the stream and when they enter Upper Newport Bay is about eight hours. Therefore, laboratory toxicity that is not manifested until a day or two after the initiation of the test is not a proper measure of toxicity to zooplankton in the Upper Newport

Bay tributary streams. These zooplankton may experience no toxicity due to the OP pesticides prior to the time that they are killed by the salinity in the Bay. There may, however, be toxicity to benthic organisms in the tributary streams due to the toxic pulses associated with stormwater runoff that needs to be assessed as to whether this toxicity is adverse to the beneficial uses of these streams. While these streams are classified as having aquatic life beneficial uses, they are basically concrete-lined channels whose primary function is to transport stormwater to prevent flooding.

The situation in the city of Sacramento, where studies have shown that Arcade Creek, which drains predominantly residential areas, has sufficient diazinon to be toxic to *Ceriodaphnia* over extended exposures, is of concern with respect to potential impacts on the aquatic life resources of Arcade Creek. Since, in general, urban aquatic life toxicity is associated with stormwater runoff events, the fact that there is a potential for aquatic life toxicity in Arcade Creek, even under dry weather flow conditions, requires that studies be conducted of the dry weather flow to determine the sources of the diazinon that are present under those conditions. According to Denton (pers. comm., 2001), the elevated concentrations of diazinon under dry weather flow are found throughout Arcade Creek and seem to originate in its headwaters. Forensic studies of the headwaters should be conducted to determine the origin of the diazinon under dry weather flow.

Studies on the fate of the Arcade Creek toxicity within the Sacramento River have shown that this toxicity does not persist in the River due to its rapid dilution in the River water. Therefore, the water quality significance of the Arcade Creek toxicity issue needs to be evaluated in terms of whether this toxicity is significantly adverse to the beneficial uses of the Creek and most importantly, how the beneficial uses of the Creek would improve, if at all, if the diazinon- and chlorpyrifos-caused toxicity were eliminated.

The same kind of issues need to be addressed in assessing the water quality significance of laboratory measured toxicity in irrigated agriculture discharges/runoff that causes agricultural drains and agriculturally dominated waterbodies to be toxic to aquatic life under standard laboratory conditions. Jones-Lee and Lee (2000b) have discussed the approach that they feel should be followed in developing a TMDL to control aquatic life toxicity in stormwater runoff associated with the use of diazinon and chlorpyrifos in urban and agricultural areas. As they discuss, such issues as whether the toxicity in the agricultural runoff/discharge-dominated waters is significantly adverse to the beneficial uses of the agricultural drain or downstream waters should be evaluated. As it stands now, without site-specific studies to evaluate this issue, the toxicity in agricultural field runoff will have to be controlled to comply with Basin Plan requirements.

Lee and Jones-Lee (2001b) have completed a report presenting the results of the aquatic life toxicity that occurs in the City of Stockton sloughs. Stockton has a number of freshwater tidal sloughs which are drainage ways for urban stormwater and, for some of them, upstream agricultural areas' watershed waters. These sloughs are part of the Delta ecosystem. Studies by the Central Valley Regional Water Quality Control Board and the DeltaKeeper conducted between 1994 and 1999, as presented by Lee and Jones-Lee (2001b), have shown that the Stockton slough water becomes toxic to *Ceriodaphnia* in each rainfall event. They are generally nontoxic between events. The toxicity has been found to be primarily due to diazinon, with chlorpyrifos contributing to it occasionally.

The Stockton sloughs are connected to the Delta and could be important nursery areas for Delta aquatic life. An issue that needs to be evaluated is whether the diazinon-caused aquatic life toxicity that persists for a day or so in the slough waters and for some undefined (likely limited) distance into the Delta is significantly adverse to the beneficial uses of the sloughs and Delta waters. Lee and Jones-Lee (2001b) point out that an even more important issue is that, since the use of diazinon in urban areas is being phased out over the next three years, studies need to be initiated on the water quality impacts of the replacement pesticides that will be used in Stockton on the beneficial uses of the sloughs and the Delta.

As discussed by Lee, *et al.* (2001), it is important in evaluating the potential impacts of aquatic life toxicity, such as caused by the OP pesticides, to determine the potential improvement in ecosystem function/water quality beneficial uses associated with controlling the toxicity. As part of evaluating the water quality benefits of controlling diazinon, or for that matter, other pesticide-caused aquatic life toxicity in waterbodies, the improvement in the waterbodies' beneficial uses should be evaluated. A determination of the appropriateness of controlling aquatic life toxicity due to agricultural use of pesticides for some waterbodies needs to evaluate how the elimination of toxicity will improve, if at all, the designated beneficial uses of the waterbodies and downstream waterbodies.

It is important to understand that the issue is not one of controlling toxicity caused by one pesticide without potentially substituting another pesticide which could be even more toxic to a greater group of organisms than the OP pesticide. In many situations, pesticides are going to be used. The current US EPA Office of Pesticide Programs and the California Department of Pesticide Regulation's approach for registering pesticides does not evaluate whether the use of a registered pesticide in accord with the registration label can lead to aquatic life toxicity in the receiving waters for stormwater runoff from the area where the pesticide is applied. So long as these conditions prevail, where one pesticide can be substituted for another, and thereby cause even greater aquatic life resource damage than the one that caused the original concern, there is need to carefully develop the regulatory approach which would eliminate the use of an effective pesticide as a pest control agent only to substitute another pesticide without proper evaluation of water quality impacts of the replacement pesticide.

An important aspect of toxicity impact assessment is the need to continue to focus on toxicity measurements as opposed to chemical measurements as a surrogate for toxicity. This is especially true today, where there is substantial substitution of other pesticides, such as pyrethroid pesticides, for the OP pesticides in urban and in rural areas. A false sense of security can be obtained through seeing decreases in diazinon concentrations that are equated, without toxicity tests, to a decrease in impacts caused by diazinon, when in fact the impacts due to the other pesticides that are substituted for diazinon may become greater than what they were when diazinon was used.

The evaluation of the water quality/ecological significance of the diazinon-caused toxic pulses associated with its use as a dormant spray should be funded by those who wish to continue to use and sell this pesticide. At this time, there are reasonable questions about whether the toxicity found in stormwater runoff from dormant-sprayed orchards is significantly adverse to the beneficial uses of the Sacramento and Feather Rivers as well as other Central Valley waterbodies. The current regulatory requirements, however, which mandate that this toxicity be controlled could be relaxed to properly reflect its impacts on the beneficial uses of these waters should it be found that they do not significantly impact higher trophic organisms. Without the needed studies, there can be little doubt that the ability to use diazinon as an orchard dormant spray will ultimately be curtailed in order to satisfy current "worst-case" Clean Water Act regulatory requirements.

Evaluation of Runoff Water Quality BMP Efficacy

One of the major problems with trying to evaluate the efficacy of a particular BMP to reduce the impact of the use of diazinon as a dormant spray on receiving water beneficial uses is the essentially unknown coupling that exists between the presence of diazinon in a stream and its impact on the beneficial uses of the waterbody. For the purposes of TMDL implementation and evaluation, it is assumed that the assessment of aquatic life toxicity, together with measurements of diazinon concentrations, is a reliable surrogate for beneficial use assessment. The BMP evaluation monitoring program should include some focused bioassessment studies. Transport fate studies should be conducted to measure the concentrations and flows of the runoff and the waterbody receiving the runoff. It is suggested that samples taken every two to four hours prior to and during runoff events be collected.

When conducting a pesticide runoff BMP evaluation, several years of pre-BMP implementation monitoring of the aquatic biota and chemical characteristics in the water column and sediments upstream, near the point of discharge of the runoff from the treated area, and downstream of this location should be conducted immediately prior to, during, and just after the pesticide application season. At least two upstream stations and two downstream stations should be used. The physical habitat characteristics of each station should be similar, in terms of water depth, velocity, bottom substrate characteristics, etc.

It should be recognized that the efficacy of BMPs of the type that are typically being considered for managing diazinon runoff from dormant-sprayed orchards, as well as the control of other constituents in irrigated agricultural runoff, is likely dependent on the magnitude of the stormwater runoff event, where BMPs such as grassy strips, detention basins, etc., may be somewhat effective at low flow and for small storms, but are not likely to be effective at high flow. It is the high-flow situations which are of greatest concern, since this would likely result in the greatest transport of any diazinon applied for dormant spray from the sprayed area to nearby surface waters. This situation typically applies to near-field (the point of discharge). However, in far-field situations, higher flows may actually dilute the diazinon or other potential pollutants in downstream waters. The monitoring program needs to be able to evaluate these situations for both near-field and far-field impact information as a function of rainfall runoff intensity and duration. Failure to do so could readily result in an incorrect assessment of the water quality impacts of irrigated agricultural discharges and stormwater runoff as related to a particular BMP efficacy.

Data Management and Reporting

A typical water quality monitoring program is a passive program which involves establishing a monitoring plan and executing this plan for a year or so. At the end of the data collection period, an attempt is made to analyze the data with respect to the information provided on the water quality characteristics of the waterbody sampled. This approach, while bureaucratically simple to administer, often leads to far less reliable and useful results than if an active monitoring program had been conducted.

Lee and Jones (1983b) have recommended that water quality monitoring programs be conducted on an active rather than passive basis. In an active program, those responsible for developing the program are aggressively pursuing continuous review of the data as it is collected to assess data quality and the implications for providing information on the water quality characteristics of the waterbody. As part of planning the program, from 10 to 20 percent of the total funds available are set aside for special-purpose sampling to follow up on data generated that is of particular interest or of questionable reliability. In an active monitoring program, if the ongoing data review reveals that the monitoring program needs to be changed to maximize useful information from the funds available, then this change can be made.

A key component of the data review is an evaluation of whether it makes sense. Someone who is sufficiently familiar with the system being studied and data of this type for other similar systems should be involved in data review as the data first become available to be certain that errors in data handling and posting have not occurred. This responsibility should not be left to a data input clerk. Further, someone familiar with data and its use in a regulatory framework should personally review all data entered into the data storage and retrieval system to flag particularly significant data that may need followup.

Cost

Information has been compiled (see Table 5) on the unit cost of analysis for various parameters, as well as sampling, data review and reporting. These costs are based on the experience by the Sacramento River Watershed Program (SRWP) water quality monitoring program, the CVRWQCB SWAMP and Pacific EcoRisk in conducting studies of this type. The actual cost may be somewhat different, based on the number of samples collected and processed at one time.

Cost of Sample Collection. Pacific EcoRisk has estimated that the total cost for collection and handling of 12 sampling events for 12 sites in the Sacramento River watershed and 16 sites in the San Joaquin River watershed is $82,000/yr.

Cost of Fish Collection. Fish collection is estimated to cost about $5,000/day. Typically, one day per collection event should be adequate.

Table 5
Unit Cost of Sample Analysis

Analyte	Unit Cost ($/sample)	
	CVRWQCB SWAMP	SRWP/Pacific EcoRisk
Alkalinity		20.00
Bioassessment	1,000.00	
BOD	30.00	
Boron	5.40	
Chlorophyll and Pheophytin		75.00
Fish Tissue-Dissection and Digestion		88.00
Fish Tissue-Mercury		96.00
Fish Tissue-PCBs & Chlorinated Pesticides		838.00
Mercury		80.00
Methylmercury		115.00
Minerals[a]	62.00	
Molybdenum	15.00	
Nutrients[b]	134.00	
Nutrients-Ammonia		22.00
Nutrients-Nitrate		20.00
Nutrients-Nitrite		20.00
Nutrients-Phosphorus (Dissolved Ortho-P)		20.00
Nutrients-Phosphorus (Total P)		30.00
Nutrients-TKN		30.00
OCl Scan	200.00	
OP Scan	200.00	
OP ELISA Testing for Diazinon and Chlorpyrifos		130.00
Organic Carbon-Dissolved (DOC)		45.00
Organic Carbon-Total (TOC)	16.00	38.50
Pathogens-*Enterococci*		44.00
Pathogens-*E. coli*, Total and Fecal Coliform		50.00
Pesticides-Carbamates/Ureas		190.00
Pesticides-Triazines		150.00
Pesticides-OP		150.00
Selenium	14.60	
Sediment TE[c]/size	120.00	
Sediment OCl Scan	50.00	
Sediment Toxicity	1,000.00	
TDS		20.00
TE[c] – Total and Dissolved	104.40	
Tox Test – 96/48-hr acute	225.00	
Tox Test – Short-Term Chronic *Ceriodaphnia dubia*		175.00
Tox Test – Evaluation of Toxic Units		2,500.00
Toxicity Identification Evaluation (TIE)		6,000.00
TSS	10.00	20.00
UVA 254		40.00

The costs listed above do not include the QA samples that are needed. The number of QA samples depends on the total number of samples processed at one time. The cost for a QA sample would be the same as the cost for a regular sample.

These costs also do not include project administration and report writing.

a Total Minerals - B, Cl, SO_4, CO_3, HCO_3, Na, K, Alkalinity, TDS, Ca, Mg, Total Hardness, pH, Conductivity

b Nutrients - NO_3, NH_3-N, TKN, P, PO_4, K

c Trace Elements – Cu, Cr, Pb, Ni, Zn, Hg, Cd, Arsenic

References

AWWA, APHA, and WEF, Standard Methods for the Examination of Water and Wastewater**,** American Public Health Association, American Waterworks Association, Water Environment Federation, 20th Edition, Washington D.C. (1998).

Azimi-Gaylon, S.; Reyes, E. and Collins, J., "Quality Assurance for Effective Monitoring of Pesticides in the San Joaquin River Basin, California," Proc. US Committee for Irrigation and Drainage Conference, Helping Irrigated Agriculture Adjust to TMDLs, Sacramento, CA, October (2002).

Baggett, A. G., "The State Water Board Seeks Statewide Input on Creation of Controls for Agricultural Runoff," State Water Resources Control Board, Sacramento, CA, March (2002).

Barbour, M. T.; Gerritsen, J.; Snyder, B. D.; and Stribling, J. B., "Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish," Second Edition, EPA 841-B-99-002, U.S. Environmental Protection Agency; Office of Water; Washington, D.C. (1999).

Bryan, M. D. and Rasmussen, R. L., "Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for pH and Turbidity at Deer Creek, El Dorado & Sacramento Counties," Draft Staff Report and Functional Equivalent Document, California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, February (2002).

Cabelli, V. J.; Dufour, A. P.; McCabe, L. J. and Levin, M. A., "Swimming-Associated Gastroenteritis and Water Quality," *American Journal of Epidemiology,* 115:606-616 (1982).

CVRWQCB, "Staff Report: Inland Surface Waters Plan," California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA (1992).

CVRWQCB, The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Fourth Edition, California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA (1998).

CVRWQCB, "A Compilation of Water Quality Goals," Central Valley Regional Water Quality Control Board, Sacramento, CA (2000).

CVRWQCB, "Control of Discharges from Irrigated Lands," California Regional Water Quality Control Board, Central Valley Region, Resolution No. 5-01-236, Sacramento, CA, September (2001a).

CVRWQCB, "Staff Report: Development of Monitoring Programs Addressing Discharges from Irrigated Lands," California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA (2001b).

CVRWQCB, "Draft Proposed Water Quality Monitoring Program for Discharges from Irrigated Lands," California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, February (2002a). http://www.swrcb.ca.gov/~rwqcb5/programs/56_site_list.pdf

CVRWQCB, "Central Valley Regional Water Quality Control Board Surface Water Ambient Monitoring Program (SWAMP) DRAFT Work Plan," California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, April (2002b).

Deanovic, L.; Cortright, K.; Larsen, K.; Bailey, H.; Hinton, D. E. and Connor, V., "Guidelines for Conducting Toxicity Identification Evaluation Procedures in Urban Runoff, a Laboratory Manual," Draft Report Prepared for the Central Valley Regional Water Quality Control Board, Sacramento, CA, June (1998). (Being updated.)

DHS, "Appendices – Draft Guidance for Salt- and Fresh Water Beaches," California Department of Health Services, Sacramento, CA, July (2000). http://www.dhs.ca.gov/ps/ddwem/beaches/beaches_appendices.htm

DHS, Drinking Water Standards, California Department of Health Services, Sacramento, CA, January (2001). www.dhs.ca.gov

Domagalski, J., "Mercury and Methylmercury in Water and Sediment of the Sacramento River Basin, California," *Applied Geochemistry,* 16:1677-1691 (2001).

Dufour, A. P., "Health Effects Criteria for Fresh Recreational Waters," Health Effects Research Laboratory, Office of Research and Development, US Environmental Protection Agency, EPA 600/1-84-004, Washington, D.C. (1984).

Foe, C.; Gowdy, M. and McCarthy, M., "Draft Strawman Source and Linkage Analysis for Low Dissolved Oxygen in the Stockton Deepwater Ship Channel," Report prepared for San Joaquin River DO TMDL Steering Committee and TAC by California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, April (2002). Available from www.sjrtmdl.org.

Fong, S.; Reyes, E.; Larsen, K.; Louie, S. and Deanovic, L., "Sacramento-San Joaquin Delta Toxicity Test Monitoring Report: 1998-99, the Final Report for DeltaKeeper," Aquatic Toxicology Laboratory, University of California, Davis, CA (2000).

George, D. B.; Klein, N. A. and Leftwich, D. B., "The Lubbock Land Treatment System Research and Demonstration Project, Volume III, Agricultural Research Study," EPA/600/2-86/027c, Robert S. Kerr Environmental Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Ada, OK, February (1986).

Grubbs, G., "Development and Adoption of Nutrient Criteria into Water Quality Standards," Office of Science and Technology, US Environmental Protection Agency, WQSP-0101, Washington, D.C. (2001).

Harrington, J. and Born, M., Measuring the Health of California Streams and Rivers: A Methods Manual for Water Resource Professionals, Citizen Monitors, and Natural Resource Students, Second Edition, Sustainable Land Stewardship International Institute, Sacramento, CA (1999).

Hall, L. and Killen, W., "Characterization of Benthic Communities and Physical Habitat in Agricultural Streams in California's San Joaquin Valley," Report, University of Maryland Agricultural Experiment Station, Queenstown, Maryland, September (2002).

Jones-Lee, A. and Lee, G. F., "Evaluation Monitoring as an Alternative to Conventional Water Quality Monitoring for Water Quality Characterization/Management," Proc. of the NWQMC National Conference, "Monitoring: Critical Foundations to Protect Our Waters," US Environmental Protection Agency, Washington, D.C., pp. 499-512 (1998).

Jones-Lee, A. and Lee, G. F., "Proactive Approach for Managing Pesticide-Caused Aquatic Life Toxicity," Report of G. Fred Lee & Associates, El Macero, CA, October (2000a).

Jones-Lee, A. and Lee, G. F., "Development of TMDLs for Control of Organophosphate Pesticide Caused Aquatic Life Toxicity in Urban Stormwater Runoff," Proceedings WEFTECH 2000 Water Environment Federation annual meeting, Anaheim, CA, October (2000b).

Kennedy, J. H.; Ammann, L. P. and Waller, W. T., "Some Statistical Problems Associated with Biological Assessment – Implications and Solutions," In: Warrick, John J. (Ed.), AWRA Annual Spring Specialty Conference Proceedings, "Water Quality Monitoring and Modeling," American Water Resources Association, Middleburg, VA, TPS-01-1, pp. 193-197 (2001).

Kuivila, K. M., "Pesticides in the Sacramento-San Joaquin Delta: State of Knowledge," CALFED Bay-Delta Program Science Conference 2000, Sacramento, CA, October (2000).

Kuivila, K. M. and Foe, C. G., "Concentration, Transport, and Biological Effects of Dormant Spray Pesticides in the San Francisco Bay Estuary, California," *Envir. Toxiciology and Chem.* 14:1141-50 (1995).

Lee, G. F., "Analytical Chemistry for Plant Nutrients," Proc. Symposium on Eutrophication, National Academy of Sci., pp. 646-658, Washington, D.C. (1969).

Lee, G. F. and Jones, R. A., "Interpretation of Chemical Water Quality Data," *Aquatic Toxicology*, STP 667, ASTM, Philadelphia, PA (1979).

Lee, G. F. and Jones, R. A., "An Approach for Evaluating the Potential Significance of Chemical Contaminants in Aquatic Habitat Assessment," Proc. of Symposium, "Acquisition and Utilization of Aquatic Habitat Inventory Information," American Fisheries Society, pp. 294-302 (1982).

Lee, G. F. and Jones, R. A., "Translation of Laboratory Results to Field Conditions: The Role of Aquatic Chemistry in Assessing Toxicity," Aquatic Toxicology and Hazard Assessment: 6th Symposium, STP 802, ASTM, Philadelphia, PA, pp. 328-349 (1983a).

Lee, G. F. and Jones, R. A., "Active versus Passive Water Quality Monitoring Programs for Wastewater Discharges," *Journ. Water Pollut. Control Fed.*, 55:405-407 (1983b).

Lee, G. F. and Jones, R. A., "Effects of Eutrophication on Fisheries," Reviews in *Aquatic Sciences*, 5:287-305, CRC Press, Boca Raton, FL (1991).

Lee, G. F. and Jones-Lee, A., "Guidance for Conducting Water Quality Studies for Developing Control Programs for Toxic Contaminants in Wastewaters and Stormwater Runoff," Report of G. Fred Lee & Associates, El Macero, CA, July (1992).

Lee, G. F. and Jones-Lee, A., "Public Health Significance of Waterborne Pathogens in Domestic Water Supplies and Reclaimed Water," Report to State of California Environmental Protection Agency Comparative Risk Project, Berkeley, CA (1993).

Lee, G. F. and Jones-Lee, A., "Comments on US EPA Proposed Sediment Quality Criteria Based on Acid Volatile Sulfide Normalization Heavy Metal Data," submitted to the Science Advisory Board Sediment Criteria Subcommittee, US Environmental Protection Agency, Washington, D.C., by G. Fred Lee & Associates, El Macero, CA, December (1994).

Lee, G. F. and Jones-Lee, A., "Independent Applicability of Chemical and Biological Criteria/Standards and Effluent Toxicity Testing," *The National Environmental Journal*, 5(1):60-63, (1995), Part II, "An Alternative Approach," 5(2):66-67 (1995).

Lee, G. F. and Jones-Lee, A., "Appropriate Use of Numeric Chemical Water Quality Criteria," *Health and Ecological Risk Assessment*, 1:5-11 (1995). Letter to the Editor, Supplemental Discussion, 2:233-234 (1996).

Lee, G. F. and Jones-Lee, A., "Evaluation Monitoring vs Chemical Constituent Monitoring: Chemical Concentrations vs Chemical Impacts," Presented at CA Water Environment Association Training Seminar, "Recent Advances in Receiving Water Monitoring," Anaheim, CA, February (1999).

Lee, G. F. and Jones-Lee, A., "Issues in Developing the San Joaquin River Deep Water Ship Channel DO TMDL," Report to Central Valley Regional Water Quality Board, Sacramento, CA, August (2000).

Lee, G. F. and Jones-Lee, A., "Assessing the Water Quality Impacts of Phosphorus in Runoff from Agricultural Lands," Proceedings of American Chemical Society Agro Division Symposium, "Environmental Impact of Fertilizer Products in Soil, Air and Water," Chicago, IL, August (2001a), to be published by the American Chemical Society.

Lee, G. F. and Jones-Lee, A., "Review of the City of Stockton Urban Stormwater Runoff Aquatic Life Toxicity Studies Conducted by the CVRWQCB, DeltaKeeper and the University of California, Davis, Aquatic Toxicology Laboratory between 1994 and 2000," Report to the

Central Valley Regional Water Quality Control Board, G. Fred Lee & Associates, El Macero, CA, October (2001b).

Lee, G. F. and Jones-Lee, A**.**, “City of Stockton Mosher Slough and Five Mile Slough Diazinon and Chlorpyrifos Aquatic Life Toxicity Management Report,” California Water Institute Report TP 02-08 to the California State Water Resources Control Board/Central Valley Regional Water Quality Control Board, 44 pp, California State University Fresno, Fresno, CA, December (2002a).

Lee, G. F. and Jones-Lee, A., “Synthesis of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel Near Stockton, CA,” Report Submitted to SJR DO TMDL Steering Committee/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, May (2002b).

Lee, G. F. and Jones-Lee, A., “An Integrated Approach for TMDL Development for Agricultural Stormwater Runoff and Tailwater Releases,” Proc. of USCID Conference on Helping Irrigated Agriculture Adjust to TMDLs, Sacramento, CA, October, (2002c).

Lee, G. F. and Jones-Lee, A., “Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance,” California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002d).

Lee, G. F. and Jones-Lee, A., “Developing Nutrient Criteria/TMDLs to Manage Excessive Fertilization of Waterbodies,” Proceedings of the 2002 WEF TMDL Conference, Water Environment Federation, Alexandria, VA, (2002e). Available on CD-ROM.

Lee, G. F. and Jones-Lee, A., “Review of Management Practices for Controlling the Water Quality Impacts of Potential Pollutants in Irrigated Agriculture Stormwater Runoff and Tailwater Discharges,” California Water Institute Report TP 02-05 to California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 128 pp, California State University Fresno, Fresno, CA, December (2002f).

Lee, G. F. and Jones-Lee, A, “Appropriate Incorporation of Chemical Information in a Best Professional Judgment Triad Weight of Evidence Evaluation of Sediment Quality,” Proceedings of Fifth International Symposium on Sediment Quality, Aquatic Ecosystem Health and Management Society, Chicago, IL, October (2002g).

Lee, G. F.; Jones, R. A.; and Newbry, B. W., “Water Quality Standards and Water Quality,” *Journ. Water Pollut. Control Fed*., 54:1131-1138 (1982a).

Lee, G. F.; Jones, R. A.; and Newbry, B. W., “Alternative Approach to Assessing Water Quality Impact of Wastewater Effluents,” *Journal Water Pollut. Control Fed*., 54(2):165-174 (1982b).

Lee, G. F.; Jones-Lee, A.; and Rast, W., “Secchi Depth as a Water Quality Parameter,” Report of G. Fred Lee & Associates, El Macero, CA (1995).

Lee, G. F.; Jones-Lee, A. and Taylor, S., "Evaluation of the Water Quality Significance of OP Pesticide Toxicity in Tributaries of Upper Newport Bay, Orange County, CA," Ninth Symposium on Environmental Toxicology and Risk Assessment: Recent Achievements in Environmental Fate and Transport, ASTM STP 1381, pp 35-51, (2000).

Lee, G. F. and Taylor, S., "Results of Aquatic Life Toxicity Studies Conducted During 1997-98 in the Upper Newport Bay Watershed and Review of Existing Water Quality Characteristics of Upper Newport Bay, Orange County, CA and its Watershed," Report to the State Water Resources Control Board, Santa Ana Regional Water Quality Control Board, and the Orange County Public Facilities and Resources Department to meet the requirements of a US EPA 205(j) Project, G. Fred Lee & Associates, El Macero, CA and Robert Bein, William Frost Associates, Irvine, CA, October (1999).

Lee, G. F.; Taylor, S. and County of Orange Public Facilities and Resources Department, "Upper Newport Bay Water Quality Enhancement Project, Final Report," Agreement Nos. 8-023-258-0 and 8-174-250-0, submitted to State Water Resources Control Board, Santa Ana Regional Water Quality Control Board and Orange County Public Facilities and Resources Department to meet the requirements of the US EPA 319(h) Project, G. Fred Lee & Associates, El Macero, CA and RBF Consulting, Irvine, CA, May (2001).

Lee, G. F.; Taylor, S. and Palmer, F., "Results of Aquatic Toxicity Testing Conducted During 1999-2000 in the Upper Newport Bay Watersheds," submitted to State Water Resources Control Board, Santa Ana Regional Water Quality Control Board and Orange County Public Facilities and Resources Department to meet the requirements of the US EPA 319(h) Project, G. Fred Lee & Associates, El Macero, CA and RBF Consulting, Irvine, CA, January (2001).

Lewis, P. A.; Klemm, D. J.; Lazorchack, J. M.; Norberg-King, T.; Peltier, W. H. and Heber, M. A., "Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms," Environmental Monitoring Systems Laboratory, Cincinnati, OH; Environmental Research Laboratory, Duluth, MN; Region 4, Environmental Services Division, Athens, GA; Office of Water, Washington, D.C.; Environmental Monitoring Systems Laboratory, Cincinnati, OH; Office of Research and Development, US Environmental Protection Agency, Cincinnati, OH (1994).

Lewis, W. M. and Morris, D. P., "Toxicity of Nitrite to Fish: A Review," *Transactions of the American Fisheries Society,* 115:183-195 (1986).

Letey, J., "Dilemma: Managing Ground Water Quality and Irrigated Agriculture," Proc. of the 19th Biennial Conference on Ground Water, "Are California's Ground Water Resources Sustainable?" Water Resources Center Report No. 84, ISSN 0575-4968, December (1994).

Majewski, M. S. and Capel, P. D., "Pesticides in the Atmosphere: Distribution, Trends, and Governing Factors," Open File Report 94-506, National Water-Quality Assessment Program, US Geological Survey, Sacramento, CA (1995).

NAS/NAE, Water Quality Criteria 1972, National Academy of Sciences/National Academy of Engineering, EPA-R3-73-033, Washington, D.C., March (1973).

NRC, Managing Troubled Waters: The Role of Marine Environmental Monitoring, National Research Council, National Academy Press, Washington, D.C. (1990).

OEHHA, Water – Public Health Goals, California Office of Environmental Health Hazard Assessment, Sacramento, CA, September (2001). http://www.oehha.ca.gov/

Oppenheimer, E. I. and Grober, L. F., "Total Maximum Daily Load for Salinity and Boron in the Lower San Joaquin River," California Regional Water Quality Control Board, Central Valley Region, Sacramento, CA, January (2002).

Rast, W. and Lee, G. F., "Nutrient Loading Estimates for Lakes," *J. Environ. Engr.* (Div. ASCE) 109:502-517 (1983). [See also closure discussion, "Nutrient Estimates for Lakes," *Journ. Environ. Engr.* 110:722-724 (1984).]

SFEI, "Grassland Bypass Project Annual Report 1999-2000," prepared by San Francisco Estuary Institute for the Grassland Bypass Project Oversight Committee, February (2002).

Siepmann, S. and Findlayson, B., "Water Quality Criteria for Diazinon and Chlorpyrifos," California Department of Fish and Game, Administrative Report 00-3, Rancho Cordova, CA (2000).

Solbe, J. F. de L. G., The Environmental Effects of Nitrite (FT 0163C), WRc Environment, Marlow, Bucks, England (1981).

Strauss, A., "Comments on the Use of Probabilistic Ecological Risk Assessment to Establish Organophosphate Pesticide Aquatic Life Toxicity TMDL Goal," Letter to G. Carlton, Executive Officer, Central Valley Regional Water Quality Control Board, Sacramento, CA, from EPA Region IX, San Francisco, CA (2000).

Suverkropp, C., "Discharge Monitoring Frequency Evaluations," Memorandum to the City of Sacramento, Larry Walker Associates, Davis, CA, November 23 (1998).

SWRCB, "1998 California 303(d) List and TMDL Priority Schedule," State Water Resources Control Board, Sacramento, CA, April (1998).

SWRCB, "Plan for California's Nonpoint Source Pollution Control Program (NPS Program Plan)," State Water Resources Control Board, Sacramento, CA (2000).
http://www.swrcb.ca.gov/nps/protecting.html

SWRCB, "Plan for California's Nonpoint Source Pollution Control Program: Second Addendum to Five-Year Implementation Plan for 1998-2003," State Water Resources Control Board, Sacramento, CA (2001a).

SWRCB, "Toxic Substances Monitoring Program," State Water Resources Control Board, Sacramento, CA (2001b).
http://www.swrcb.ca.gov/programs/smw/index.html

SWRCB/TSM, "Toxic Substances Monitoring Program," State Water Resources Control Board, Toxic Substances Monitoring Program, databases and annual reports, Sacramento, CA (2002). Available from http://www.swrcb.ca.gov/programs/smw/index.html,

Tanji, K. K. (ed.), Agricultural Salinity Assessment and Management, ASCE Manuals & Reports on Engineering Practice No. 71, American Society of Civil Engineers, Reston, VA (1990). Available from http://www.pubs.asce.org/books2.html

UC Davis ATL, "Standard Operating Procedures," Aquatic Toxicology Laboratory, Institute of Ecology, University of California, Davis, CA, February 26 (1999).

US Congress, Federal Water Pollution Control Act Amendments of 1972, PL 92-500, Washington, D.C. (1972).

US Congress, "Clean Water Act," Water Quality Act of 1987, PL 100-4, Washington, D.C. (1987).

USDA, Handbook 60, US Department of Agriculture (1969), out of print. Available from http://www.ussl.ars.usda.gov/hb60/hb60requ.htm

US EPA, Quality Criteria for Water, US Environmental Protection Agency, Washington, D.C., July (1976).

US EPA, "Ambient Water Quality Criteria for Bacteria," US Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, EPA 440/5-84-002, Washington, D.C., January (1986).

US EPA, Quality Criteria for Water 1986, US Environmental Protection Agency, Office of Water Regulations and Standards, EPA 440/5-86-001, Washington, D.C., May (1987).

US EPA, "Water Quality Standards Handbook: Second Edition," US Environmental Protection Agency, Office of Water, EPA-823-B-94-005b, Washington, D.C., August (1994a).

US EPA, "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates," US Environmental Protection Agency, EPA/600/R-94/024, Washington, D.C., June (1994b).

US EPA, "Stay of Federal Water Quality Criteria for Metals; Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants; States' Compliance—Revision of Metals Criteria; Final Rules," US Environmental Protection Agency, *Federal Register*, 60(86):22228-22237 (1995).

US EPA, "Water Quality Criteria and Standards Plan – Priorities for the Future," US Environmental Protection Agency, Office of Water, EPA 822-R-98-003, Washington, D.C., June (1998).

US EPA, "Water Quality Criteria; Notice of Availability; 1999 Update of Ambient Water Quality Criteria for Ammonia; Notice, Part VI," US Environmental Protection Agency, *Federal Register* 64:245, FRL-6513-6 (1999a).

US EPA, "National Recommended Water Quality Criteria-Correction," EPA 822-Z-99-001, US Environmental Protection Agency, Office of Water, Washington, D.C. (1999b).

US EPA, "Mercury Update: Impact on Fish Advisories," EPA-823-F-99-016, US Environmental Protection Agency, Office of Water, Washington, D.C. (1999c).

US EPA, "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Vol. II, Risk Assessment and Fish Consumption Limits," Second Edition, EPA 823-B-97-004, US Environmental Protection Agency, Office of Water, Washington, D.C. (1999d).

US EPA, "Selected OW Methods and Guidance," EPA-821-C-00-002, US Environmental Protection Agency, Washington, D.C., September (2000a).

US EPA, "Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule," US Environmental Protection Agency, Region 9, *Federal Register* 40 CFR Part 131, Vol. 65, No. 97, [FRL-6587-9], RIN 2040-AC44, San Francisco, CA (2000b).

US EPA, "Nutrient Criteria Technical Guidance Manual: Rivers and Streams," US Environmental Protection Agency, Office of Water, EPA-822-B-00-002, Washington, D.C. (2000c).

US EPA, "National Water Quality Inventory 1998 Report to Congress, US Environmental Protection Agency, EPA-841-R-00-0001, Washington, D.C. (2000d).

US EPA, "Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment: Status and Needs," EPA-823-R-00-001, US Environmental Protection Agency, Washington, D.C., February (2000e).

US EPA, "Nutrient Criteria Development; Notice of Ecoregional Nutrient Criteria," US Environmental Protection Agency, *Federal Register,* 66(6):1671-1674 (2001a). http://www.epa.gov/fedrgstr/EPA-WATER/2001/January/Day-09/w569.htm

US EPA, "Water Quality Criteria for the Protection of Human Health: Methylmercury," EPA-833-F-01-001, US Environmental Protection Agency, Office of Water, Washington, D.C. (2001b).

US EPA, "Water Quality Criteria: Notice of Availability of Water Quality Criterion for the Protection of Human Health: Methylmercury," US Environmental Protection Agency, *Federal Register*, 66(5):1344-1359 (2001c).

US EPA, "Uncertainty in Well Water Analysis," US Environmental Protection Agency, Lava Cap Mine Newsletter, November (2002a).

US EPA, "Implementation Guidance for Ambient Water Quality Criteria for Bacteria," Draft, US Environmental Protection Agency, Washington, D.C. (2002b). http://www.epa.gov/water/science/standards/bacteria

US EPA, Ecotoxicity Database, US Environmental Protection Agency, Office of Pesticide Programs, Washington, D.C. (2002c).

US EPA, "Strategy for Water Quality Standards and Criteria: Strengthening the Foundation of Programs to Protect and Restore the Nation's Waters (Draft)," US Environmental Protection Agency, Office of Water, Washington, D.C. (2002d). www.epa.gov/waterscience/standards

Weston, D. P., "Toxicological Implications of Changing Pesticide Use in the Central Valley," *Norcal SETAC News*, 13(1):15-16, March (2002).

Woodard, R., "Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies Taken from the Sacramento-San Joaquin Delta," Prepared for the CALFED Bay-Delta Program, September 22 (2000).

Woods, P., pers. comm., US Environmental Protection Agency, Region 9, San Francisco, CA (2000, 2001).

Yolo County, "Cache Creek Annual Status Report 1998," Yolo County Planning & Public Works Dept. and Cache Creek Technical Advisory Committee, Woodland, CA (1998).

Yolo County, "Cache Creek Annual Status Report 1999," Yolo County Planning & Public Works Dept. and Cache Creek Technical Advisory Committee, Woodland, CA (1999).

Appendix A
CVRWQCB Staff Draft March 13, 2002, Phase I Ag Waiver Monitoring Program

Site Number	Site Description	County	Receiving Water	Historical Monitoring/ Comments	Current Studies	CONSTITUENTS							
						Flow	Total Suspended Solids / Turbidity (Frequency in Months)	Toxicity [Three Species Bioassay] (Frequency in Months)	Additional Constituents		Data currently being collected pertinent to Resolution #5-01-236; Control of Discharges to Irrigated Lands	Data still needed from this site	Other current sampling
	SACRAMENTO BASIN												
1	South Fork Pit River at Alturus	Modoc	Pit River			12	12	12	Nutrients, DO, temp (303d Pit River)			12 months: TSS, toxicity, flow, nutrients, DO, temp (303d Pit River)	
2	Burney Creek at Clarks Creek Road	Shasta	Pit River			12	12	12	Nutrients, DO, temp (303d Pit River)			12 months: TSS, toxicity, flow, nutrients, DO, temp (303d Pit River)	
3	Fall River at the PG&E Diversion Dam	Shasta	Fall River/ Pit River			12	12	12	Nutrients, DO, temp (303d Pit River)			12 months: TSS, toxicity, flow, nutrients, DO, temp (303d Pit River)	
4	Anderson Creek at bridge crossing on Road A17	Shasta	Sacramento River	1970s NPDES monitoring, Anderson-Cottonwood Irrigation District		12	12	12				12 months: TSS, toxicity, flow	
5	Rice Creek at Capay Road *	Tehama	Sacramento River	1970s NPDES monitoring, Tehama County Flood Control and Water Conservation District		12	12	12				12 months: TSS, toxicity, flow	

6	Reclamation District 108's drain near confluence with Sacramento River	Yolo	Sacramento River	1970s NPDES monitoring, Sac Valley Water Quality Committee		12	12	12	Diazinon (seasonal)			12 months: TSS, flow, toxicity, diazinon (seasonal)	
7	Reclamation District 787's drain near confluence with Colusa Drain	Yolo	Sacramento River	1970s NPDES monitoring, Sac Valley Water Quality Committee		12	12	12	Diazinon (seasonal)			12 months: TSS, flow, toxicity, diazinon (seasonal)	
8	Reclamation District 1001's drain near confluence with Sacramento River	Placer	Sacramento River	1970s NPDES monitoring, Sac Valley Water Quality Committee		12	12	12	Diazinon (seasonal)			12 months: TSS, flow, toxicity, diazinon (seasonal)	
9	Morrison Slough	Sutter	Sacramento River			12	12	12	Diazinon (seasonal)			12 months: TSS, flow, toxicity, diazinon (seasonal)	
10	Butte Slough at Pass Rd. *	Sutter	Sacramento River	1970s NPDES monitoring near Butte Slough confluence with Sutter Bypass, Sac Valley Water Quality Committee	Dormant Season Diazinon Study	12	12	12	Diazinon (seasonal)		Diazinon - Dormant Season Diazinon Study (4-5 storm events)	12 months: TSS, toxicity, flow, diazinon (seasonal)	
					Rice Pesticide Program monitors molinate (on 303(d))								Molinate -Rice Pesticide Program
11	Wadsworth Creek (Suggested Monitoring Location: at Acacia Rd)	Sutter	Sacramento River	Wadsworth Canal near confluence with Sutter Bypass was part of 1970s NPDES monitoring, Sac Valley Water Quality Committee	Bioassessment in Ag and Effluent Dominated Water Bodies	12	12	12				12 months: TSS, toxicity, flow	bioassessment, turbidity, pH, DO, ammonia, temp, hardness & alkalinity - Bioassessment in Ag and Effluent Dominated Water Bodies

12	Gilsizer Slough at Obanion Outfall	Sutter	Sacramento River		Bioassessment in Ag and Effluent Dominated Water Bodies	12	12	12				12 months: TSS, toxicity, flow	bioassessment, turbidity, pH, DO, ammonia, temp, hardness & alkalinity - Bioassessment in Ag and Effluent Dominated Water Bodies
13	Sacramento Slough - Upstream of confluence with Sacramento River *	Sutter	Sacramento River	1970s NPDES monitoring at Sacramento Slough near confluence with Sutter Bypass, Sac Valley Water Quality Committee	Dormant Season Diazinon Study	12	12	12	Diazinon (seasonal)		Diazinon - Dormant Season Diazinon Study (4-5 storm events)	12 months: fathead minnow & algae toxicity, flow; Ceriodaphnia: 6 months not covered by SWRP; TSS: 8 months not covered by SRWP; diazinon (seasonal)	
					Sacramento River Watershed Program						TSS 4X/yr, Ceriodaphnia 6x/yr - SRWP		Hg, hardness, alkalinity (all 4X/yr), TOC/DOC, UVA 254, TDS, nutrients, OP pesticides, carbamate pesticides, pathogens (all 6 x/yr) - SRWP
14	Colusa Basin Drain at Hwy 20	Colusa	Sacramento River	Colusa Basin Drain at Hwy 20 monitored as part of 1970s NPDES monitoring, Sac Valley Water Quality Committee	Rice Pesticide Program monitors for carbofuran / furadan, malathion, methyl parathion, molinate - on 303(d)	12	12	12	Azinphos methyl; Diazinon (seasonal)			12 months: toxicity, TSS, flow, Azinphos methyl; seasonal: diazinon	carbofuran / furadan, malathion, methyl parathion, molinate - Rice Pesticide Program
15	Colusa Basin Drain at Knights Landing *	Yolo	Sacramento River	Monitored as part of 1970s NPDES monitoring, Sac Valley Water Quality Committee	Sacramento River Watershed Program	12	12	12	Azinphos methyl; Diazinon (seasonal)		TSS & OP pesticides 4X/yr, Ceriodaphnia 6X/yr -SRWP	12 monthsr: fathead minnow & algae toxicity, azinphos methyl , flow; Ceriodaphnia : 6 months not covered by SRWP; TSS: 8 months not covered by SRWP; diazinon (seasonal)	Hg, carbamates, TOC/DOC, TDS, nutrients - SRWP

16	Yolo Bypass (Toe Drain)	Yolo	Sacramento River	1970s NPDES monitoring, Sac Valley Water Quality Committee	Sacramento River Watershed Program	12	12	12					OP pesticides, Hg, TOC - SRWP
					USGS						Frequency of USGS TSS monitoring is UNKNOWN at this time	12 months: toxicity, TSS, flow	Hg, trace elements, major elements, TSS, hardness, alkalinity, TOC/DOC, TDS, nutrients, OP pesticides, carbamate pesticides, triazines
					Bioassessment in Ag and Effluent Dominated Water Bodies								bioassessment, turbidity, pH, DO, ammonia, temp, hardness & alkalinity - Bioassessment in Ag and Effluent Dominated Water Bodies
17	Willow Slough at Hwy 113 (Cache Creek)	Yolo	Sacramento River	1970s NPDES monitoring, Yolo County Flood Control and Water Conservation District		12	12	12				12 months: toxicity, TSS, flow	
18	Wyandotte Creek at South Palmero Ditch	Butte	Feather River	1970s NPDES monitoring, Oroville-Wyandotte Irrigation District		12	12	12				12 months: toxicity, TSS, flow	
19	Reclamation District 784's drain near confluence with Feather River	Sutter	Feather River	1970s NPDES monitoring, Sac Valley Water Quality Committee		12	12	12	Diazinon (seasonal)			12 months: TSS, toxicity, flow; diazinon (seasonal)	
	Jack Slough (Suggested Monitoring Location: at Doc Adams Rd)	Yuba	Feather River	Jack and Simmerly Slough near confluence with Feather River was part of the 1970s	Dormant Season Diazinon Study (tentative study)	12	12	12	Diazinon (seasonal)		Diazinon - Dormant Season Diazinon Study (4-5 storm events)	12 months: TSS, toxicity, flow; diazinon (seasonal)	

20				NPDES monitoring, Sac Valley Water Quality Committee									
					Bioassessment in Ag and Effluent Dominated Water Bodies								bioassessment, turbidity, pH, DO, ammonia, temp, hardness & alkalinity - Bioassessment in Ag and Effluent Dominated Water Bodies
21	Representative Site in El Dorado Irrigation District Area	El Dorado	South Fork American River or North Fork Consumnes River	1970s NPDES monitoring, El Dorado Irrigation District		12	12	12				12 months: TSS, toxicity, flow	
22	Alamo Creek at Brown Alamo Dam OR Sweeney Creek at Weber Road *#	Solano	Delta	1970s NPDES monitoring, Solano Irrigation District		12	12	12				12 months: TSS, toxicity, flow	
	SAN JOAQUIN BASIN												
23	Cosumnes River @ Twin Cities Rd.	Sacramento	Cosumnes River		SWAMP, Nutrient Project	12	12	12			6 months TSS, 2 species toxicity testing - SWAMP	12 months: algal toxicity testing, flow; 6 months: TSS	EC, pH, temp, DO, minerals, TE, TOC, BOD, nutrients, pathogens, sediment (SWAMP & Nutrient Project),
24	Mokelumne River @New Hope Rd.	Sacramento / San Joaquin	Mokelumne River		SWAMP, Nutrient Project	12	12	12				12 months: toxicity testing, flow, TSS	EC, pH, temp, DO, minerals, TE, TOC, BOD, pathogens, sediment - SWAMP
25	Pixley Slough @Davis Rd.	San Joaquin	Disappoint-ment Slough (Delta)		SWAMP	12	12	12	EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: toxicity testing, TSS, flow; seasonal chlorpyrifos; seasonal diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAMP

26	Bear Creek@ Thornton Road	San Joaquin	Disappoint-ment Slough (Delta)		SWAMP, OP TMDL, OP Synoptic	12	12	12	EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO-SWAMP	12 months: toxicity testing, TSS, flow; seasonal chlorpyrifos; seasonal diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment, bioassesment - SWAMP; proposed biannual OP pesticides
27	French Camp Slough @ Airport (SJR)	San Joaquin	San Joaquin River		SWAMP	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: toxicity testing, flow, TSS, boron; seasonal chlorpyrifos; seasonal diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAMP
28	Lone Tree Creek @ Austin Rd	San Joaquin	French Camp Slough		SWAMP, OP TMDL, STOCKTON DO	12	12	12	Ammonia, BOD10, EC		12 months EC, BOD, DO - SWAMP	12 months: toxicity, TSS, flow & ammonia	pH, temp, DO minerals, TE, nutrients, TOC, sediment, bioassesment - SWAMP; VSS, DOC, chlorophyll A - USGS; OP pesticides (storm events) - OP TMDL
29	New Jerusalem Drain (SJR) !	San Joaquin	San Joaquin River		SWAMP	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, 2 species toxicity testing - SWAMP	12 months: algal toxicity testing, TSS, flow, boron; seasonal chlorpyrifos; seasonal diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P
30	Modesto Irrigation Dist. Main Drain near confluence w/ San Joaquin River	Stanislaus	San Joaquin River	Stanislaus-Tuolumne Rivers Water Quality Committee site 1970s		12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)			12 months: TSS, toxicity, flow, boron, EC; Jun-Nov BOD 10, seasonal: chlorpyrifos & diazinon	
31	Modesto Irrigation Dist. Main Canal near confluence with Stanislaus River	Stanislaus	Stanislaus River	Stanislaus-Tuolumne Rivers Water Quality Committee site 1970s		12	12	12	Diazinon (Seasonal)			12 months: TSS, toxicity, flow; seasonal: diazinon	

32	Oakdale Irrigation Dist. Palmer Drain near confluence w/ Dry Creek	Stanislaus	Dry Creek	Stanislaus-Tuolumne Rivers Water Quality Committee site 1970s		12	12	12				12 months: TSS, toxicity, flow	
33	Hospital Creek @ River Rd	Stanislaus	San Joaquin River		SWAMP, OP Synoptic	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: toxicity, boron, TSS, flow; Jun-Nov BOD 10, seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P; TSS - SWAMP storm events
34	Ingram Creek @ River Rd	Stanislaus	San Joaquin River		SWAMP, OP Synoptic, OP TMDL	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: toxicity, boron, TSS, flow; Jun-Nov BOD 10, seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P; TSS - SWAMP storm events
35	Turlock Irrigation Dist. laterals no. 6&7 near confluence with San Joaquin River	Stanislaus	San Joaquin River			12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)			12 months: TSS, toxicity, flow, boron; Jun-Nov BOD 10, seasonal: chlorpyrifos & diazinon	
36	Turlock ID lateral #5 nr Patterson !!	Stanislaus	San Joaquin River		SWAMP Salt/B/Selenium, In-Season Pesicides, OP Synoptic, Nutrient Project , OP TMDL	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, 2 species toxicity - SWAMP	12 months: algal toxicity, flow, TSS, boron; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P; OP pesticides, TSS (storm events) - SWAMP Storm. Bioassesment - OP TMDL
37	Lower Stevinson Lateral near confluence w/ Merced River	Merced	Merced River	TID site 1970s		12	12	12	Chlorpyrifos (Seasonal), Diazinon (Seasonal)			12 months: TSS, toxicity, flow; seasonal: chlorpyrifos & diazinon	
38	Livingston Canal near confluence with Merced River !!!	Merced	Merced River	Merced Irrigation Dist. Site 1970s & 80s		12	12	12	Chlorpyrifos (Seasonal), Diazinon (Seasonal)			12 months: TSS, toxicity, flow; seasonal: chlorpyrifos & diazinon	

39	Grayson Drain	Stanislaus	San Joaquin River		SWAMP	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: toxicity, TSS, flow, boron; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P
40	Del Puerto Cr @ Vineyard Rd	Stanislaus	San Joaquin River		SWAMP , In-Season Pesticides, OP Synoptic, Nutrient Project , OP TMDL	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, 2 species toxicity - SWAMP	12 months: algal toxicity, flow, TSS, boron; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment-SWAMP; bioassesment- In Season Pesticide project; OP pesticides - proposed - OP synoptic
41	Solado Creek @ Hwy 33	Stanislaus	San Joaquin River		SWAMP	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: flow, TSS, boron & toxicity; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC - SWAM P
42	Orestimba Cr @River Rd nr Crows Lndg	Stanislaus	San Joaquin River		SWAMP, In-Season Pesticides, OP Synoptic, Nutrient Project , OP TMDL, SANJ HIP/	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, - SWAMP; Flow: Gauge/telemetered site - USGS; TSS bimonthly - Stockton DO	12 months: boron & toxicity; 6 months: TSS; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment, bioassesment- SWAM P & In Season Pesticide project; OP pesticides - proposed - OP synoptic project
43	Mud Slough (north) downstream of SLD terminus (site D)	Merced	San Joaquin River	(current monitoring by CVRWQCB, USGS, USFWS, USBR, BES)	GBP phase II	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, Se, B, Mo - SWAMP; Flow: Gauge / telemetered site - USGS; 6 months TSS - nutrient project	12 months: toxicity; 6 months: TSS; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P; bioassesment- OP TMDL; In Season Pesticide project; OP pesticides - proposed - OP synoptic project

44	San Luis Drain between Check 1 & terminus (site B) (SJR)	Merced	San Joaquin River		GBP phase II (currently monitored by CVRWQCB, USGS, USBR, BES)	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, Se, B, Mo - SWAMP; 6 months TSS - nutrient project	12 months: flow, toxicity; 6 months: TSS; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment OP pesticides (proposed) - SWAM P; OP pesticides (proposed)
45	Turner Slough	Merced	San Joaquin River		SWAMP Salt/B/Selenium	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: flow, boron, TSS & toxicity; seasonal: chlorpyrifos & diazinon	EC, pH, temp, DO,
46	Salt Slough @Lander/Hwy 165 (SJR)	Merced	San Joaquin River		SWAMP Salt/B/Selenium, In-Season Pesticides, OP Synoptic, Nutrient Project , OP TMDL	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO, Se, B & Mo, 2 species toxicity - SWAMP; 6 months TSS - nutrient project	12 months: algal toxicity, flow; 6 months: TSS; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P; bioassesment- OP TMDL; In Season Pesticide project; OP pesticides - proposed - OP synoptic project
47	Bear Creek @ Bert Crane !!!	Merced	San Joaquin River		SWAMP	12	12	12	Boron, EC, BOD10 (for DO, Jun-Nov), Chlorpyrifos (Seasonal), Diazinon (Seasonal)		12 months EC, BOD, DO - SWAMP	12 months: flow, boron, TSS & toxicity; seasonal: chlorpyrifos & diazinon	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P
48	Deep Slough Green House Rd.	Merced	Bear Creek		SWAMP	12	12	12			12 months EC, BOD, DO - SWAMP	12 months: toxicity, TSS, flow	pH, temp, minerals, TE, nutrients, TOC, sediment - SWAM P
49	Representative drain in Madera County such as Ash Slough or Berenda Slough	Madera				12	12	12				12 months: TSS, toxicity, flow	
50	Fresno Slough	Fresno		Only if discharges		12	12	12				every month of discharges: TSS, toxicity, flow	
	TULARE BASIN												

51	South Fork Kings River at Cresent By-pass **	Kings	Kings River		Kings River Conservation District monitoring site no. 7 (since 1978) EC, temp, pH	12	12	12				12 months: TSS, toxicity, flow	EC, temp, pH - KRCD
52	Ag drain into Clarks Fork upstream of confluence with Kings River	Kings	Kings River			12	12	12				12 months: TSS, toxicity, flow	
53	South Fork of Kings River at Lemoore Canal and Irrigation Company spill * *	Kings	Kings River		Kings River Conservation District monitoring site no. 12 (since 1978) EC, temp, pH	12	12	12				12 months: TSS, toxicity, flow	EC, temp, pH - KRCD
54	Deer Creek south of Pixley ## SEE NOTE	Tulare	Deer Creek			12	12	12				12 months: TSS, toxicity, flow	
55	White River near Earlimart ## SEE NOTE	Tulare	White River			12	12	12				12 months: TSS, toxicity, flow	
56	Representative Ag drain into Kern River	Kern	Kern River			12	12	12				12 months: TSS, toxicity, flow	

TE= Trace Elements (copper Chromium Lead, Nickel, Zinc) VSS= Volatile suspended Solids. DOC = Dissolved Organic Carbon; TOC= Total Organic Carbon

site included on CWQC's 29 site list

* site selected by Sacramento watershed group for potential monitoring at Colusa meeting 1-28-02

** selected by Tulare basin group for potential monitoring@ Fresno meeting 2/15/02
#SITE 22 - Sacramento watershed group indicated that Delta, not Sacramento basin stakeholders should be responsible for monitoring here.
SITES 54 & 55 - At Fresno meeting 2-15-02 theTulare basin group indicated that Kaweah &/or Tule River would be more appropriate than these 2. They plan to add a site on one or both of these.
! SITE 29- Modesto meeting 3-8-02 comment received that this site gets no surface dranage from irrigated ag.
!! SITE 36 - Modesto meeting 3-8-02 TID rep indicated this site receives muni input.
!!! SITES 38 & 47 - Modesto meeting 3-8-02 Merced Irrigation District rep. Indicated that both sites receive urban input

Appendix B
Summary of Drs. G. Fred Lee and Anne Jones-Lee's Expertise and Experience in Developing Water Quality Monitoring Programs

Dr. G. Fred Lee is President of G. Fred Lee and Associates, which consists of Drs. G. Fred Lee and Dr. Anne Jones-Lee (Vice President) as the principals in the firm. They specialize in addressing advanced technical aspects of water supply water quality, water and wastewater treatment, water pollution control, and solid and hazardous waste impact evaluation and management.

After obtaining a bachelor's degree at San Jose State University in 1955, a Master of Science Degree in Public Health from the University of North Carolina in 1957 and a PhD from Harvard University in 1960 in Environmental Engineering and Environmental Sciences, Dr. Lee taught graduate-level university environmental engineering and environmental science courses for 30 years at several major U.S. universities. During this time, he conducted over $5 million of research and published over 850 papers and reports.

Dr. Lee was active as a part-time consultant during his 30-year university teaching and research career. Drs. G. F. Lee and A. Jones-Lee have been full-time consultants since 1989. Dr. Lee has extensive experience in developing approaches that work toward protection of water quality without significant unnecessary expenditures for chemical constituent control. He has been active in developing technically valid, cost-effective approaches for the evaluation and management of chemical constituents in domestic and industrial wastewater discharges and urban and rural stormwater runoff since 1960.

Dr. Anne Jones-Lee was a university professor for a period of 11 years in environmental engineering and environmental sciences. She has a BS degree from Southern Methodist University and obtained a PhD in Environmental Sciences in 1978 focusing on water quality evaluation and management from the University of Texas at Dallas. At the New Jersey Institute of Technology she held the position of Associate Professor of Civil and Environmental Engineering with tenure. She and Dr. G. F. Lee have worked together as a team since the mid-1970s.

Dr. G. F. Lee has been an active participant in helping to organize and review the adequacy of the water quality monitoring programs conducted in the Sacramento River Watershed Program since the mid-1990s. Further, he is familiar with the San Joaquin River watershed and Delta water quality monitoring database through active participation in the San Joaquin River DO TMDL program, where he is currently PI coordinator for an approximately $2 million/year CALFED-sponsored Directed Action water quality evaluation and management program in the San Joaquin River watershed, as it relates to impacts of constituents derived from the watershed on water quality in the San Joaquin River and the Deep Water Ship Channel near Stockton. During the past year Dr. G. F. Lee has been a part of the review team for the IEP monitoring program for water quality in the Delta.

Dr. G. F. Lee has been a member of the APHA, *et al*., (1998) Standard Methods committee for development of Standard Methods for the Examination of Water and Wastewater since the early 1960s. Also during this time, he has been a member of the ASTM Committee D-19 on Water. This committee work involves his periodically reviewing new or revised analytical methods for water and wastewater components. It enables him to stay current with analytical method development and their appropriate utilization.

The authors have recently completed an approximately half-million-dollar, five-year water quality monitoring and evaluation study in Orange County, CA on behalf of the Santa Ana Regional Water Quality Control Board. Their work included studies on organophosphate (OP) and organochlorine pesticides and PCBs (OCls) and heavy metals. The results of this program are being used by the Santa Ana Regional Board as a basis for developing several TMDLs in the Upper Newport Bay watershed.

Dr. G. F. Lee has over 37 years of experience working on helping to develop, implement and evaluate water quality criteria and state standards based on US EPA criteria. This experience includes advising a number of states (such as Wisconsin, Texas and Colorado) on the development of appropriate water quality criteria. Further, Dr. G. F. Lee was part of the National Academies of Science and Engineering's "Blue Book" of water quality criteria peer review panel that developed the Blue Book of water quality criteria in 1972. In the late 1970s he was a member of the American Fisheries Society Water Quality Section panel that reviewed the US EPA "Red Book" of water quality criteria released in 1976. Further, in the early 1980s Dr. G. F. Lee was a US EPA invited peer reviewer for the then proposed water quality criteria development approach. This is the approach that is still being used today to develop new water quality criteria. In addition, Dr. G. F. Lee served as an invited peer reviewer for several sections of the US EPA "Gold Book" of water quality criteria (ammonia and copper) as part of promulgating the Gold Book criteria in 1986.

During the 1990s, he provided detailed comments on the California State Water Resources Control Board's proposed water quality objectives that were adopted by the State Board in the early 1990s, and then rescinded by the court because the State Board did not comply with Porter-Cologne requirements for conducting an economic evaluation of the impact of adopting these criteria. Further, Dr. G. F. Lee has been an active participant in review of the California Toxics Rule criteria that were adopted in July 2000. At this time he is an active participant in the US EPA RTAG nutrient criteria development program for California and the Central Valley.

Overall, Dr. G. F. Lee is highly familiar with how water quality criteria have been developed, their strengths and weaknesses, and, most importantly, their proper application in water quality management programs. He and Dr. Jones-Lee published an invited paper, "Appropriate Use of Numeric Chemical Water Quality Criteria," discussing how the US EPA criteria and state water quality standards based on these criteria should be implemented, considering the approach for their development and their appropriate use to regulate constituents in ambient waters from various sources.

Dr. G. F. Lee has extensive experience in conducting water quality monitoring/water quality impact evaluation studies from agricultural and urban stormwater runoff. These studies were initiated in the early 1960s while he held the position of Professor of Water Chemistry and Director of the Water Chemistry Program at the University of Wisconsin, Madison. As Vice Chair of the Lake Mendota Problems Committee, he worked with the committee members representing various university departments to develop nutrient export coefficients from various types of agricultural lands in the Lake Mendota watershed. These coefficients have subsequently, through additional studies, been found to have national application in assessing the amounts of nitrogen and phosphorus derived from agricultural lands, as well as urban areas.

In the 1970s, the US EPA Great Lakes program selected Dr. G. Fred Lee to develop a water quality monitoring program for the Great Lakes focusing on toxic constituents. Upon moving back to California in 1989, Dr. G. Fred Lee and Dr. Anne Jones-Lee brought that report up-to-date with respect to broadening its scope where it now focuses on stormwater runoff water quality impacts. That report emphasizes the importance of properly developing a monitoring program to ensure that meaningful results are developed that can be used to appropriately manage water quality without unnecessary expenditures for constituent control from various sources.

Appendix C
Central Valley Agriculturally Dominated Waterbodies

ITEM: 11

SUBJECT: Consideration of Water Body Designations to Comply with Provisions of the Water Quality Control Plan for Inland Surface Waters of California (ISWP)

DISCUSSION: The State Water Resources Control Board (State Water Board) adopted the Water Quality Control Plan for Inland Surface Waters of California (ISWP) on 11 April 1991. The Plan includes narrative, toxicity, and numerical water quality objectives for the protection of freshwater aquatic life and for protection of human health.

The numerical water quality objectives in the Plan are intended to apply to all waters in the State. However, the State Water Board recognized that some surface waters are not natural streams, and for these waters, some of the numerical objectives may not be appropriate. The Plan allows the Regional Board to establish special categories of waters for which site specific objectives or performance goals* can be established in lieu of the numerical water quality objectives in the ISWP. These special categories are waters that are dominated by reclaimed water discharges or by agricultural nonpoint source flows.

The Board, at its March 1992 meeting, adopted a listing of the water bodies dominated by reclaimed water discharges. The Plan also directs the Regional Board to designate by 12 October 1992 whether a water body would fall within one of two other special categories. These special categories are natural water bodies dominated by agricultural drainage [Category (b)] or water bodies constructed primarily for the purpose of conveying or holding agricultural drainage [Category (c)].

The attached Resolution and Staff Report are intended to fulfill these 12 October 1992 Plan requirements. They recommend waters for designations in these two special categories, but because of the complexity of the agricultural supply and drainage system in the Region, several subdivisions of these categories are used to facilitate understanding. In addition, the staff report includes information on objectives that are not appropriate for the water bodies and a priority listing for water quality problems.

RECOMMENDATION: Adopt the Resolution as proposed.

* Performance goals are concentrations of water quality constituents established for receiving waters that a discharger must make best efforts to meet in discharging waste to waters of the State.

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

RESOLUTION NO.

IDENTIFYING CATEGORY (b) AND (c) WATER BODIES AND
CONSTITUENTS PURSUANT TO THE INLAND SURFACE WATERS PLAN

WHEREAS, the State Water Resources Control •Board (hereafter State Water Board) adopted the Inland Surface Waters Plan (ISWP) on 11 April 1991; and

WHEREAS, the ISWP requires the Regional Water Quality Control Board (hereafter Board) to list and rank the Category (b) and (c) water bodies within its region; and

WHEREAS, the ISWP further requires the Board to identify the Tables 1 and 2 objectives which are inappropriate for the listed water bodies based on available data; and

WHEREAS, the list of Category (b) and (c) waters must be submitted to the State Water Board by 12 October 1992; and

WHEREAS, the attached lists comprise all of the known Category (b) and Category (c) waters in the Central Valley Region; and

WHEREAS: the Board, at a public meeting, heard and considered all comments pertaining to these lists. Therefore, be it

RESOLVED, that the attached Category (b) and Category (c) water body lists using the subcategories outlined in Appendix A be submitted to the State Water Board in fulfillment of the requirements of the Inland Surface Waters Plan.

I, WILLIAM H. CROOKS, Executive Officer, do hereby certify the foregoing is a full, true, and correct copy of a Resolution adopted by the California Regional Water Quality Control Board, Central Valley Region, on 25 September 1992.

WILLIAM H. CROOKS, Executive Officer

Attachment

STAFF REPORT

This report would not have been possible without the help of the 340 water, drainage and reclamation agencies who responded to our request for information.

I. INTRODUCTION

The State Water Resources Control Board (State Water Board) adopted Resolution No. WQ 91-93, approving the Water Quality Control Plan for Inland Surface Waters of California or Inland Surface Waters Plan (ISWP) on 11 April 1991. By 12 October 1992, the ISWP requires, in part, that the Regional Board identify and rank in priority order those natural water bodies that, as of 11 April 1991, are dominated by agricultural drainage and constructed water bodies, used for conveying or holding agricultural drainage. The ISWP further requires the Regional Board to identify the ISWP water quality objectives that are inappropriate for the listed water bodies. The purpose of this staff report is to provide the necessary information to fulfill the 12 October 1992 ISWP requirements.

II. SUMMARY OF THE ISWP

Section 303(c)(2)(B) of the Federal Clean Water Act (CWA) required all states to adopt water quality objectives for the 129 Priority Pollutants that the U.S. Environmental Protection Agency (EPA) has published criteria under Section 304(a) of the CWA. If the State failed to do this, EPA would promulgate these criteria as objectives. The Porter-Cologne Act (California Water Code Section 13170) authorizes the State Water Board to adopt Water Quality Control Plans (Basin Plan) that include the objectives required by the CWA. The State Water Board used this authority in order to continue their role as the agency implementing the CWA in California.

As required of all water quality cdntrol plans, the Plan includes designation of beneficial uses, water quality objectives and an implementation program. The ISWP does not include any new beneficial uses but rather incorporates, by reference, beneficial uses in existing Basin Plans and other statewide plans. The ISWP includes five new narrative water quality objectives (Chapter II, Part A, page 3 of Plan), two toxicity objectives (Chapter II, Part B, page 3 of Plan), and numerical water quality objectives for the protection of freshwater aquatic life and for the protection of human health [Chapter II, Part C, pages 4 and 5 of ISWP (Table 1 and 2)]. The Implementation Program of the ISWP (Chapter III, pages 10-25) outlines specific actions for:

(a) point and. nonpoint sources (including stormwater)
(b) waters which support threatened/endangered species, and
(c) waters which are predominately composed of reclaimed water or agricultural drainage.

The water quality objectives in the ISWP apply in all surface waters within the State. All agricultural supply canals and drains, whether constructed or flowing in natural channels, are considered surface waters or waters of the State and must conform with the ISWP (State

Attorney General's Opinion No. 65-259 [48 Ops. Cal. Atty. Gen. 30]). The State Water Board recognized, however, that many of the agricultural facilities are not natural waters and that the objectives listed in Table 1 and 2 of the ISWP may not be appropriate. The ISWP establishes special categories of water bodies which are described as follows for categories (b) and (c):

(b) *Natura1 water bodies, or segments thereof, that, as of the date of adopt Ion of the ISWP are dominated by agricultura1 drainage; and*

(c) *Water bodies, or segments thereof, that, as of the date of adoption of the ISWP, have been constructed for the primary purpose of conveying or holding agricultural drainage and were not natural water bodies which supported aquatic habitat beneficia1 uses. Such drains may include drains constructed in normally dry washes and low-lying areas.*

The ISWP allows, in these special category water bodies, establishment of site-specific objectives* or performances goals** in lieu of the Table 1 and 2 objectives in the ISWP.

The plan is to have site-specific objectives* or performance goals** in place within a six-year period. The schedule for the two types of categories are as follows:

Water Body Category	**What Applies Upon Adoption**	**What Applies Within 6 Years or Less**
(b) Water Bodies Dominated by Agricultural Drainage	- All Narrative Water Quality Objectives - All Toxicity Objectives - Numerical Objectives Apply as Performance Goals for Purposes of Regulating Agricultural Drainage Discharges & Other NonPoint Sources	- All Numerical Objectives in the Plan or Alternate Site-Specific Objectives Established by the C V Reg Board
(c) Constructed Agricultural Drains	- All Narrative Water Quality Objectives - All Toxicity Objectives - The Numerical Objectives Apply as Performance Goals for Purposes of Regulating Agricultural Drainage Discharges & Other NonPoint Sources	- Initial Performance Goals apply or Alternate Site-Specific Performance Goals Established by the Central Valley Regional Board

* A site-specific objective is identical to a water quality objective but has been developed for special local conditions using a site-specific data base rather than the national data base upon which EPA water quality criteria are developed.

** Performance goals, as defined in the Plan, "are concentrations of water quality constituents established for receiving waters that a discharger must make best efforts to meet in discharging waste to waters of the State. For nonpoint source dischargers, these best efforts must be made pursuant to the Nonpoint Source Management Plan. Performance goals will serve as a measure of success in improving water quality."

III. ISWP REQUIREMENTS TO BE COMPLETED BY 12 OCTOBER 1992

The ISWP contains a range of actions that must be completed by the Regional Board by 12 October 1992.

For Category (b) water bodies, by 12 October 1992, the Regional Board must:

- Identify Category (b) water bodies (develop a list).
- Establish a priority list of these waters, consistent with the State Water Board's Clean Water Strategy** (CWS), to identify where early Regional Board action is necessary.
- Identify which numerical objectives defined in Tables 1 and 2 of the ISWP are inappropriate for Category (b) water bodies based on available data.
- Submit the information to State Water Board for consideration and approval.

** The aim of the California Clean Water Strategy (CWS) is to direct State and Regional Board efforts to those water bodies where they will have the greatest impact. To establish CWS priorities, each water body is characterized in terms of relative resource value and severity of impairment of threat. Proposed actions on these water bodies are screened with regard to feasibility.

By 11 April 1993, the State Water Board will act to approve or disapprove the list of Category (b) water bodies and constituents for site-specific objectives (statewide objectives apply in cases of disapproval). Regional Board staff will then proceed to develop the site-specific objectives for Regional Board adoption by 11 April 1997. Until numerical objectives are adopted for Category (b) water bodies, the ISWP Table 1 and 2 objectives apply as performance goals.

For Category (c) water bodies, by 12 October 1992, the Regional Board must:

- Identify Category (c) water bodies (develop a list).
- Establish a priority list of these waters, consistent with the State Water Board's CWS, to identify where early Regional Board action is necessary.
- Submit the information to State Water Board for consideration and approval.

By 11 April 1993, the State Water Board will act to approve or disapprove the list of Category (c) water bodies (statewide objectives apply in cases of disapproval). Tables 1 and 2 objectives in the ISWP will be applied as performance goals to Category (c) waters. For Category (c) water bodies, site-specific performance goals may be developed as needed. The State Water Board shall approve or disapprove the site-specific performance goals.

Natural and constructed water bodies associated with agricultural irrigation not listed as either category (b) or (c) water bodies will have statewide water quality objectives from the ISWP applied to them as if they are natural streams.

IV. REGIONAL BOARD ACTIONS TO COMPLY WITH ISWP

The Regional Board is responsible to prepare the 12 October 1992 report to the State Water Board, but in practicality, the Regional Board can only act as a coordinator. As noted in the Plan, all of the work, described in the previous section, must be conducted with the strong assistance of the water and drainage entities. These agencies have the expertise and information to determine which category a water body should be in.

To compile the information needed to complete the report to the State Water Board, staff contacted by mail over 700 water agencies to request their aid in identifying category (b) and (c) water bodies. Unfortunately most of the agencies were not even aware of the existence of the ISWP; therefore, staff held over 60 area meetings to explain the ISWP and how it impacts agricultural operations. Staff have received reports from over 340 Water, Irrigation, Reclamation, Levee and Drainage Districts which cover over 90 percent of the Region's irrigated area. These reports vary greatly in depth depending upon the information that was available and the agency's understanding of the ISWP.

This wide variability has caused staff a great deal of trouble in trying to bring the information together in one report. This effort was also complicated by the diverse nature of irrigation and drainage system in the Region. Often irrigation canals and drains are used interchangeably as greater and greater portions of the drainage water is recycled through the canal systems.

Because of the diverse topography and nature of irrigation practices in the Central Valley, staff elected to evaluate the information by defined drainage basin. The Region was initially divided between foothills and the valley floor. The valley floor was then divided into four distinct areas with boundaries similar to those of Basin Plans 5A, 5B, 5C and 5D. The four valley floor zones were further subdivided into drainage basins, as shown in Figure 1. These drainage basins represent areas of similar hydrology and common discharge locations and will be used to define future monitoring efforts. The information from the district reports was used to categorize water bodies within each drainage basin.

a. Designation of Water Body Categories

Table 1 lists the category (b) and (c) water bodies. Category (b) are natural channels whose flow and quality are dominated by irrigation activities. The category (c) list is composed of two components. The first is natural dry channels which have been extensively reconstructed and realigned as irrigation/drainage facilities. The second is other constructed facilities named in water agency submittals but too numerous to list in Table 1. The length of the affected reach of each water body is listed.

b. Priority Listing of Water Bodies

The prioritization for all listed category (b) and (c) water bodies is shown in Table 1. This prioritization is based on staff judgments, as little water quality data was available.

c. Inappropriate Water Quality Objectives

Table 1 shows the water quality concerns for each of the category (b) water bodies. These concerns point to groups of water quality objectives that may be. inappropriate, but there was little or no available data for most of the ISWP objectives.

V. DISCUSSION

As specified in the ISWP, staff relied heavily on the information provided by local water agencies. Over 340 informational reports were reviewed, but time and budget constraints have limited the amount of verification possible. The current designations represent the best judgment' of staff along with input from local water agencies. Modifications may be necessary before the final approval by the State Water Board.

The ISWP directed the Regional Board to classify water bodies as either natural bodies dominated by agricultural *drainage* or constructed to transport agricultural *drainage*. The district reports showed, however, that three other types of agriculturally dominated water bodies provide beneficial uses which would not exist without the flows resulting from irrigated agriculture. These three types are natural waterways used to transport agricultural *supply* water, constructed facilities used to transport agricultural *supply* ,water, and dry washes that have been reconstructed and realigned to be an integral component of the *supply* or *drainage* system.

Because of this complex system, Regional Board staff reviewed the reports and placed the water bodies in one of the following subcategories based on information supplied by the districts:

Natural Water Body

Category (b) Water Bodies:

(b1) - Natural water bodies dominated by agricultural drainage water.
(b2) - Natural water bodies dominated by agricultural supply water.

Constructed Facility

Category (c) Water Bodies:

(c1) - Constructed facilities designed to carry agricultural flows or drainage.
(c2) - Constructed facilities designed to carry irrigation water and may, at times, carry recycled return flows.
(c3) - Natural dry washes that have been altered and now carry agricultural supply water or return flows during time periods.

The criteria for each subcategory are described in Appendix A along with an illustration of a decision-making flow chart. The process outlined in Appendix A was used to categorize all water bodies within each drainage basin. A description of each drainage, basin and the agriculturally dominated natural water bodies is presented in Appendix B. **(Appendix B will be mailed under a separate cover).** Appendix B also presents a summary of all constructed agricultural facilities as provided by the cooperating agencies.

Most of the major natural water bodies in the Central Valley are not dominated by agricultural activities although, in many cases, they do provide either agricultural supply water or receive extensive amounts of agricultural drainage flows. One major water body, the San Joaquin River, is agriculturally dominated. With the construction of Friant Dam and the Friant-Kern Canal, most natural flows downstream of Highway 99 ceased. A 22.8-mile reach of the River is used to convey imported supply of water (Mendota Pool to Sack Dam), but the majority of the River (a 109.7-mile reach from Sack Dam to the Stanislaus River confluence) is dominated by agricultural return flows, drainage water, and ground water seepage.

Also noted in Table 1 are major constructed facilities which have greatly altered the flow of water throughout the Central Valley. These water supply and flood control facilities in many cases either completely eliminated the natural flow to or caused complete realignment of former natural streams. These facilities include the:

Natornas-Cross Canal	Sacramento Ship Channel
Tehema-Colusa Canal	California Aqueduct
Glenn-Colusa Canal	Folsom-South Canal
Colusa Basin Drain	Delta Mendota Canal
Madera Canal	Friant-Kern Canal
Yolo Bypass	Tisdale Bypass
Sutter Bypass	Cross Valley Canal
Knights Landing Ridge Cut	

The evaporation basins used for tile drainage are not included in the list of (b) or (c) water bodies. The ISWP in its introduction, clearly states that it *"does not app7y to waste treatment systems, including treatment ponds, evaporation ponds, or lagoons designed to meet the requirements of the federal Clean Water Act"* (emphasis added). The ponds are designed to contain the waste without discharge to waters of the United States. This is the same position that State Water Board staff took when responding to issues raised by E.P.A. In their report of 26 September 1991 to Walt Pettit and State Water Board members, the State Water Board staff recommended not to change this portion of the plan.

The second direction to the direction to the Board under the ISWP is to *"establish a priority list of the listed category (b) and (c) water bodies to identify where early Regional Board action is necessary."* Using the State Water Board's Clean Water Strategy, almost all the listed water bodies would be in the lowest priority state wide. An additional prioritization was conducted, however, to rank these water bodies based upon their potential to have water quality problems present or create similar problems downstream. To make this second assessment consistent with the Clean Water Strategy, the following five factors were used:

1. Magnitude of existing beneficial uses
2. Water Body size.(length)
3. Flow (perennial vs. intermittent and volume)
4. Degree of beneficial use impairment
5. Degree of threat to downstream water quality

The prioritization for all listed category (b) and (c) water bodies is shown in Table 1. This prioritization is based upon staff judgment as little water quality data is available.

The third direction to the Board under the ISWP is to *"identify which numerical objectives defined in Table 1 and 2 of the ISWP are inappropriate for the category (b) water bodies based on available data"*. For most agricultural drains, canals and natural water bodies dominated by these flows, there is little or no data available on most of the ISWP numerical objectives. Table 1 shows the water quality concerns for each of the category (b) water bodies. These designations point to 'groups of water quality objectives that may be inappropriate, but more thorough monitoring needs to be conducted before a site-specific objective workplan can be prepared. The designation of water quality concerns was based upon the following observations:

- The water bodies showing elevated selenium concentrations are located principally in the west side of the San Joaquin Valley.

- Elevated boron and total dissolve solids concentrations are common in many water bodies dominated by agricultural drainage and in natural and constructed facilities that carry ground water or recycled agricultural drainage water.

- Monitoring shows that water quality objectives for metals (As, Cd, Cr, Cu, Pb, Ni, Ag and Zn) are violated when total recoverable analytical techniques are used for analysis. These elevated levels are commonly due to the natural levels of metals on sediment. This sediment is commonly found in water bodies dominated by agricultural drainage. This sediment also has attached pesticides residues, such as' DDT, DDE, toxaphene, chlordane, endosulfan, and other persistent pesticides.

- Concentrations of pesticides can be found in all water bodies that are dominated by agricultural drainage and at times in agricultural supply canals as a result of recycling of drainage water, pumped ground water or maintenance operations that are conducted on constructed canals and drains.

- Maintenance operations in constructed canals and drains may cause water quality objective violations including violation of the toxicity objectives. These maintenance operations, such as use of copper sulfate or other chemicals are critical to maintaining the integrity of the facility's use.

- Many of the category (b) and (c) water bodies are subject to inflows from urban areas.

VI. RECOMMENDATION

Staff recommendation is to adopt Table 1 and all the agency submittals by reference. This approach recognizes the requirement to submit the list but also recognizes the complexity of defining these water bodies. The Resolution for adoption also recognizes the need to include all types of agriculturally dominated water bodies by directing staff to submit the listing to the State Water Board using the 5 subcategories outlined in the Appendix A of the Staff Report. This approach will allow ourselves and State Water Board staff to make modifications to the category designations as they are needed. In addition, the adoption should be done with a clear public understanding that these designations are not intended to impact existing beneficial use designations; rather, these designations are to provide a logical process for developing and implementing water quality objectives consistent with the Federal Clean Water Act.

Figure 1. Location of Drainage Basins within the Central Valley, California for the Inland Surface Waters Plan

HYDROBASIN INDEX

4	Tehama
8	Enterprise Flat-Lower Cottonwood
10	North Delta
11	Valley Putah-Cache
15	Marysville
19	Valley-American
20A	Colusa
20B	Butte
20C	Sutter Bypass
20D	Sycamore-Sutter
32	East of the Delta
35A	Turlock
35B	Merced
40	Westside San Joaquin River
41	Grasslands
44A	Central Delta
44B	West of the Delta
44C	South Delta
45	San Joaquin Valley Floor
51A	Kings River
51B	Westside
57	Kern River
58A	Kaweah River
58B	Tule River
58C	Poso
58D	Tulare Lake

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (b) WATER BODIES			
SACRAMENTO RIVER BASIN			
DRAINAGE BASIN 20A			
Unnamed Tributaries to Walker Creek	7	5	3,4
Walker Creek	15	3	3,4
Sheep Corral/White Cabin Creek	5.5	5	3,4
Wilson Creek (Upstream of Road 35, Glenn County)	4	5	3,4
Freshwater Creek	4	5	3,4
Salt Creek (North)	2.5	5	3,4
Cortina Creek	4	5	3,4
Hopkins Slough (Within boundaries of Colusa NWR)	1.5	3	3,4
Hunters Creek (Within boundaries of Sacramento NWR)	1.7	3	3,4
North Fork of Logan Creek (Within boundaries of Sacramento NWR)	6	3	3,4
Logan Creek (Within boundaries of Sacramento NWR)	9	3	3,4
Funks Creek	6	5	3,4
Buckeye Creek	12	5	3,4
Lurline Creek (Tehema Colusa Canal to Glenn-Colusa Canal)	3	5	3,4
DRAINAGE BASIN 20B			
Butte Creek	44	1	3,4
Hamlin Slough	18.5	3	3,4
Butte Slough	6	2	3,4
Butte Sink	10	2	3,4
Angel Slough	21	5	3,4
Campbell Slough	8	5	3,4
Howard Slough	6	5	3,4
Little Butte Creek	6	5	3,4
DRAINAGE BASIN 20C			
Butte Slough	9.4	2	3,4
Willow Slough	1	5	3,4
Nelson Slough	1.3	5	3,4
Sacramento Slough (Downstream of Karnak)	1.5	3	3,4
Gilsizer Slough (Downstream of O'Banion Road)	6	5	3,4
DRAINAGE BASIN 15			
Grasshopper Slough (Diversion to Grass Valley Road)	1	5	3,4,6
Messick Lake	1	5	3,4
Reeds Creek	7.6	5	3,4
Dry Creek (South)	6	5	3,4,6
Clark Slough (Upstream of Plumas Lake Canal)	3	5	3,4,6
Hutchinson Creek	5.1	5	3,4

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (b) WATER BODIES CONTINUED			
DRAINAGE BASIN 15 Continued:			
Best Slough (HWY 65 to Forty Mile Road)	3	5	3,4
No Name Creek	5.5	5	3,4
Tennessee Creek	5.3	5	3,4
Prairie Creek	6.8	5	3,4
Dry Creek (North)	11.6	2	3,4
Wilson Creek	3.7	5	3,4
North Honcut Creek	3.3	3	3,4
South Honcut Creek	15.3	3	3,4
Jack Slough (Upstream of Trainer Hills)	5.2	2	3,4
DRAINAGE BASIN 19			
Yankee Slough	9.9	3	3,4
Coon Creek (Upstream of the East Side Canal)	9.4	5	3,4,6
Bunkham Slough (Upstream of Pleasant Grove Road)	9.4	5	3,4
Markham Ravine (Upstream of Pleasant Grove Road)	6.8	5	3,4
Auburn Ravine (Upstream of Pleasant Grove Road)	4.4	5	3,4,6
King Slough (Upstream of Western Pacific Railroad)	5	5	3,4
Pleasant Grove Creek	4.5	4	3,4
Ping Slough (Upstream of Cornelius Avenue)	5	4	3,4
DRAINAGE BASIN 11			
Cache Creek	26	2	2,3,4
Goodnow Slough	12	5	2,3,4,6
Almondale Slough	4	5	2,3,4
South Fork of Willow Slough	21	5	2,3,4
Cottonwood Slough	8	5	2,3,4
North Fork of Willow Slough	3	5	2,3,4
Willow Slough	17	5	2,3,4
Union Slough	28	5	2,3,4,6
Moody Slough	16	5	2,3,4
Cache Slough (Upstream of Haas Slough)	3	2	2,3,4
Dry Slough	17.5	5	2,3,4
Putah Creek	16	3	2,3,4
Haas Slough	3	2	2,3,4,6
Old Alamo Creek	3	5	2,3,4
Gordon Slough (Lower West Adams)	6	5	2,3,4
Lamb Valley Slough	2	5	2,3,4
Shag Slough	2.5	3	2,3,4
Duck Slough	1.5	3	2,3,4

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (b) WATER BODIES CONTINUED			
SAN JOAQUIN RIVER BASIN			
DRAINAGE BASIN 40			
Orestimba Creek	5	3	1,2,3,4,5
Old San Joaquin River Channel at Laird Slough	5.3	4	2,3,4
Del Puerto Creek	5.5	4	2,3,4,5
Tom Payne Slough	13	5	3,4
Mountain House Creek	3.5	5	2,3,4
San Joaquin River (Merced river to Stanislaus River)	34.8	1	1,2,3,4
DRAINAGE BASIN 41			
Los Banos Creek	24	5	2,3,4,6
San Luis Creek	8	5	2,3,4
Garzas Creek	4	5	2,3,4,6
Salt Slough	10	1	1,2,3,4
Mud Slough (south)	3.1	4	2,3,4
Mud Slough (north)	5.1	1	1,2,3,4
San Joaquin River (Mendota Pool to Merced River)	86.7	1	1,2,3,4
DRAINAGE BASIN 35A			
Lone Tree Creek	29	3	3,4
French Camp Slough	6.5	3	3,4
Walthall Slough	5	5	3,4
Littlejohns Creek (Goodwin Dam to Farmington Fld Cntrl Basin)	15	5	3,4
Dry Creek (Crabtree Road to Wellsford Road)	17	4	3,4
Lesnini Creek	3	5	3,4
Simmons Creek	5	5	3,4
DRAINAGE BASIN 35B			
Bear Creek	39	2	3,4
Mariposa Creek	11	5	3,4
Duck Slough	11	5	3,4
Cottonwood Creek	2.5	5	3,4
South Slough	3.5	5	3,4
Black Rasca1 Creek	16.5	5	3,4
Deadman Creek (Downstream of El Nido Canal)	5.5	5	3,4
Canal Creek	19.5	5	3,4
Edendale Creek	3.2	5	3,4
Parkinson Creek	3	5	3,4
Hartley Slough	2.5	5	3,4
Fahrens Creek	5	5	3,4
Lake Yosemite	N/A	5	3,4

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (b) WATER BODIES CONTINUED			
DRAINAGE BASIN 35B Continued:			
Miles Creek	7	5	3,4
Owens Creek	26	5	3,4
Dutchman Creek	13	5	3,4
Chowchilla River	12	5	3,4
DRAINAGE BASIN 45			
Root Creek	1	5	3,4,6
Lone Willow Slough	18	5	3,4
Schmidt Creek	2	5	3,4,6
Fresno River	6	5	3,4
Berenda Creek	9	5	3,4
Dry Creek	7	5	3,4
Cottonwood Creek	20	5	3,4
Berenda Slough	1.7	5	3,4
Ash Slough	5	5	3,4
SACRAMENTO-SAN JOAQUIN DELTA			
DRAINAGE BASIN 10			
Mayberry Slough	4.7	5	3,4
DRAINAGE BASIN 44B			
Frisk Creek	3.8	5	3,4
Brushy Creek	2.4	5	2,3,4
Marsh Creek	9	5	2,3,4
DRAINAGE BASIN 44C			
Old River	6	1	2,3,4
Paradise Cut	7.6	3	2,3,4
DRAINAGE BASIN 32			
Pixley Slough	9.7	5	3,4
Bear Creek	13.6	5	3,4
Mosher Creek	19.3	5	3,4
Mormon Slough	13.4	5	3,4
Laguna-Hadelville Creek	10.8	5	3,4
Consumnes River	10.5	1	3,4
Deer Creek	15	5	3,4

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (b) WATER BODIES CONTINUED			
TULARE LAKE BASIN			
Kings River (Downstream of Peoples Weir)	71.6	1	3,4
Wahtoke Creek	14.9	5	3,4
Navelencia Creek	2.4	5	3,4
Sand Creek	2.2	5	3,4
Traver Creek	10.1	5	3,4
Kaweah River	11.3	4	3,4
St. Johns River	14.1	4	3,4
Elk Bayou	9.9	5	3,4
Outside Creek	6.2	5	3,4
Deep Creek	12	5	3,4
Elbow Creek	16.3	5	3,4
Cottonwood Creek	5.4	5	3,4
Cross Creek	11.7	4	3,4
Byrd Slough	8.3	5	3,4
Cameron Slough	5.3	5	3,4
Clarks Fork	5	4	3,4
Cole Slough	8.8	5	3,4
Dutch John Cut	2.5	5	3,4
Fresno Slough	20	5	2,3,4
Lower North Fork Kings River	5.3	1	3,4
Lower South Fork Kings River	8.7	1	2,3,4
Old Fresno Slough	1.8	4	3,4
Poso Creek	6.5	3	3,4
Buena Vista Lake	N/A	5	3,4
Surprise Creek	2.4	5	3,4
Wooten Creek	2.4	5	3,4
Negro Creek	1.3	5	3,4
Long Creek	1.8	5	3,4
FOOTHILLS			
Jackson Creek	7	5	
Dry Creek (Amador County)	2	5	3,4
Wolf Creek	12	5	
Coon Creek	12	5	6
Auburn Ravine	6	5	6

* Water Quality Concerns:
1 = selenium and molybdenum
2 = boron and total dissolved solids
3 = Metals
4 = pesticides
5 = DDT, Endosulfan, etc.
6 = urban, dairy wastes, WWTP

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES

MAJOR CONSTRUCTED FACILITIES WITHIN THE CENTRAL VALLEY

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Natomas Cross Canal	5	3	
Tehama-Colusa Canal	111	2	
Glenn-Colusa Canal	66	2	
Colusa Basin Drain	75	1	
Knights Landing Ridge Cut	6	3	
Yolo Bypass	16.5	1	
Tisdale Bypass	4.5	3	
Sutter Bypass	32	1	
California Aquaduct (Central Valley)	300+	1	
Corning Canal	21	2	
Toe Drain	23	1	
Folsom-South Canal	26.8	2	
Delta Mendota Canal	116+	1	
Madera Canal	36	3	
Friant-Kern Canal	152	2	
Eastside Bypass (plus the Eastside Canal)	45	2	
Cross Valley Canal	20	3	
San Luis Drain	84.8	1	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

USBR
DWR
Friant-Kern Water Users Association
San Luis-Delta Mendot Water Users Authority
Tehama Colusa Water Users Association

SACRAMENTO RIVER BASIN

DRAINAGE BASIN 4

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Poberta Water District
Corning Water District

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (c) WATER BODIES CONTINUED			
DRAINAGE BASIN 20A			
Orland -Artois Unnamed "A"	9.5	5	
Orland -Artois Unnamed "B"	13	5	
Lateral "A"	13	5	
East Branch of Walker Creek	5	5	
Shepherd Slough	10	5	
Bounde Creek	13	5	
Hopkins Slough	9	5	
Willow Creek	13	5	
North Fork Logan Creek	2.5	5	
Logan Creek	2.5	5	
Hunters Creek	7	5	
Funks Creek (Downstream of Glenn-Colusa Canal)	4	5	
Stone Corral Creek	12	5	
Lurline Creek (Downstream of Glenn-Colusa Canal)	3	5	
Freshwater Creek (Glenn-Colusa Canal to Salt Creek)	6	5	
Salt Creek (North) [Glenn-Colusa Canal to Colusa Trough]	6.5	5	
Spring Creek	3	5	
Cortina Creek	5.5	5	
Wilkins Slough	8	5	
Sycamore Slough	16	5	
Hayes Hollow Creek	3.1	5	
French Creek	6.8	5	
South Fork of Willow Creek (Downstream of Tehama-Colusa Canal)	17	5	
Glenn Valley-Manor Slough	13	5	
Wilson Creek (Road 35 to Willow Creek)	7	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Colusa Basin Drainage District
Glenn-Colusa Irrigation District
Orland-Artois Water District
Provident Irrigation District
Princeton-Cordova-Glenn Irrigation District
Glide Water District
Kanawha Water District
Holthouse Water District
Westside Water District
Maxwell Irrigation District
Cortina Water District

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 20A Continued:

Colusa Water District
Dunnigan Water District
Knights Landing Ridge Drainage District
Reclamation District 2047
Reclamation District 479
Reclamation District 108
Reclamation District 787

DRAINAGE BASIN 20B

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Durham Slough	7	5	
Little Dry Creek	15	5	
Drumheller Slough	11	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Western Canal Water District
Butte County Drainage District #2
Drainage District 200
Richvale Irrigation District
Butte Water District
Reclamation District 833
Biggs-West Gridley Water District
Reclamation District 1004
Butte Sink Waterfowl Association

DRAINAGE BASIN 20C

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Morrison Slough	11	5	
Snake River	30	5	
Live Oak Slough	23	5	
Gilsizer Slough (Yuba City of O'Banion Road)	11	5	
Poodle Creek	5	5	
Sutter Bypass (East and West Borrow Pit Channels)	60	1	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Biggs-West Gridley Water District
Butte Water District
Sutter Extension Water District

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 20C Continued:

Reclamation District 777
Reclamation District 2056
Reclamation District 2054
Drainage District No. 1
Tierra Buena Drainage District
Sutter County Water Agency
Feather Water District
Tudor Mutual Irrigation Company
Hamatani Ranch
Garden Highway Mutual Water Company
Sutter Butte Mutual Water Company
Sutter National Wildlife Refuge
Goose Club Farms (Sutter Bypass Properties)
Department of Water Resources, State of California

DRAINAGE BASIN 20D

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Long Lake	2	5	
Sacramento Slough (Within RD 1500)	2.5	5	
Tisdale Bypass	4.4	4	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Meridian Farm Water Company
Sutter Buttes Mutual Water Company
Reclamation District No. 1660
Reclamation District No. 70
Tisdale Irrigation Company
Butte Slough Irrigation Company
Sutter Mutual Water Company
Pelger Mutual Water Company
Sutter Mutual Water Company
Reclamation District 1500

DRAINAGE BASIN 15

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Plumas Lake Drain	2	5	
Algodon Slough Drain	4.1	5	
Baxter Slough	2.9	5	
Kimball Creek	2.5	5	

Table 1. Summary of Category (b) and(c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (c) WATER BODIES CONTINUED			
DRAINAGE BASIN 15 Continued:			
Simmerly Slough	3.4	5	
Jack Slough (Downstream of Trainer Hills)	6	2	
Clark Slough (Downstream of Plumas Lake Canal)	4.4	4	
Best Slough (Downstream of Forty Mile Road)	2.2	5	
Grasshopper Slough (Downstream of Grass Valley Road)	2	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Oroville-Wyandotte Irrigation District
Yuba County Water Agency
Brophy Water District
South Yuba Water District
Browns Valley Irrigation District
Cordura Irrigation Company
Hallwood Irrigation Company
Ramirez Water District
City of Wheatland
Wheatland Irrigation District
Reclamation District 784
Plumas Mutual Irrigation District
Camp Far West Irrigation District
Dana & Dana, Inc.

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
DRAINAGE BASIN 19			
Curry Creek (Within RD 1000)	1.2	5	
Ping Slough (Downstream of Cornelius Ave.)	4	5	
Coon Creek (Downstream of the East Side Canal)	2.5	5	
Bunkham Slough (Downstream of Pleasant Grove Rd.)	1.1	5	
Markham Ravine (Downstream of Pleasant Grove Rd.)	1.6	5	
Auburn Ravine (Downstream of Pleasant Grove Rd.)	2.1	5	
King Slough (Downstream of the Western Pacific Railroad)	0.9	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

South Sutter Water District
Natomas Central Mutual Water Company
Reclamation District 1000
Reclamation District 1001

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 19 Continued:

Neveda Irrigation District
Placer County Water Agency

DRAINAGE BASIN 11

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Walnut Canal	6.2	5	
South Fork of Putah Creek	10	5	
Willow Slough Bypass	7	5	
Sweeney Creek	4	5	
Gibson Canyon Creek	5.5	5	
Ulatis Creek	5.5	5	
Ulatis Channel	13	4	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Cowell Ranch
Reclamation District 2093
Reclamation District 2060
Reclamation District 730
Reclamation District 2104
Reclamation District 1600
Reclamation District 537
Reclamation District 2068
Reclamation District 2098
Reclamation District 2035
Reclamation District 827
Reclamation District 785
Reclamation District 2084
Dixon Resource Conservation District
Maine Prairie Water District
Solano Irrigation District
Solano County Water Agency
Yolo County Flood Control and Water Conservation District

SAN JOAQUIN RIVER BASIN

DRAINAGE BASIN 40

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Corral Hollow Creek (Downstream of the Delta Mendota Canal	2.5	5	

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (c) WATER BODIES CONTINUED			
DRAINAGE BASIN 40 Continued:			
Ingram Creek (Downstream of Interstate 5)	6.5	5	
Hospital Creek (Downstream of Interstate 5)	8	5	
Salado Creek (Downstream of the Delta Mendota Canal)	6	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

West Stanislaus Irrigation District
Kasson Reclamation District #2085
New Jerusalem Drainage District
Banta-Carbona Irrigation District
Patterson Water District
Newman Drainage District
Hospital Water District
Naglee Burk Irrigation District
Paradise Mutual Water Company
Pescadero Reclamation District 2058
El Solyo Water District
Kern Cañon Water District
Salado Water district
Sunflower Water District
Orestimba Water District
Oak Flat Water District
Foothill Water District
Davis Water District
Central California Irrigation District
Reclamation District 1602
Reclamation District 2099
Reclamation District 2101
Reclamation District 2102
Westside Irrigation District
Byron-Bethany Irrigation District

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
DRAINAGE BASIN 41			
Santa Rita Slough	7	5	

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 41 Continued:

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Central California Irrigation District
Mustang Water District
Quinto Water District
Romero Water District
Centinella Water District
Mercy Springs Water District
Eagle Field Water District
Pacheco Water District
Oro Loma Water District
San Luis Water District
Broadview Water District
Panoche Water and Drainage District
Firebaugh Canal Water District
Grassland Water District
San Luis Canal Company
Poso Canal Company
Charleston Drainage District
Gustine Drainage District
Widren Water District
Dos Palos Drainage District

DRAINAGE BASIN 35A

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
Littlejohns Creek (Downstream of Farmington Fld Cntrl Basin)	17		

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Modesto Irrigation District
Turlock Irrigation District
McMullin Reclamation District #2075
Oakdale Irrigation District
South San Joaquin Irrigation District
Reclamation District 17

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
CATEGORY (c) WATER BODIES CONTINUED			
DRAINAGE BASIN 35B			
Mariposa Slough	6.3	5	
Miles Creek (Downstream of Puglizevich Dam)	5.6	5	
North Slough	1	5	
Deadman Creek (upstream of the El Nido Canal)	11	5	
Turner Slough	3	5	
Deep Slough	1.4	5	
Sand Slough	7	5	
Chamberlain Slough	3.2	5	

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Merced Irrigation District
Turner Island Water District
Stevenson Water District
Merquin County Water District
El Nido Irrigation District
LeGrand-Athlone Water District
La Branza Water District
Lone Tree Mutual Water Company

DRAINAGE BASIN 45

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Madera Irrigation District
Gravely Ford Water District
Columbia Canal Company
Chowchilla Water District

SACRAMENTO-SAN JOAQUIN DELTA

DRAINAGE BASIN 10

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into-this table by reference.

North San Joaquin Water Conservation District
Reclamation District 765 (Glide District)
Reclamation District 999

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 10 Continued:

Reclamation District 307 (Lisbon District)
Reclamation District 501 (Ryer Island)
Reclamation District 551 (Pierson)
Reclamation District 3 (Grand Island)
Reclamation District 554 (Walnut Grove)
Reclamation District 2110 (McCornnack-William Tract)
Reclamation District 556 (Upper Andrus Island)
Reclamation District 2086 (Canal Ranch Tract)
Reclamation Disthct 2111 (Dead Horse Island)
Reclamation District 813 (Erheardt Club)
Reclamation District 348 (New Hope Tract)
Reclamation District 563 (Tyler Island)
Reclamation District 38 (Staten Island)
Reclamation District 341 (Sherman Island)

DRAINAGE BASIN 44A

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Central Delta Water Agency
Reclamation District 2033 (Brack Tract)
Reclamation District 548 (Terminous Tract)
Reclamation District 756 (Bouldin Island)
Reclamation District 2026 (Webb Tract)
Reclamation District 2059 (Bradford Island)
Reclamation District 2044 (King Island
Reclamation District 2029 (Empire Tract)
Reclamation District 2023 (Venice Island)
Reclamation District 2114 (Rio Blanco Island)
Reclamation District 2042 (Bishop Tract)
Reclamation District 2027 (Mandeville Island)
Reclamation District 2041 (Medford Island)
Reclamation District 2030 (McDonald Tract)
Reclamation District 2037 (Rindge Tract)
Reclamation District 2115 (Shima Tract)
Reclamation District 799 (Hotchkiss Tract)
Reclamation District 2025 (Holland Tract)
Reclamation District 2090 (Quimby Island)

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 44A Continued:

Reclamation District 2028 (Bacon Island)
Reclamation District 2119 (Wright-Elmwood Tract)
Reclamation District 2036 (Palm Tract)
Reclamation District 2024 (Orwood Tract)
Reclamation District 800 (Byron Tract)
Reclamation District 2117 (Coney Island)
Reclamation District 2040 (Victoria Island)
Reclamation District 2072 (Woodward Island)
Reclamation District 2039 (Upper Jones Tract)
Reclamation District 2038 (Lower Jones Tract)
Reclamation District 684 (Lower Roberts Island)
Reclamation District 2113 (Fay Island)
Reclamation District 2118 (Little Mandeville Island)
Shin Kee Tract
Bethel Island Municipal Improvement District
Drexler-Honker Lake Tract
Franks Tract State Park

DRAINAGE BASIN 44C

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Reclamation District 2 (Union Island West)
Reclamation District 1 (Union Island East)
Reclamation District 773 (Private Landowners)
Reclamation District 2062 (Stewart Tract)
Reclamation District 2089 (Stark Tract)
Reclamation District 544 (Upper Roberts Island)
Reclamation District 524 (Middle Roberts Island)

DRAINAGE BASIN 32

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Omuchumne-Hartnell Water District
Galt Irrigation District
North San Joaquin Water Conservation District
Woodbridge Irrigation District
Stockton East Water District

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

DRAINAGE BASIN 32 Continued:

Reclamation District 2074 (Sargent-Barnhart Tract)
Reclamation District 1614 (Smith Tract)
San Joaquin Flood Control and Water Conservation District

DRAINAGE BASIN 44B

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

East Contra Costa Irrigation District
Byron - Bethany Irrigation District

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*
TULARE LAKE BASIN			
China Slough	7.3	5	
Phillips Ditch	1.6	5	
Carmelita Ditch	3.1	5	
Rice Ditch	1.1	5	
Short Ditch #1	1	5	
McLaughlin Ditch	1.7	5	
Farm Ditch #1	1.8	5	
Farm Ditch #3	1.5	5	
Jacobi Ditch	0.3	5	
Fink Ditch	1	5	
Turner Ditch	1.6	5	
Hanke Ditch	2.9	5	
Byrd Ditch	1.1	5	
Jack Ditch	1.4	5	
Cameron Ditch	0.7	5	
Tale River (Below Friant-Kern Canal)	41	5	
Porter Slough	11.5	5	
Old Fresno Slough	8.2	5	
Harris Slough Ditch	1.8	5	
Bates Slough	4.3	5	
Lewis Creek	3.3	5	
Inside Creek	5.2	5	
Mill Creek	26.7	5	
Cameron Creek	8.4	5	
Tule River (above Friant-Kern Canal)	9	5	
White River	12	5	
Deer Creek	24	5	

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

TULARE LAKE BASIN Continued:

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Alpaugh Irrigation District
Alta Irrigation District
Angiola Water District
Arvin-Edison Water Storage District
Berenda Mesa Water District
Buena Vista Water Storage District
Cawelo Water District
City of Bakersfield
Consolidated Irrigation District
Corcoran Irrigation District
Crescent Canal Company
Delano-Earlimart Irrigation District
Devil’s Den Water District
Dudley Ridge Water District
Empire West Side Irrigation District
Exeter Irrigation District
Friant Kern Water Users Authority
Fresno Irrigation District
Henry Miller Water District
Ivanhoe Irrigation District
James Irrigation District
Kaweah & St. Johns River Association
KCWA Improvement District #4
Kern Delta Water District
Kern River Levee District
Kern-Tulare Water District
Kings County Water District
Kings River Water District
Laguna Irrigation District
Lakeside Irrigation District
Last Chance Water Ditch Company
Lemoore Canal & Irrigation Company
Lewis Creek Water District
Lindmore Irrigation District
Lindsay-Strathmore Irrigation District
Lost Hills Water District

Table 1. Summary of Category (b) and (c) Water Bodies Within the Central Valley of California

Watershed/Drainage Basin	Mileage	Priority	Water Quality Concerns*

CATEGORY (c) WATER BODIES CONTINUED

TULARE LAKE BASIN Continued:

North Kern Water Storage District
Peoples Ditch Company
Rag Gulch Water District
Reclamation District No. 1601
Riverdale Irrigation District
Rosedale-Rio Bravo Water Storage District
Saucelito Irrigation District
Semitropic Water Storage District
Shafter-Wasco Irrigation District
Southern San Joaquin Municipal Utilities District
Stinson Canal & Irrigation Company
Stone Corral Irrigation District
Terra Bella Irrigation District
Tranquillity Irrigation District
Tulare Lake Drainage District
Tule River Association
Westlands Water District
Wheeler Ridge-Maricopa Water Storage District
Zalda Reclamation District 801

FOOTHILLS

All constructed canals and drains and their tributaries as designated in reports submitted by the following agencies are incorporated into this table by reference.

Tuolumne Regional Water District
Tuolumne Public Utility District
Northridge Water District
Citrus Heights Irrigation District
Squaw Valley Co. Water District
Tehachapi-Cummings Co. Water District
Fall River Conservation District
Nevada Irrigation District
Amador County Water Resources
Jackson Valley Irrigation District
Omochumne-Hartnell Water District
El Dorado Irrigation District
Mill Race Group
Placer County Water Agency
West Lake Resources Conservation District
Sierra County Department of Planning
Yuba County Water District
Plumas County
Plumas County Private Rancher
Indian-American Valleys RCD
Calaveras County Water District
Big Valley Irrigation District
Pit RCD Resource Conservation District
South Fork Irrigation District

APPENDIX A (to Appendix C)

Category (b1): Natural water bodies dominated by agricultural drainage water. Criteria set down in the ISWP.

Category (b2): Natural water bodies dominated by agricultural supply water. Almost every stream, creek and river within the Central Valley is dominated by water that will be used for agricultural supply. It is not our intent to list all these waterways. The only water bodies we have included carry all of the following criteria:

a) Agricultural supply water dominated the flow and water quality of the water body.

b) The agricultural supply water is not the same natural flow that would have been in the water body.

c) The flow is released into the natural channel and subject to significant changes in volume.

d) The natural channel would not have had significant flow or aquatic life beneficial uses in the absence of the agricultural supply flows.

e) The agricultural supply flows are subject to releases and diversions and are not necessarily continuous throughout the irrigation season or year.

Category (c1): Water bodies that are constructed (drains) for the primary purpose of conveying or holding agricultural return flows or drainage and were not natural water bodies which supported aquatic life beneficial uses. Does not include on-farm facilities, such as furrows, beds, checks, ditches and sumps.

Category (c2): Water bodies that are constructed (canals or channels) to carry irrigation supply water and may, at times, carry blended or recycled agricultural drainage or return flows as supply water.

Category (c3): Natural dry water bodies that have been altered and now only carry agricultural return flows or agricultural supply water. These water bodies may only be dominated by these flows for defined periods each year and the (c3) designation would only apply during this time interval. Water bodies designated under this category must meet all of the following criteria.

a) In the absence of agricultural return flows or irrigation supply water, the water body is ephemeral and only carries flow during heavy rainfall events or very wet periods.

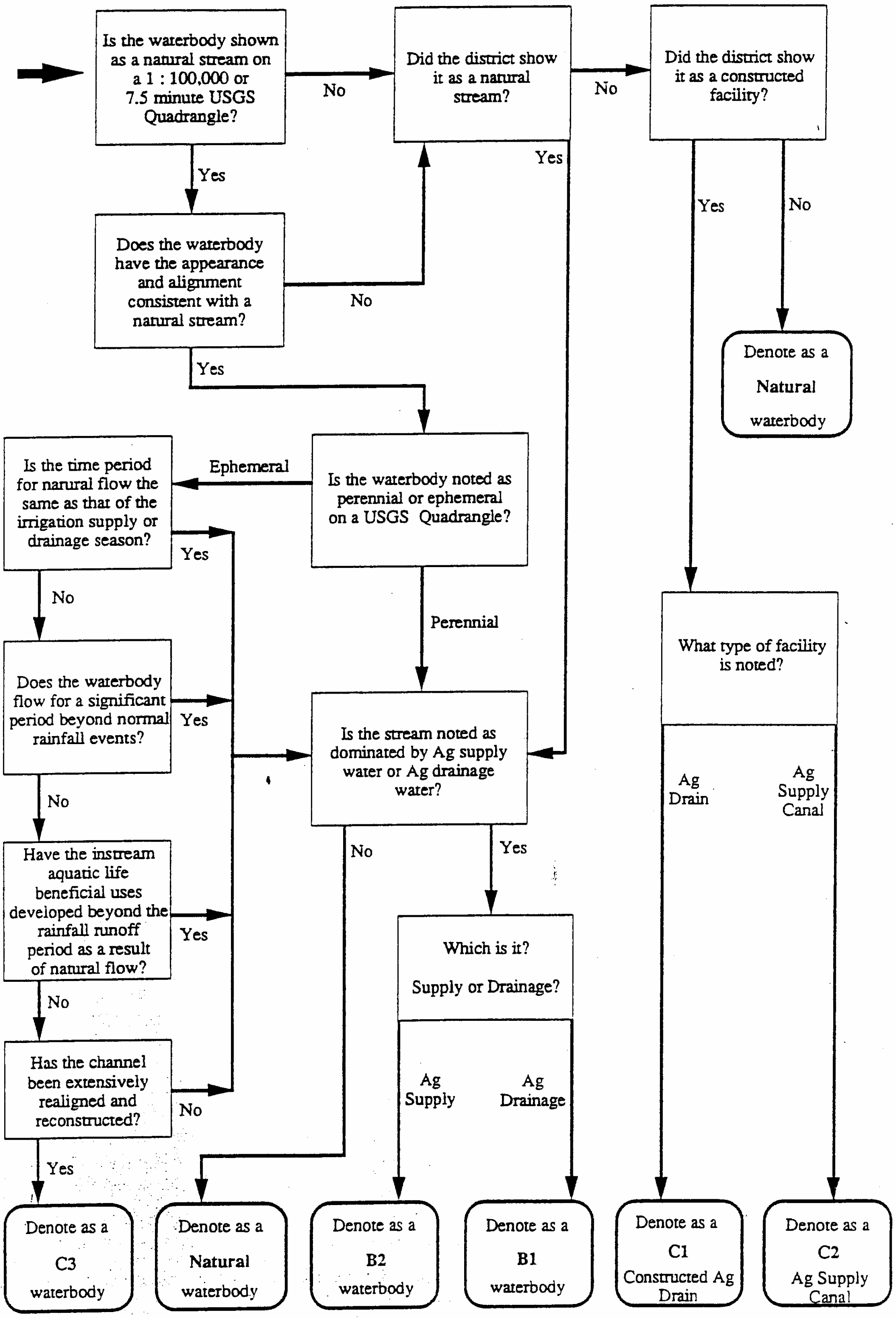
b) In the absence of agricultural return flows or irrigation supply water, in-stream aquatic life beneficial uses would not be present.

c) Shows evidence of extensive in-stream channel modifications including-reconstruction and realignment.

d) Riparian habitat has developed as a result of the presence of agricultural return flows or agricultural supply water.

Figure A-1

Flowchart for Categorization of Water Bodies According to the Guidelines of the California Inland Surface Waters Plan



Appendix D
CUWA Memorandum Regarding Nonpoint Source Monitoring

MEMORANDUM

DATE: December 6, 2002

TO: Fred Lee

FROM: Elaine Archibald, California Urban Water Agencies

SUBJECT: Nonpoint Source Monitoring

Thank you for asking us to provide information on monitoring needed to adequately characterize and protect drinking water supplies in the Central Valley. We understand that you have recommended monitoring of the major rivers and their tributaries for a number of constituents of concern to drinking water suppliers. Lynda Smith, Walt Pettit, and I discussed this issue and developed several ideas for possible incorporation into the document you are preparing for the Central Valley Regional Board. You may have already incorporated many of these concepts into your report. We would welcome the opportunity to review your report and discuss how we can provide more focused comments.

- The water quality constituents of most concern to drinking water suppliers are DBP precursors (TOC, DOC, UVA254, SUVA, THMFP, bromide); pathogens and their surrogates (*Giardia*, *Cryptosporidium*, total coliforms, *E. coli*); dissolved minerals (TDS, chloride); nutrients; and, in the Sacramento basin, rice pesticides. Depending on the specific purposes of the monitoring program, all of these constituents would not necessarily be monitored. For example, for a broad-scale nonpoint source monitoring program pathogen indicator organisms should be monitored. But for monitoring investigations or special studies focused on sources of microbial contamination monitoring should include the actual pathogens as well.

- Although there are a number of nonpoint sources of drinking water constituents, the focus of a monitoring program should be on agricultural drainage and runoff due to the large amount of the Central Valley watershed devoted to agriculture and the current lack of information on the concentrations and loads of key drinking water constituents.

- It is unlikely that adequate funding will be available to conduct comprehensive monitoring of all agricultural operations at all locations in the Central Valley. We recommend a two-pronged approach. First, monitoring should be conducted at key confluences to identify watersheds of most concern. As problems are identified, monitoring would proceed upstream until problem areas are identified. Second, we recommend that the monitoring program focus on identifying typical crop types and typical farming operations in the various geographic areas of the Central Valley. Factors that would need to be considered include location (eastside vs. westside of the valley), soil types, rainfall, irrigation practices, etc. Information is needed on the quality and quantity of drainage and storm runoff from the key crops grown in the Central Valley.

- The Department of Pesticide Regulation monitors a number of locations in the Sacramento Basin for rice pesticides. Those same locations should be monitored for other drinking water constituents.

- There is a need to monitor the receiving waters upstream and downstream of the points where major drainage canals discharge to the rivers to attempt to identify the impacts of the major drains on water quality. This monitoring should be designed to capture both the irrigation runoff and storm runoff from agricultural operations.

Appendix E
QUALITY ASSURANCE FOR EFFECTIVE MONITORING OF PESTICIDES IN THE SAN JOAQUIN RIVER BASIN, CALIFORNIA[a]

Shakoora Azimi-Gaylon[b]
Emilie L. Reyes[c]
Jacob Collins[d]

ABSTRACT

A well-designed monitoring study requires a quality assurance project plan (QAPP) that encompasses all aspects of the study design from the planning stage through the completion of data analysis. The lower San Joaquin River Basin is listed for Total Maximum Daily Load (TMDL) development for diazinon and chlorpyrifos, Organophosphorus (OP) pesticides with both agricultural and urban applications. Monitoring is necessary to characterize and define the source of these compounds. Several monitoring programs that have included analysis for these constituents have been conducted in the basin. Agricultural sources have been monitored since 1991, while urban sources have only been monitored in 1995 and 2001. Monitoring efforts for TMDL development are currently underway in both surface water sites and wet/dry deposition sites. The most critical factor for collecting useful data is preparing a QAPP that covers the field and laboratory procedures.

INTRODUCTION

Pesticide levels in surface water, even at seemingly low concentrations, can affect the growth, reproduction and/or survival of sensitive aquatic species. Pesticides of potential concern to aquatic life in the San Joaquin River (SJR) system include Organophosphorus (OP), carbamate, triazine pesticides and possibly pyrethroid class compounds. The detection of some of these classes of pesticides at elevated concentrations has resulted in lower San Joaquin River is being placed on the Federal Clean Water Act Section 303d list of impaired waters. As required by the Federal Clean Water Act, a Total Maximum Daily Load (TMDL) is currently being developed for this listing. Monitoring programs focusing on various aspects required for the development of this TMDL also are underway.

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[a] Published in Proc. "Helping Agriculture Adjust to TMDLs" US Committee on Irrigation and Drainage, Denver, pp 151-159, October, 2002
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[d] Student Assistant, Central Valley Regional Water Quality Control Board (CVRWQCB), 3443 Routier Rd. Suite A, Sacramento, CA 95827.

This paper focuses on the essential components of a quality assurance project plan (QAPP) necessary for pesticide monitoring being conducted for the OP pesticide TMDL development for the lower San Joaquin River. A QAPP is a written document outlining procedures the monitoring project will use to ensure that samples, data and reports are of high quality, sufficient to meet project needs. Discussion will be limited to quality assurance relating to monitoring for chemical constituent analysis. QAPPs for toxicological or bioassessment purposes will by necessity have components that may or may not be applicable to chemical monitoring. These will not be discussed here due to space limitations. The final part of this paper summarizes one of the monitoring programs currently underway for OP pesticide TMDL development for the lower SJR and its associated quality assurance program.

COMPONENTS OF A QAPP FOR PESTICIDE MONITORING

Planning and Sampling Rationale

Several factors should be considered in the design of monitoring programs for the development of the SJR OP TMDL. In addition to a review of historical data, the objective and criteria for data collection must be established. The general objective for all monitoring is to produce data that represent as closely as possible, the *in situ* conditions in the SJR, through the use of accepted methods for the collection and analysis of water, sediment and possibly biota samples. All measurements are considered critical and any non-standard method requires validation.

For monitoring for TMDL purposes, sampling site location is based on several factors including the documented use of specific pesticides of interest upstream from the monitoring locations and/or the historical detection of pesticide-caused toxicity. The sampling design is not only influenced by the key characteristics to be estimated, but also by the practicality and feasibility, and the resource requirements and limitations.

Field Procedure and Sample Custody Documentation

For chemical monitoring at specific sites in the TMDL area of interest, surface water samples should be collected using sampling techniques that ensure that the sample being collected is representative of the flow in the cross section. Ideally, samples should be collected using a standard multi-vertical depth integrating method in order to obtain the most representative isokinetic sample possible. This method allows for water samples entering the sampler to be hydrodynamically equivalent to the portion of the stream being sampled. In cases when this is not possible to achieve for logistical reasons, for example, approved abbreviated sampling methods can be used.

The holding time for samples collected for organophosphorus analysis has been established at 7 days. All samples must be stored at 4 degrees. All field activity requires adequate and consistent documentation in order to support data interpretation and data defensibility. In addition, adequate sample custody procedures must be established in order to provide a mechanism for making the sample possession traceable. This includes specific documentation procedures, chain of custody forms and other shipping and handling procedures.

Analytical Method Requirements

Although a wide range of analytical methods and instruments are available for the analysis of individual compounds or a list of compounds, the selection of the appropriate method to be used for OP pesticide analysis (and analysis for other chemical constituents) is generally based on the sensitivity of the method (detection limit), reproducibility, analytical cost and laboratory preparation procedures. Water quality objectives, including acute and chronic criteria established by federal and state limits, define the project objectives and data quality goals. Specifically, the laboratory quantitation limits have to be less than the required regulatory limit (action level) so that the sample data meets the project objectives.

Reproducibility and costs are both important factors in the choice of analytical method. Choosing gas chromatography/ mass spectrometry (GC/MS) over high-pressure liquid chromatography (HPLC) technique may produce more reliable and reproducible results but is dependent upon the chemical structure and physical properties of a compound. Selecting approved screening procedures such as ELISA with 20% GC confirmation may be more cost effective than GC analysis only. Laboratory preparation procedures should also be considered because different solvents and procedures yield different recoveries for the same compound.

Quality Control Requirements and Quality Assurance Objectives

Data Quality Objectives (DQOs) and Quality Assurance Objectives (QAOs) are related data quality planning and evaluation tools for all sampling and analysis activities. DQOs specify the underlying reason for collection of data, data type, quality, quantity, and uses of data collection. For monitoring programs relating to SJR OP TMDL development, definitive data using standard US Environmental Protection Agency (EPA) or other reference methods is produced by laboratories experienced in the analysis of pesticides. The QAOs used for these programs represent the minimum acceptable specifications for field data collection and data analyses that should be considered routinely for respective field and analytical procedures. Quality assurance objectives (QAOs) are the detailed QC specifications for precision, accuracy, representativeness and completeness, collectively referred to as PARC (U. S. EPA, 1997.) These elements are discussed briefly below.

Precision

Precision measures the reproducibility of repetitive measurements. Precision is evaluated by calculating the RPD between duplicate spikes, duplicate sample analyses or field duplicate samples and comparing it with appropriate precision objectives established for the program. Analytical precision is developed using repeated analyses of identically prepared control samples. Field duplicate samples analyses results are used to measure the field QA and matrix precision.

Accuracy

Accuracy measures correctness, or how close a measurement is to the true or expected value. Accuracy is measured by determining the percent recovery of known concentrations of analytes spiked into field sample or reagent water before extraction. The stated accuracy objectives for laboratory control spike or matrix spike should reflect the anticipated concentrations and/ or middle of the calibration range.

Representativeness

Representativeness is obtained by using standard sampling and analytical procedures for this program to generate data that is representative of the sites.

Completeness

Completeness is calculated for each method and matrix for an assigned group of samples. Completeness for a data set is defined as the percentage of unqualified and estimated results divided by the total number of the data points. This represents the usable data for data interpretation and decision-making. Completeness does not use results that are qualified as rejected or unusable, or that were not reported as sample loss or breakage. The overall objective for completeness is 95% for this project.

Field Quality Control

All monitoring programs for SJR OP pesticide TMDL development are designed to incorporate both field and laboratory quality controls. Field QC samples are used to assess the influence of sampling procedures and equipment used in sampling and to characterize matrix heterogeneity. The types of samples used include field blanks, field duplicates and when applicable, matrix spikes. Field blanks are used to demonstrate that sampling procedures do not result in contamination of the environmental samples. Field duplicates are used to demonstrate the precision of sampling and analytical processes.

In general, the number of field duplicates and field blanks is set to achieve an overall rate of at least 10% of all analyses for a particular parameter. QC samples are rotated among sites and events to achieve the overall rate of a minimum of 10% field duplicate samples and minimum of 10% field blanks (as appropriate for specific analyses).

Laboratory Quality Control

Laboratory QC is incorporated to control the analytical process within method and project specifications, and to assess the accuracy and precision of analytical results. Laboratory QCs typically consist of method blanks, laboratory control samples, laboratory duplicates and surrogate added to each sample. Method blanks are used to demonstrate that the analytical procedures do not result in sample contamination. Laboratory control samples are used to demonstrate the accuracy of the analytical method. Laboratory duplicates are used to demonstrate the precision of the analytical method, and matrix spikes were used to demonstrate the performance of the analytical method in a particular sample matrix.

Data Assessment Procedure

Measurement data must be consistently assessed and documented to determine whether project quality assurance objectives (QAOs) have been met, and quantitatively assess data quality and identify potential limitations on data use. Assessment and compliance with quality control procedures are undertaken during the data collection phase of the project. Performance assessment of the sampling procedures is performed by the field sampling crews. The laboratory is responsible for following the procedures and operating the analytical systems within the statistical control limits. These procedures include proper instrument maintenance, calibration of the instruments, and the laboratory QC sample analyses at the required frequency (i.e., method blanks, laboratory control samples, etc.). Associated QC sample results are reported with all sample results so the project staff can evaluate the analytical process performance.

Project data review established for these programs include several steps including an initial review of analytical and field data for complete and accurate documentation, and an evaluation of method and field blank results to identify random and systematic contamination. All spike and duplicate results must be compared. Data qualifiers are assigned to reflect limitations. The entity conducting the data assessment is responsible for ensuring that data qualifier flags are assigned, as needed, based on the established QC criteria.

Corrective Actions

During the course of sample collection and analysis in this study, the laboratory supervisors, field supervisors and team members ascertain that all measurements and procedures are followed as specified in the QAPP. Any related systematic problems are also identified. Problems about analytical data quality that require corrective action are documented in the laboratories' QA/QC Guidance. Problems about field data quality that may require corrective action are documented in the field data sheets.

Data Validation and Usability

Laboratory Data Review, Verification and Reporting

The laboratory quality assurance manual is used to accept, reject or qualify the data generated by the laboratory. The laboratory management is responsible for validating the data generated by the laboratory. The analytical process includes verification or a quality assurance review of the data. After the data has been reviewed and verified, the laboratory reports are signed for release and distributions. The laboratory submits only data that have acceptable deviations. When QA requirements are not met, the samples are reanalyzed when possible and only the results of the reanalysis are be submitted provided they are acceptable.

CASE STUDY: SJR OP TMDL IN SEASON MOnitoring Project

The final part of this paper is a brief discussion of one of the monitoring programs currently underway for OP pesticide TMDL development for the lower SJR and its associated quality assurance program. A number of governmental agencies and organizations have developed monitoring and investigative studies to characterize the concentrations and distributions of pesticides in the SJR Basin. The early studies concentrated on the occurrence of pesticides and the regions and seasons of highest contamination. Later studies increasingly focused on specific types of pesticides used in the basin and the specific sources of the pesticides.

In 2001, The United States Geological Service (USGS) and The California Central Valley Regional Water Quality Control Board (RWQCB) staff conducted a joint study to collect the necessary data to support OP pesticide TMDL development for the lower SJR. The monitoring program was designed to determine the irrigation return flow loads from different drainage areas in SJR. The sampling program was conducted in April 2001 through August 2001 to bracket most of the irrigation season in the San Joaquin Basin. Sampling was conducted weekly at twelve sites both on the main stem river and tributary sites. The sampling area where the various sites are located is presented in Figure 1.

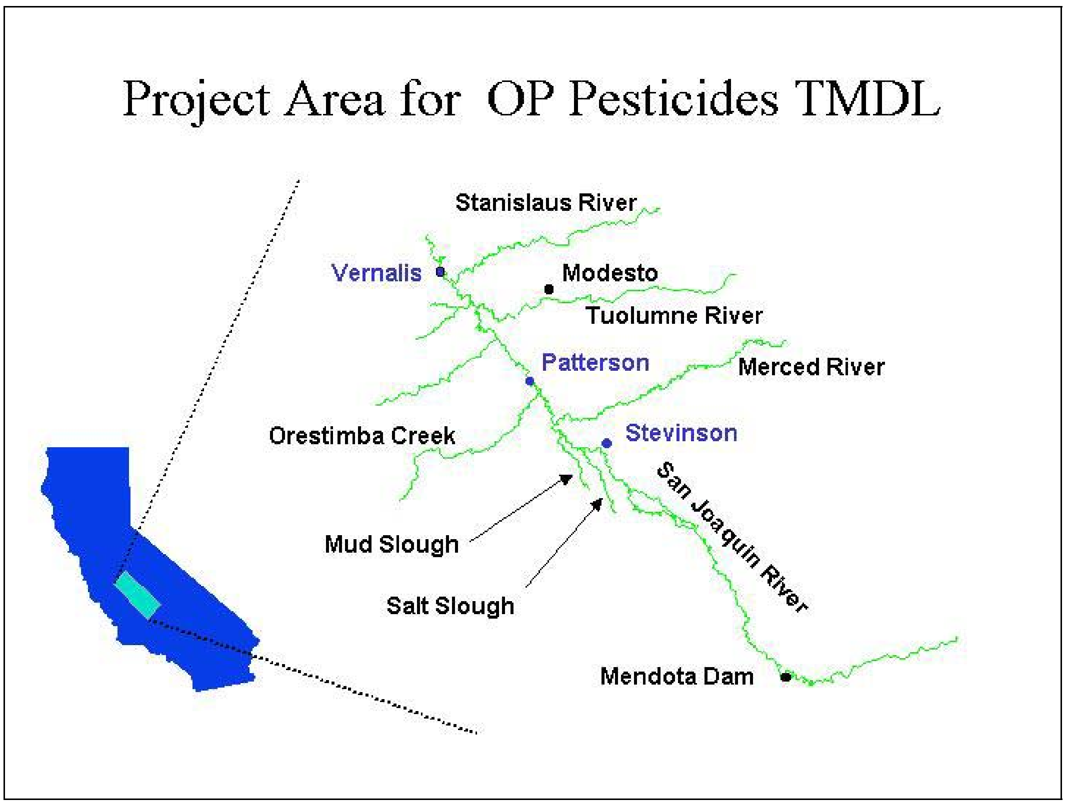

Figure 1. Geographic area for OP pesticide TMDL in the lower San Joaquin River.

Mitigation at each sampling site was assessed by RWQCB and USGS staff to determine the appropriate sampling method: grab or width and depth integrated. Water quality parameters (i.e. pH, and EC) were measured for each sample. For ungaged sites, an instantaneous streamflow measurement was made for each sample collected. Samples were stored between 2-6 degrees Celsius.

All samples were analyzed for dissolved chlorpyrifos and diazinon by the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado using a gas chromatograph/ mass spectrometer (GC/MS). All samples were also analyzed for total suspended solids (TSS). Total and dissolved diazinon and chlorpyrifos were measured for all samples by RWQCB staff using enzyme-linked immunosorbent assay (ELISA) to evaluate the differences on calculated values for total and dissolved analysis. The U.S. EPA Region IX laboratory in Richmond, California performed a competitive ELISA for diazinon on approximately 20% of samples. The quantitation limits for these methods are presented in Table 1. Some of the associated field and laboratory QC measures taken are summarized in Table 2 below.

Table 1. Quantitation limits for ELISA and GC/MS methods.

Analytical Method	Chlorpyrifos	Diazinon
ELISA	0.004 ug/ L	0.03 ug/L
GC/MS	0.004 µg/L	0.02 ug/L

µg/L = microgram per liter
ELISA= Enzyme-linked immunosorbant assay
GC/MS= Gas Chromatograph/ Mass Spectrometer

Table 2. San Joaquin River OP Pesticide In season Monitoring
Preliminary Quality Control Samples Summary

San Joaquin River OP Pesticide In season Monitoring Preliminary Quality Control Samples Summary					
Laboratory QC Type	Number	% Frequency	Field QC Type	Number	% Frequency
Method Blanks	8	50*	Field Blank	12	14
Lab Control Spike	8	50	Field Duplicate	16	19
Matrix Spike	7	50*			
Surrogate	83	100			

* Two per laboratory batch

Preliminary review of the data shows that Diazinon, and chlorpyrifos and other pesticides were frequently detected in surface water collected from many of the sampling sites. Although the pesticides were detected frequently, most concentrations were low, and for diazinon, the concentrations were generally low. The data are currently being reviewed by the USGS staff and a draft Water Quality Investigation Report is scheduled to be completed by the end of 2002.

CONCLUSION

Monitoring is an important tool used for Organophosphorus pesticide TMDL development in the lower San Joaquin River. It is necessary in the process of characterization and definition of the sources of these compounds in the study area. Several monitoring programs that have included analysis for these constituents have been conducted in the basin in the past 10 years. One of the most critical factors for collecting useful data is preparing a QAPP that covers the field and laboratory procedures. A quality assurance program that includes appropriate field and laboratory procedures ensures data defensibility and will help in the design of future monitoring programs.

REFERENCES

U. S. EPA. 1997. Test Methods for Evaluating Solid Wastes, Physical/Chemical SW846, Third Edition. revised November 1986, Update II, September 1994, Update IIB, January 1995, and Update III, January 1997.