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TECHNICAL MEMORANDUM

Date: August 16, 2012

To: Linda Dorn, SRCSD
Terrie Mitchell, SRCSD

From: Michael Bryan, Ph.D.

Subject: Additional Scientific Information for the State Water Resources Control Board's Comprehensive (Phase 2) Review and Update of the Bay-Delta Plan

Introduction

The State Water Resources Control Board (State Water Board) has scheduled informational workshops in advance of its consideration of changes to the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The State Water Board is approaching update of the Bay-Delta Plan in a phased manner. The workshops currently scheduled for September 2012 are intended to elicit input from stakeholder experts with regard to recent scientific and technical information the State Water Board and staff should consider in its update of the Bay-Delta Plan. Specifically, the State Water Board has requested input regarding new or additional scientific information that has been developed or was not fully considered in the 2009 Staff Report[1] or 2010 Delta Flow Criteria Report[2].

Related to the receipt of information at the scheduled workshops, the State Water Board has requested that workshop participants submit written information, including scientific and technical report summaries, prior to the workshops. This memorandum conveys information concerning specific water quality issues. While we have understood that the State Water Board intends to defer specific water quality constituent concerns such as pesticides and toxicity to the Regional Water Quality Control Boards (i.e., Region 2 and Region 5), this information is provided, as you have requested, for the State Water Board's consideration with regard to its continued coordination and collaboration with the Regional Water Boards and for consideration with regard to any new or revised flow objectives and related purposes.

Issues for Consideration – New Scientific Information

Delta Water and Sediment Quality

As a potential stressor related to the pelagic organism decline (POD), toxicity and contaminants have been the subject of scientific scrutiny, particularly that linked to pesticides. Since adoption

[1] State Water Board. 2009. Periodic Review of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, Staff Report. Adopted by Resolution 2009-0065. August 4, 2009.
[2] State Water Board. 2010. Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem. Prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009. Adopted by Resolution 2010-0039. August 3, 2010.

of the 2009 Staff Report, several notable related studies and reports have been published, or will be published in the imminent future.

While the ability to predict future water quality issues related to changing flow objectives is difficult, the State Water Board should consider implementation of a comprehensive monitoring program as part of its supporting implementation program. The following list of citations present tools and recommendations for how such a comprehensive monitoring program could be organized, and thus are worthy of the State Water Board's review and consideration. Citations and brief summaries are provided below.

Johnson, M.; I. Werner; S. Teh; F. Loge. 2010. *Evaluation of Chemical, Toxicological, and Histopathologic Data to Determine Their Role in the Pelagic Organism Decline*. April 20, 2010.

> The State Water Board, in collaboration with the Central Valley Regional Water Quality Control Board, contracted with the University of California in the preparation of the above-cited report, often referred to by its short name, the *Contaminants Synthesis Report*. The Contaminants Synthesis Report represents the single most comprehensive gathering of recent and historic contaminant (pesticide, metals, toxicity, histopathology) data for the Delta and nearby surface waters. The report approached the possible role of contaminants through an evaluation of six hypotheses addressing whether contaminants could be wholly or partially responsible for the POD. In general, the study found that there was insufficient data to make definitive conclusions regarding contaminants and the POD. While the study could not completely eliminate contaminants as the cause of the POD, the study concluded that contaminants were unlikely to be a major cause of the POD.
>
> Perhaps more pertinent to the State Water Board's current efforts regarding update of the Bay-Delta Plan or Delta issues generally, the study concluded with a series of recommendations regarding current and future Delta monitoring programs. The studies comprehensive list of recommendations for future Delta monitoring programs stem from the deficiencies the authors encountered with the manner contaminants are currently and have historically been collected. In response to these deficiencies, it was recommended that a long-term monitoring program be developed such that the involvement of contaminants in future phenomena such as the POD could be identified. Such a program would include an element that would allow the rapid identification of new and emerging contaminants. Moreover, toxicity testing should accompany analytical chemistry, and where appropriate, histophathology should be applied to a targeted selection of samples. Toxicant effects are often observable at the cellular level well before effects are observed at population levels.

Hoogeweg, C. G.; W.M. William; R. Breuer; D. Denton; B. Rook, C. Watry. 2011. *Spatial and Temporal Quantification of Pesticide Loadings to the Sacramento River, San Joaquin River, and Bay-Delta to Guide Risk Assessment for Sensitive Species.* CALFED Science Grant #1055. November 2, 2011

The authors of this modeling study performed a risk assessment whereby the spatial and temporal co-occurrence of listed special status species with that of 40 different present-use pesticides were estimated. The modeling investigation estimated pesticide loadings to surface waters from agricultural and urban land uses based on actual pesticide use as recorded in the California Department of Pesticide Regulation's (DPR) pesticide use reporting database. Pesticide loadings from sites of application were estimated based on various environmental fate models, resulting in both spatial and temporal estimates of concentration, and "indicator days" (**Figure 1**), defined as a risk quotient greater than one for at least one pesticide. Risk quotients were expressed as the ratio of the estimated concentration to a toxicity benchmark. Ultimately, the spatial and temporal occurrence of special status species were combined with the indicator day estimates in a manner allowing approximations of toxicological risk (**Figure 2**, shown in terms of 80^{th} percentile co-occurrence estimates). Areas of potential concern are also noted, where high levels of co-occurrence were estimated and monitoring is currently not conducted, or conducted infrequently.

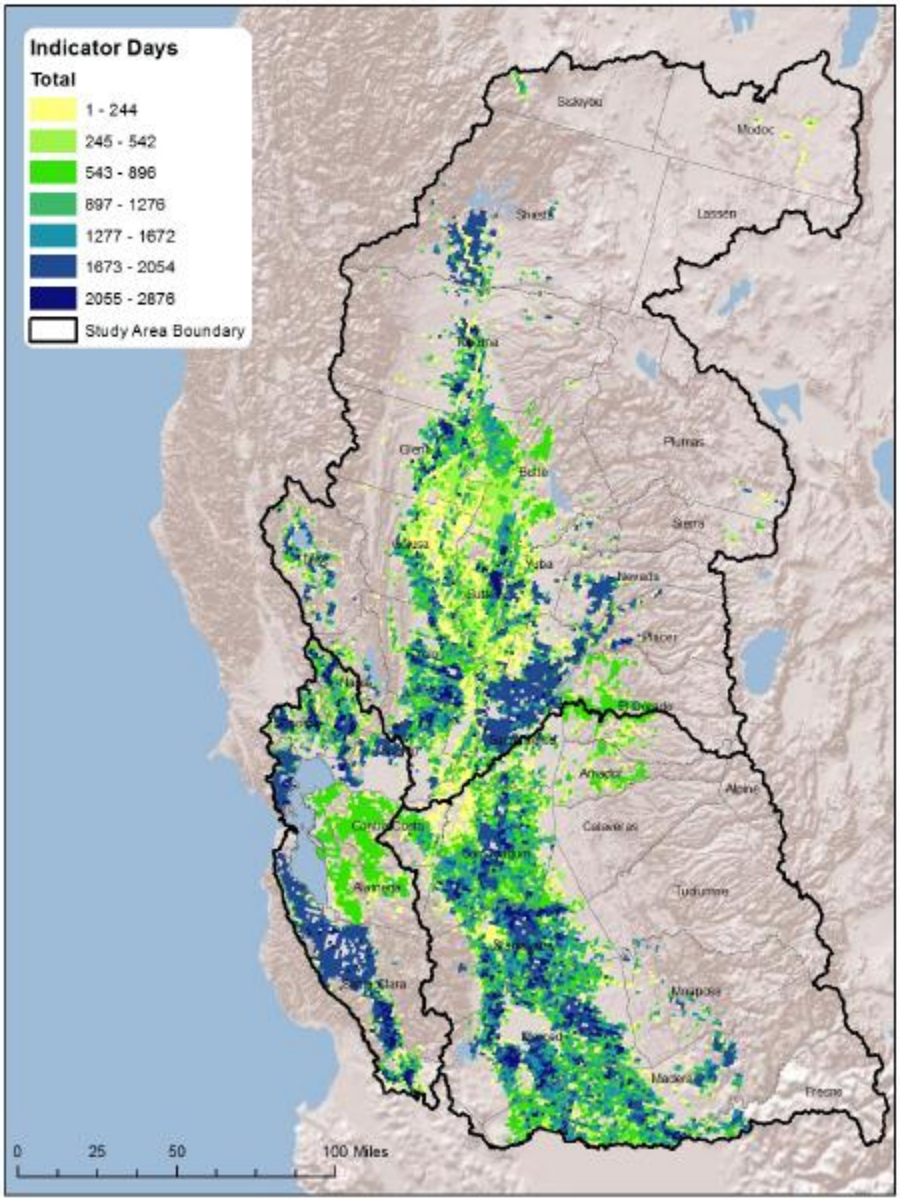


Figure 1: Spatial distribution of total indicator days for the period 2000-2009 (Hoogeweg et al., 2011)

While the presence of an indicator day is not a formal prediction of expected toxicity, the density of indicator days does provide information on potential risk, especially when combined with the occurrence of species of concern. The risk estimates generated provide a logical and intelligent foundation for planning future possible monitoring activities for pesticides and/or pesticide related toxicity.

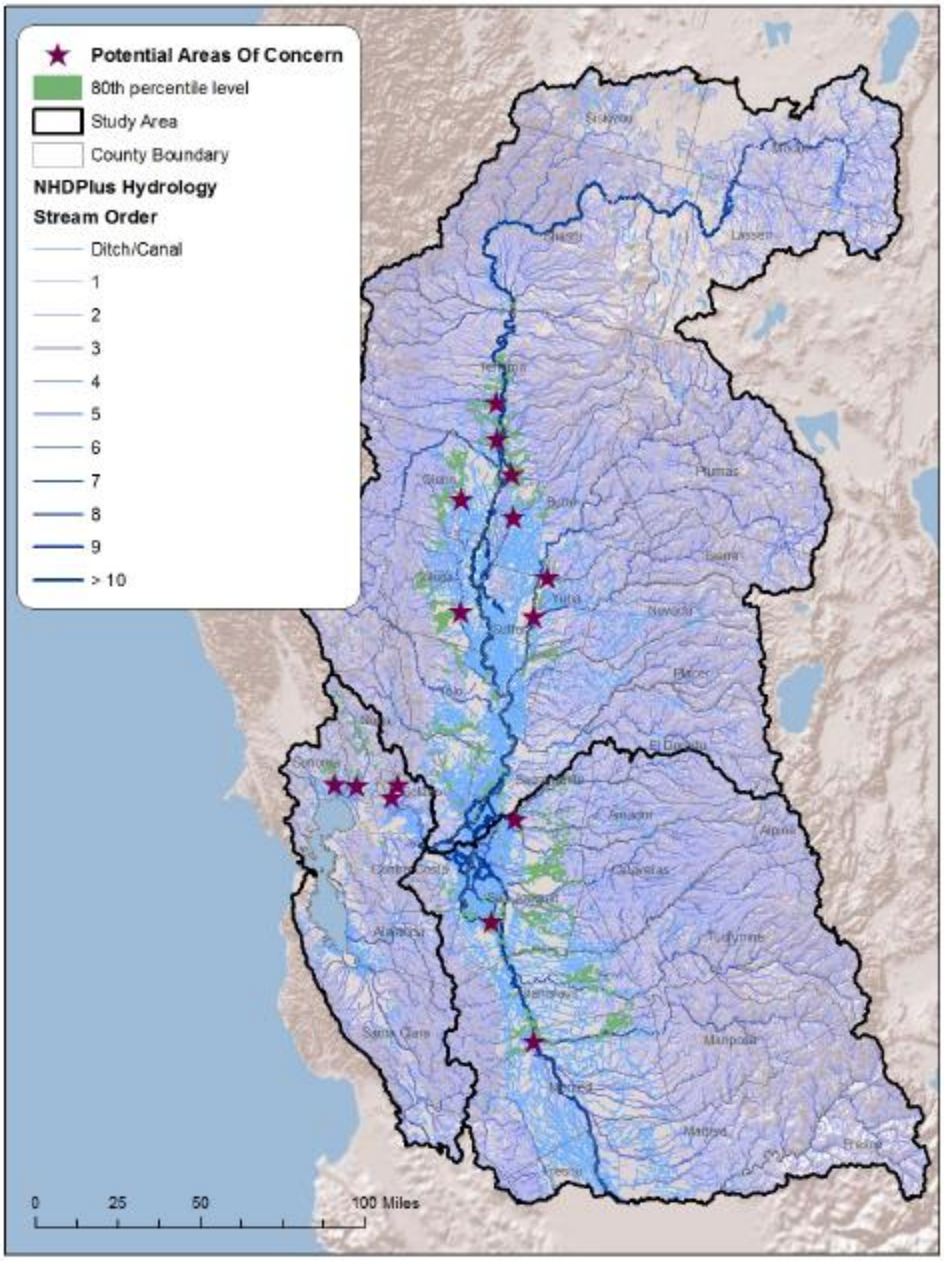


Figure 2: Spatial distribution of 80th percentile co-occurrence estimates and potential areas of concern (Hoogeweg et al., 2011)

Southern California Coastal Water Research Project. *Assessing the Direct Effects of Sediment Contamination in the Sacramento and San Joaquin River Delta*. In preparation. Preliminary findings at: http://www.sccwrp.org/ResearchAreas/Contaminants/SedimentQualityAssessment/

For many hydrophobic contaminants, sediments are long-term integrators of contaminant exposure and as a result, the potential for contaminated sediments to impact aquatic ecosystems is often discussed (see the citation of Johnson et. al.

2010). Until recently, there has been no single comprehensive survey of Delta sediment quality. The Southern California Coastal Water Research Project (SCCWRP) performed such a comprehensive survey in 2007 and 2008. A total of 144 monitoring sites were analyzed for toxicity to the epibenthic arthropod *Hyalella azteca*, of which a subset of 75 were subject to the full sediment quality triad analysis, including sediment chemistry, toxicity, and benthic community composition. Overall, toxicity in sediments was observed to be low, with only 3% of samples found to be acutely toxic (Figure 3). While a final study report summarizing the full sediment quality triad results is pending (expected to be finalized in 2012), concern over Delta sediment quality overall appears to be relatively low.

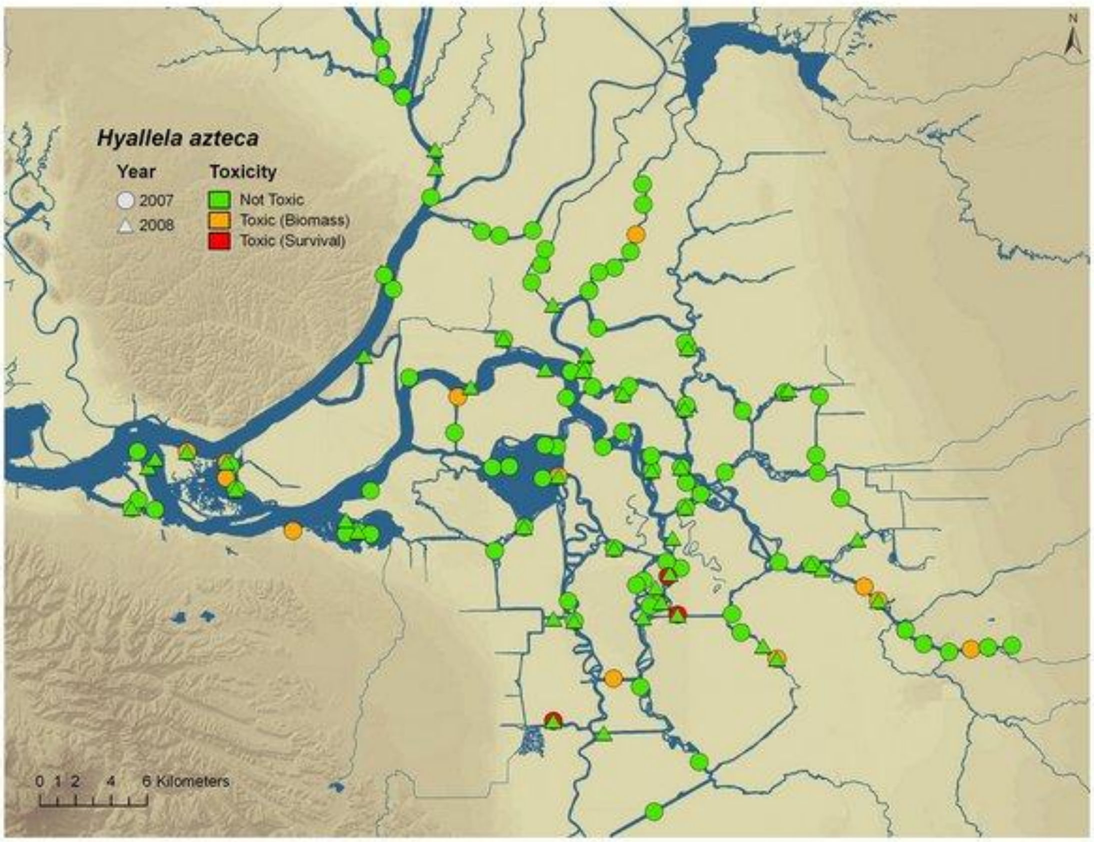


Figure 3: Toxicity to Hyalella azteca in Delta sediments, 2007-2008. (SCCWRP, in preparation)

Pyrethroid Insecticides and POTWs

Research in the field of pyrethroids has advanced considerably since preparation of the 2009 Staff Report. Much recent attention has been given to pyrethroid insecticides, including pyrethroids discharged in POTW effluent. Since adoption of the 2009 Staff Report, several notable related studies and reports have been published, or will be published in the imminent future.

While the following summary of recent studies focuses on the issue of pyrethroid insecticides in POTW effluent, it is worthy to note that the most recent research continues to confirm that the prevalence of pyrethroid related toxicity is centered around urban usage and storm water runoff. In response, DPR has recently taken significant and aggressive actions to curtail the environmental impacts of urban pyrethroid usage. Surface water protection rules were adopted by DPR in July 2012 that target the application of pyrethroids for structural pest control and landscape maintenance by professional pest control applicators. In a recently published modeling effort, an 80% reduction in pyrethroid related toxicity units was predicted[3].

Weston, B.P.; M.J. Lydy. 2010. Urban and agricultural sources of pyrethroid insecticides to the Sacramento-San Joaquin Delta of California. *Environ. Sci. Tech.* 44:1833-1840.

In this often cited research article, Weston and Lydy present pyrethroid monitoring results, including analysis of POTW effluent for pyrethroids and acute toxicity to *Hyalella azteca*. Pooling of results across three separate POTWs employing varying treatment technologies was necessary for the authors to find a statistical correlation between pyrethroid concentration and expected toxic effect. Nevertheless, no statistical correlation existed when data were reviewed on an individual POTW basis. At times pyrethroids were present in effluent at levels expected to cause substantial toxicity, but no toxicity was evident, and at times substantial toxicity was present, but no pyrethroids were detected.

While the article is often cited out of concern that POTWs may be discharging pyrethroid burdened toxic effluent, the article is in fact most notable for its detection of pyrethroids in final effluent. Pyrethroid insecticides are extremely hydrophobic, and very high levels of removal would be expected. Moreover, the amount of pyrethroid that passes through a POTW would predominantly be associated with suspended solids and organic colloids, and thus be biologically unavailable. This expectation has led others, including Weston and Lydy, to conduct follow-up studies to confirm whether pyrethroids in POTW effluent are truly bioactive.

Presently Unpublished Follow-Up Studies

Robertson-Bryan, Inc. *In prep*. Easterly Wastewater Treatment Plant Water Quality Monitoring Plan: Final Report for Monitoring Pyrethroids in Effluent and Receiving Water.

Any consideration of pyrethroid insecticides in POTW effluent discharged to the Delta must include the work of two critical follow-up studies. The City of Vacaville's Easterly Wastewater Treatment Plant (EWWTP) monitored pyrethroids and acute toxicity to *Hyalella azteca* in influent (chemistry only), effluent and receiving waters. While removal of pyrethroids at the EWWTP was greater than 95%, specific pyrethroids were detected occasionally in final effluent, but they were never found to be acutely lethal, based on the test of significant toxicity (TST). As similarly observed by Weston and Lydy (2010) at EWWTP, actual observed bioassay effects were poorly correlated with actual

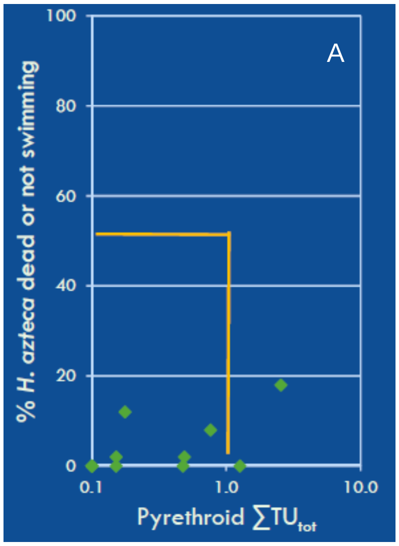
[3] Jorgenson, B.C. 2011. *Off-Target Transport of Pyrethroid Insecticides in the Urban Environment: An Investigation into Factors Contributing to Washoff and Opportunities for Mitigation.* Dissertation submitted in completion of Ph.D. by Jorgenson, Brant Coberly. University of California, Davis. 2011.

observed effluent concentration when utilizing a concentration addition toxic unit model, where a toxic unit is defined as the ratio of pyrethroid concentration to its 50% lethal concentration (**Figure 4**). The use of whole effluent, total recoverable pyrethroid analytical measurements to predict acute toxicity in *Hyalella azteca* substantially overestimated actual effects. However, accounting for phase partitioning, and the truly bioavailable dissolved pyrethroid fraction of an effluent sample, resulted in improved statistical correlation between predicted and actual effects to *Hyalella azteca*. Such observation highlights the importance of bioavailability when selecting the method of analytical measurement. A final study report is currently in preparation.

Analytical techniques for measuring dissolved pyrethroid fractions currently cannot reliably achieve necessary detection limits. The demonstrated improvement in statistical correlation between actual and predicted toxic effects in EWWTP effluent required calculation of dissolved pyrethroid concentrations through use of phase partitioning theory. This would not have been possible if not for the ongoing research of Parry and Young[4]. Organic carbon normalized pyrethroid distribution coefficients have been measured by Parry and Young for effluent suspended solids collected from the Sacramento Regional County Sanitation District (SRCSD) wastewater treatment plant. Measured distribution coefficients show that nearly all pyrethroid in SRCSD effluent is sorbed to suspended particulate matter, and thus biologically unavailable. While these data remain preliminary, publication is anticipated in 2012.

Such results from EWWTP and SRCSD challenge the simple application of laboratory bioassays, including the use of toxicity identification evaluation (TIE) techniques. Research continues with regard to pyrethroids and POTWs, but the present findings of science remains uncertain.

[4] Parry, E., and T.M. Young. 2012. Pyrethroid sorption to Sacramento wastewater effluent suspended particulate matter. 40th Annual Winter Colloquium of the Agricultural and Environmental Chemistry Graduate Group.



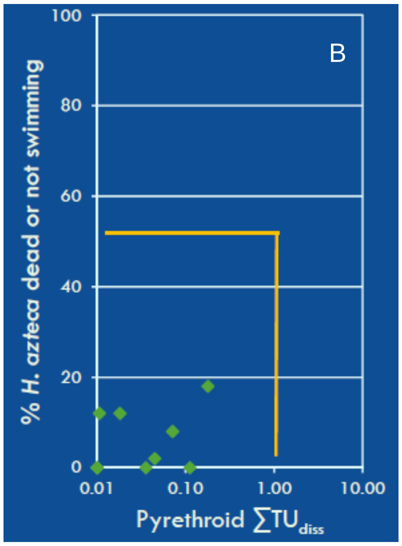


Figure 4: Acute mortality and paralysis in *Hyallela azteca* bioassays, correlated to the sum of pyrethroid TU's (total recoverable [A] and dissolved pyrethroid basis [B]). The intersection of orange lines represents expected 50% mortality/paralysis at 1 TU. Improved correlation and improved prediction is observed when basing TU calculation on dissolved fraction. (City of Vacaville, in preparation)

Constituents of Emerging Concern

Since adoption of the 2009 Staff Report, several notable studies and reports regarding constituents of emerging concern (CECs) in general, and in the Delta (and its watershed) specifically, have been published.

Anderson, P., N. Denslow, J. E. Drewes, A. Olivieri, D. Schlenk, G. I. Scott and S. Snyder (2012). Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems: Reommendations of a Science Advisory Panel. Southern California Coastal Water Research Project.

In 2009, the SWRCB requested that a "blue ribbon" advisory panel be convened to provide unbiased scientific recommendations for monitoring CECs in oceanic, brackish, and fresh water that receive discharge of treated municipal wastewater effluent and stormwater. This report represents the outcome of the panel process. Contained in the report are:

1. a conceptual, risk-based approach to assess and identify CECs for monitoring in California receiving waters;
2. application of the above framework to identify a list of CECs for initial monitoring;

3. an adaptive, phased monitoring approach with interpretive guidelines that direct and update actions commensurate with potential risk; and

4. research needs to develop bioanalytical screening methods, link molecular responses with higher order effects, and fill key data gaps.

The report focused almost exclusively on treated municipal wastewater effluent and stormwater, and did not address other known sources of CECs (private septic systems, industrial effluents, landfill leachates, discharges from fish hatcheries and dairy facilities, runoff from agricultural fields and livestock enclosures, and land amended with biosolids or manure). Exposure scenarios included an inland freshwater effluent dominated waterbody, coastal embayments, and ocean discharges. For the effluent-dominated freshwater environment, an assumption of no dilution was made, and the list of CECs identified for initial monitoring, based on potential effects to aquatic life, included ten compounds. Because the Delta does not fall into any of the three exposure scenarios, but rather, is an inland freshwater system with substantial dilution available to effluent and stormwater discharges, the reports' findings cannot be easily extended to the Delta. However, it is clear that out of the numerous CECs currently assessed in the report, only a handful may be of concern in the Delta based on current scientific understanding. Considerations of effects of changes in flow on CECs should be limited to those that were identified through the report to have any risk of effects on aquatic life. That said, before an appropriate monitoring paradigm can be established and effectively implemented, standardization of analytical methods used to measure these constituents is needed.

Guo, Y. C., S. W. Krasner, S. Fitzsimmons, G. Woodside and N. Yamachika (2010). Source, Fate, and Transport of Endocrine Disruptors, Pharmaceuticals, and Personal Care Products in Drinking Water Sources in California. Fountain valley, CA, Metropolitan Water District of Southern California and Orange County Water District.

The objectives of this project were to assess the occurrence of a wide range of CECs in drinking water sources to Southern California, including the State Water Project starting from the Delta, to evaluate the impact of treated wastewater discharges, and also to evaluate the fate and transport of these chemicals in the watersheds. Samples were collected quarterly for a year at five Delta locations and analyzed for 50 CECs. As expected, concentrations of target analytes varied by analyte, sample, and location, but virtually every sample had detectable concentrations of at least one analyte. That said, the report acknowledges that "the general consensus is that there is no evidence of human health risk from low levels of the commonly detected [endocrine disrupting chemicals] and [pharmaceuticals and personal care products] in drinking water or drinking water supplies." Furthermore, the report notes: "standardized analytical methods are needed to ensure high quality data and to be able to compare results from different studies. Currently, approaches from laboratories performing PPCP analysis vary widely on key analytical issues, such as blank contamination and matrix effects."

Lavado, R., J. E. Loyo-Rosales, E. Floyd, E. P. Kolodziej, S. A. Snyder, D. L. Sedlak, and D. Schlenk. 2009. Site-Specific Profiles of Estrogenic Activity in Agricultural Areas of California's Inland Waters. Environmental Science and Technology 43(24):9110–9116.

In this study, researches collected 101 samples from 16 locations throughout the Central Valley at areas impacted by agriculture, and analyzed the samples using bioassays that measure total estrogenic activity, as well as steroid hormones and nonionic detergents and their metabolites. There were infrequent detections of low concentrations of the trace organic compounds, and the concentrations of compounds frequently associated with feminization effects on fish were far below thresholds for feminization of sensitive species. Estrogenic activity was definitively detected and confirmed at two sampling sites, including the Sacramento River at Walnut Grove. These samples were subjected to fractionation to attempt to determine compounds responsible for the estrogenic activity, and fractions were analyzed for numerous pharmaceuticals, pesticides, and potential endocrine disruptors. However, none of the compounds analyzed for in the study could explain the estrogenic activity that was observed.

Although determination of compounds responsible for estrogenic activity was inconclusive, one of the primary outcomes of the study is the finding that over a large geographic and temporal scale (i.e., throughout the Delta watershed, and at several times over the course of an entire year), concentrations of chemicals known to cause estrogenic effects are predominantly below detection limits. While it is possible that the results of the study are not representative of all areas in the Delta, it is apparent that estrogenic activity is not widespread in the watershed.

Presently Unpublished Follow-Up Studies

Robertson-Bryan, Inc. *In prep*. Easterly Wastewater Treatment Plant Water Quality Monitoring Plan: Final Report for Monitoring Constituents of Emerging Concern in Effluent and Receiving Water.

The City of Vacaville monitored CECs in its Easterly Wastewater Treatment Plant undiluted effluent and its receiving water on a monthly basis for one year. Three events included split samples that were sent to a second laboratory for interlaboratory comparison. Thorough quality assurance/quality control review protocols were developed and implemented on an ongoing basis throughout the study. Concentrations measured in the study were approximately the same or lower than similar studies that have been conducted at other wastewater treatment plants and receiving waters for most compounds. Results indicated that analytes detected in the effluent largely persisted through the near-field environment. Decreased concentrations in the receiving water, downstream of the discharge location, appeared to be primarily related to dilution.

Results of the QA/QC review protocols performed on a monthly basis indicated that close inspection of laboratory QC samples and of the analytical results themselves is critical to a successful monitoring program for CECs. This was because numerous QA/QC problems were encountered for the PPCPs and steroids/hormones testing over the course of the study, including holding time exceedances, unacceptable matrix recoveries, contamination in field or method blanks, and both false negatives and false positives, mostly attributable to non-standardized sample preparation and analysis methods. Although it is clear that robust, reliable methods for measurement of CECs in wastewater exist, widespread acceptance and use of standardized sample preparation and analysis methods is necessary before an appropriate monitoring and regulatory paradigm can be established and effectively implemented.

Issues for Consideration – Need for a Comprehensive, Scientific Delta Monitoring Program Framework

Far too often, monitoring programs are developed and implemented without sufficient up-front thought and planning related to the purpose of the program (e.g., to assess compliance, to develop an understanding of ecosystem processes/limiting factors, to answer important questions) and how monitoring will be performed to achieve specific objectives in order to answer key questions, thereby achieving the overall program goal or purpose. Regional monitoring and assessment frameworks are often designed around key scientific questions that need to be answered in order to know whether regulatory requirements are adequate and, if not, how regulatory requirements need to be changed to achieve the desired environmental conditions for adequate beneficial use protection.

An effective program of implementation for the new flow objectives will need to rely on current and expanded Delta monitoring programs to provide the State Water Board with the data it needs to judge whether the flow objectives are producing the desired environmental conditions. Although several good Delta monitoring programs currently exist, and should continue, what each individual monitoring program produces has not been effectively integrated, from a scientific perspective, to ensure the programs are, collectively, gathering all the necessary types, frequency, and quality of data needed to answer the key questions that regulators and stakeholders need to have answered relative to Delta conditions and beneficial use protection. More specifically, how flows affect key water quality parameters which, in turn, affect aquatic life, agricultural, and municipal and industrial supply beneficial uses.

A comprehensive, scientific monitoring framework is needed that defines appropriate measures of Delta ecological health and how they are affected by flow, water quality, and species interactions (including those of invasive species). Such a framework would bring an overall "Delta function perspective" to determine how best to coordinate and integrate existing monitoring programs (e.g., Surface Water Ambient Monitoring Program (SWAMP)); Interagency Ecological Program (IEP), the Department of Water Resources' Municipal Water Quality Investigations (MWQI) program, and California Department of Fish and Game, U.S. Fish and Wildlife Service, and National Marine Fisheries Service fisheries monitoring programs). It also would bring a scientific perspective to how data from these individual programs could be collected and analyzed to address well-defined scientific and regulatory questions that are not being posed by the individual programs.

The Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, which was prepared and adopted by the State Water Board, Central Valley Regional Water Board, and San Francisco Bay Regional Water Board, identifies the development of a comprehensive monitoring program for the Delta as a priority action. Consistent with the strategic workplan, the Central Valley Regional Water Board issued (June 2012): "*Delta Regional Monitoring Program: A Proposal for a Regional Monitoring and Assessment Framework and its Implementation*." The impetus for the Delta Regional Monitoring Program (RMP) was, in large part, the pelagic organism decline (POD) observed in the Delta in recent years and the concern that contaminants may be the cause or a significant contributor to the observed decline. As stated in the strategic workplan, the POD highlighted "…*the need for regularly compiling, assessing, and reporting data that is currently being collected and the need to better coordinate monitoring efforts*."

The proposal for a Delta regional monitoring program (RMP) for more comprehensively assessing contaminants and toxicity within the Delta is a useful concept that is under development and will likely result in improved efficiency and collaboration for assessing Delta-wide water quality. However, coordination without a comprehensive, scientific Delta monitoring framework to direct such coordination – one that integrates ecological, hydrologic, and water quality data in search of fundamental relationships – will fall short of what is needed. Such a comprehensive framework would need to relate the water quality and toxicity data generated throughout the Delta from the RMP to key measures of ecological health, as monitored by the IEP and the fisheries agencies' monitoring programs. Cause-effect relationships between ecological parameters and water quality need to be identified when and where they exist so that as water quality changes over time (positive or negative), ecological effects can be better predicted. Our understanding of how Delta inflow and outflow affect water quality needs to be expanded well beyond salinity, to other water quality parameters affecting the Delta's ecological health. Individual efforts to do so are underway, but are not well coordinated or integrated under an overarching scientific vision of understanding how the Delta's ecology and water quality is affected, at various time-steps, by flow.

Work by Johnston et al., 2010 (see above) further illustrate the need for a more far-reaching Delta monitoring framework. These researchers compiled, assessed, and reported all available water quality and contaminant data, but could not come to any definitive conclusion regarding the role of contaminants in POD. A factor that likely contributed to this outcome is that the water quality, toxicity, and ecological monitoring programs were not designed and operated in an integrated manner to specifically relate contaminant levels in the Delta to effects at various levels of biological organization, trophic levels, or sentinel species. When programs are not designed to answer specific questions, the data they produce (based on other objectives) are often inadequate to answer said questions.

Both the need and opportunity exists today for the State Water Board to develop a truly comprehensive, science-based Delta monitoring framework that clearly: 1) identifies the regulatory and scientific questions that must be answered to determine best management scenarios for the Delta, and 2) coordinates the implementation of ongoing and modified ecological and water quality monitoring programs to produce and analyze data in a manner that will, to the greatest degree possible, definitively answer these critically important scientific and regulatory questions that have already been posed, but not fully answered.

A comprehensive Delta monitoring program framework would define the water quality and ecological conditions that are desired at key locations throughout the Delta and the monitoring parameters (i.e., ecological and water quality measurements) used to determine achievement of those desired conditions. Initial implementation of Bay-Delta Water Quality Control Plan flow objectives can then be directly evaluated to determine their role in achieving the desired Delta conditions, and the relative sensitivity of various Delta conditions to specific source flows (i.e., flow fractions from the Sacramento and San Joaquin rivers, east-side tributaries, agricultural return flows, and sea water intrusion) and other controlled variables (e.g., cross-channel gate operations, water quality). By providing such a comprehensive, science-based framework, the State Water Board can effectively harness the data-generating power of multiple monitoring programs to produce the information needed to most efficiently evaluate the efficacy of initial flow objectives, and can identify the monitoring and analyses needed to do so.

Through the development (and refinement over time) of conceptual models that include testable hypotheses as part of this framework, the State Water Board will improve its understanding of important causal relationships, including the role flow and other controllable variables play in resulting Delta conditions, and thus will better know how to modify flow objectives as climate change and changes in Sierra hydrology and CVP/SWP operations occurs over time. Through programs such as the environmental monitoring program (EMP), the State Water Board maintains tools to evaluate the effect of proposed flows objectives on water quality characteristics such as salinity. It is recommended, however, that the State Water Board further extend its understanding of flow effects into the arena of contaminants and ecological parameters so that beneficial use protection is holistically considered. For this to occur, a comprehensive Delta monitoring program framework that facilitates the effective integration of efforts from the major ecological and water quality monitoring programs is essential.

Development of a comprehensive Delta monitoring program framework by the State Water Board and other involved agencies and stakeholders should consider the following.

1. Develop an overarching vision and purpose/goal that unites stakeholders and agencies in an integrated, supportable effort.
2. Develop conceptual models that define our current understanding of Delta relationships among ecological parameters, flow, and water quality and thus define data gaps to be filled and assist in defining the fundamental scientific and regulatory questions to be answered by the program.
3. Develop a full suite of fundamental questions that stakeholders and agencies seek to have answered by the monitoring data to be collected and analyzed, which have not been adequately answered to date.
4. Define program objectives that when achieved produce the data/information needed to achieve the program goals.
5. Define specific monitoring elements, special studies, and pilot projects that constitute actions, with measurable outcomes, that will accomplish the program objectives.
6. Define the type, amount and geographic extent of specific data that will be needed to effectively address the questions, and which monitoring programs will collect these data. Determine how, if at all, various ongoing monitoring programs need to be expanded/modified to achieve the overall goal.
7. Define the kinds of analyses that will be performed to address each of the program questions. Knowing how data are to be analyzed is critical to knowing the type, amount, and quality of data to collect.
8. Define the quality and quantity of data needed to support the analyses to be performed.
9. Define how the current and planned monitoring efforts and programs will be integrated to produce the data and analyses needed to answer key scientific and regulatory questions.
10. Define an adaptive management approach that allows the individual monitoring programs to change appropriately and timely in response to new information/findings, changing environmental conditions, and new questions to be answered.