Comments on the SWRCB Staff's Proposed Approach for Developing Sediment Quality Objectives for Enclosed Bays and Estuaries of California.

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Presented herein are comments on the California State Water Resources Control Board's (SWRCB) staff's proposed approach for developing sediment quality objectives (SQOs) for enclosed bays and estuaries of California. SQOs are to be used to evaluate sediment quality as part of a regulatory program for controlling the adverse impacts of chemical contaminants in aquatic sediments that affect the beneficial uses of a waterbody. Ultimately, sediment remediation programs and source control for those sources that lead to impaired sediment quality could evolve from the SQOs. The proposed approach for SQO development is set forth at http://www.swrcb.ca.gov/bptcp/sediment.html.

As discussed herein, there are significant technical deficiencies in the staff's proposed approach that preclude it from being a reliable component of a regulatory program to manage the water quality impacts of sediment-associated contaminants in a technically valid, cost-effective manner. The major technical deficiency is that the role of aquatic chemistry in affecting how chemical contaminants in aquatic sediments impact beneficial uses of waterbodies has not been inadequately considered or incorporated. The lack of a proposed implementation approach in the staff report is another major deficiency.

In developing its proposed approach, the SWRCB staff faced a monumental task of trying to address the highly complex issues of how chemical contaminants associated with sediments affect beneficial uses of waterbodies. The staff was not provided with adequate financial resources, or sufficient time or expertise to develop implementable SQOs. The staff's report that is under review by the SWRCB should be considered a "work in progress" to be followed by a more adequately developed, technically sound regulatory program for managing contaminated sediments. Only after the technical and implementation deficiencies in the proposed approach have been corrected should the SWRCB consider its adoption as fulfilling the legislature's requirement for the Bay Protection and Toxic Cleanup Program.

Overall Evaluation of Proposed SQO Development Approach

Inappropriateness of Inclusion of "Co-Occurrence" Information. The SWRCB staff's proposed approach for evaluating the water quality significance of chemical constituents in aquatic sediments is to combine multiple "lines of evidence" (often referred to as a "triad" approach): sediment toxicity, benthic organism assemblages, and the total concentrations of selected chemicals in the sediments. While the sediment toxicity and benthic organism assemblage information are technically valid components of a biological effects-based sediment quality evaluation, the total concentration of a chemical or chemicals in a sediment, either directly, or through a co-occurrence assessment or index, is not. It has been known for more than 30 years that the total concentrations of sediment-associated chemicals, individually or collectively, do not have a cause-and-effect relationship to the impact that that sediment has on benthic organisms, aquatic life, or sediment/water quality. (The unique exception to this is truth, for some situations, is ammonia, which, as discussed subsequently, is not included in the parameters considered in the proposed SQO development approach.) The fact that an elevated concentration of a chemical may occur in a sediment that has exhibited some impact ("co-occurrence") is not evidence of a cause-and-effect relationship. Regulators need to get beyond the simplicity of the co-occurrence approaches, and realize the technical invalidity of the approaches for regulatory purposes.

Incorporating the total concentrations of sediment-associated chemicals in an SQO, while simple and straight-forward, is not technically sound and can be expected to lead to inappropriate sediment quality evaluations. Inclusion of such concentrations, or indices developed based on those concentrations, cannot be presumed to be an appropriate "safety net" or "best guess" for situations in which reliable data are lacking; it is simply not valid. Admixing an invalid or extraneous parameter with other, reliable parameters, does not make the invalid parameter valid or useful; it only serves to render the overall conclusions obtained through the triad untrustworthy, and hence useless. The same is true for the use of concentration-based elements in "screening" exercises; unreliable sediment screening approaches mislead the direction and focus of further evaluation and remediation. Sediments with higher concentrations of certain chemicals can be of less environmental quality significance than sediments having a lower concentration because the potential impact cannot be reliably keyed to the total concentration. Use of unreliable evaluations can be expected to cause dischargers, including the public, to spend large amounts of money for sediment quality "remediation" and source control without reliable justification based on the actual role of the chemical(s) in causing the sediment toxicity, altered benthic organism assemblages, or other adverse condition.

Excluded Contaminants Need Consideration. Another significant deficiency with the SWRCB staff's recommended approach is the imprudently narrow focus of the list of chemicals considered in the SQO development. While many of the chemicals included are suspected of potentially causing impacts at some undefined level and in some undefined way, notably absent from that list are numerous chemicals that are, in fact, known to cause sediment quality impairment. For example, low DO, ammonia, and hydrogen sulfide can be responsible for sediment toxicity but are not given consideration. They can, in fact, be largely responsible for toxicity erroneously attributed, through "co-occurrence" evaluation, to other chemicals that also occur in the sediment. Further, there is a vast array of potentially toxic chemicals, such as some of the widely-used pesticides, that are not being adequately considered in the staff's proposed list of chemicals that serves as the basis for SQO development.

The inclusion of total chemical concentrations in the evaluation of the role of a sediment-associated chemical in causing sediment toxicity skews the results of the entire triad, and clouds the results and insight provided by the technically valid portions of the assessment. Inclusion of total concentration can certainly be simple, straight-forward, and provide a seemingly meaningful catch-all for the evaluation. In reality, it is simply a "wild card" that is not reliably related to potential impact. Inclusion of this parameter, as is being proposed, reflects an insufficient and mistaken understanding of basic principles of aquatic chemistry and how chemicals in sediment can impact aquatic life in sediment.

In short, because the inclusion of chemical concentrations in the "triad" evaluation renders its results unreliable, the proposed approach for SQO development is not technically valid. The sediment quality evaluation should be a truly biological effects-based approach that incorporates sediment toxicity and benthic organism assemblage information, without any incorporation of "pseudo-effects" "co-occurrence" approaches. The chemical concentration component of the proposed triad should be replaced with a reliable Toxicity Identification Evaluation ("TIE") of the chemical(s) in sediment in which toxicity and/or altered benthic organism assemblages are manifested.

The Overlooked/Postponed Issues of Implementation. One of the most important elements of any environmental quality objective is the delineation of how it can and will be used to manage water quality, i.e., its implementation. One of the most significant deficiencies in the proposed approach for developing the SQOs is its lack of detailed information on how the results of the SQO triad, even if reliable, would be implemented to reliably direct and regulate the identification and cleanup of contaminated sediment, and institute appropriate source identification and control to prevent future sediment contamination. As documented herein, because the chemical component of the SQO triad is fundamentally flawed, the outcome of the SQO is unreliable for assessing the role of a chemical(s) in impacting sediment quality and, therefore, the impact of the sediment on beneficial uses of a waterbody.

The staff has asserted that the unreliability of co-occurrence can be addressed in the implementation phase of sediment quality management. First, it is not technically valid or cost-effective policy to develop a fundamentally flawed evaluation approach and then try to rectify the inherent deficiencies by manipulating its implementation. Second, even if the SQO triad evaluation approach were reliable, the proposed implementation discussion provided in the report is insufficient, at best, to enable proper review to ensure that the approach and implementation correctly identifies sediment quality problems, the chemical(s) and/or conditions responsible for biological impacts, and sources of the chemical(s). These issues are discussed further in a subsequent section.

Qualification for This Review

Dr. G. Fred Lee has been involved in sediment quality evaluation since the early 1960s. Dr. Lee's PhD degree from Harvard University focused on aquatic chemistry. For 30 years he held university graduate-level teaching and research positions at several major US universities during which time he conducted over $5 million in research on water chemistry/water quality investigations and published over 500 papers and reports on those studies. A focus of much of his work has been the role of chemicals in causing adverse impacts on organisms in the water column and aquatic sediments. Dr. Anne Jones-Lee earned a BS degree in biology and a PhD in environmental sciences from the

University of Texas at Dallas, with emphasis in aquatic toxicology. She has worked with Dr. Lee on sediment quality issues since the mid-1970s.

Their work has included conducting about $1-million in laboratory and field research for the US Army Corps of Engineers (USACE) Dredged Material Research Program in the development of dredged sediment disposal criteria for managing contaminated sediments. That research, conducted over a five-year period in the 1970s, served as the technical basis for the USACE and USEPA's biological effects-based criteria for evaluation of disposal of contaminated dredged sediment by open-water disposal. Those criteria, developed about 30 years ago, are still in effect today; receiving period review, they remain largely unchanged. As part of several of those reviews, attempts have been made to require that the USEPA and USACE incorporate co-occurrence-based sediment quality evaluations of the type proposed by the California SWRCB staff for SQO development, using total concentrations of selected chemicals in sediments. The USEPA and USACE have conducted detailed reviews of that approach and have repeatedly concluded that it is not a technically valid approach for regulating the potential impacts of chemical contaminants in sediments on aquatic life and other beneficial uses of waterbodies. Further information on Drs. Lee and Jones-Lee's qualifications to review the technical validity of the SWRCB staff's proposed approach for SQO development is available at http://www.gfredlee.com/psedqual.htm.

Throughout his 30-year university graduate-level teaching and research career and the ensuing 18 years of public service and full-time private consulting, Dr. Lee has been active in educational outreach to improve the understanding and incorporation of aquatic chemistry in environmental quality evaluation and management programs. Since retiring from university teaching and research in 1989, Dr. Lee has continued to be active in developing papers and reports primarily directed at professional educational outreach on issues of aquatic chemistry/water quality; he and Dr. Jones-Lee have developed more than 600 additional papers and reports on these issues. As part of this outreach activity they have developed a website at which these and many of his previous papers/reports are available for download (www.gfredlee.com).

One of Dr. Lee's professional outreach activities has been presenting lectures to professionals on aquatic chemistry and water quality issues. For more than 20 years he served as an American Chemical Society tour speaker, presenting invited lectures to local-section chemists and chemical engineers and others on aquatic chemistry/water quality issues thoughout the US. Each week-long tour involved presenting nightly lectures to different local ACS groups in a geographical area of the country.

He has also developed and presented short-courses on aquatic chemistry/water quality for various professional organizations and groups including America Society of Civil Engineers, American Water Resources Association, National Groundwater Association, Hazardous Material Research Institute, Environment Education Enterprises, and at University of California Extension locations in the State. Drs. Lee and Jones-Lee also presented invited short-courses in Spain, Argentina, Hong Kong, Japan, Colombia, South Africa, Israel, and the USSR.

One of Drs. Lee and Jones-Lee's major current professional educational outreach activities is their Stormwater Runoff Water Quality Newsletter. Now in its 10th year of publication, this self-published and funded, e-mail-based Newsletter addresses current topics, issues, and findings pertinent to the evaluation and management of urban and agricultural stormwater runoff/discharge and, with few exceptions, cover some key aspect of water quality and aquatic chemistry/toxicology. It is sent about monthly to bimonthly via e-mail, at no cost, to the more than 9,400 water quality professionals on the mailing list. Past newsletters are available on Drs. Lee and Jones-Lee's website (www.gfredlee.com) at http://www.gfredlee.com/newsindex.htm. An index to the topics covered in past newsletters is available at that URL.

SWRCB Staff's Approach for SQO Development

According to the SWRCB announcement on its website of the availability of the draft staff report (http://www.waterboards.ca.gov/bptcp/sediment.html),

> "*SEDIMENT QUALITY OBJECTIVES*
> *Sediments in bays and estuaries are often contaminated with a variety of pollutants stemming from sources including industrial and agricultural discharges, municipal wastewater treatment plants and stormwater. Exposure to contaminated sediments can have a significant effect on the health, diversity and abundance of invertebrates such as clams and worms. Foraging fish and birds may also be exposed by ingesting contaminated invertebrates or sediments. In turn, those organisms consuming contaminated fish may be exposed to toxic pollutants. These effects underscore the need to develop sediment quality objectives that protect aquatic ecosystems and human health.*
>
> *The State Water Resources Control Board (State Water Board) intends to develop and adopt sediment quality objectives (SQOs) for enclosed bays and estuaries. This process will require approximately four years to complete. This page contains links to information on the State Water Board's progress.*
>
> <u>*Notice of Public Hearing*</u>
> *The State Water Board will hold a public hearing November 19, 2007 to seek comments on the proposed Water Quality Control Plan for Enclosed Bays and Estuaries of California, Sediment Quality Objectives. Comments are due by November 30, 2007 (Noon).*"

The staff report and supporting documents are available at,
http://www.swrcb.ca.gov/bptcp/sediment.html

The staff report states, in *"Statement of Goals,"*

> *"The California Water Code defines sediment quality objectives as that level of a constituent in sediment established with an adequate margin of safety for the reasonable protection of beneficial uses or prevention of nuisances. The term reasonable is defined as governed by or in accordance with reason or sound*

thinking, within the bounds of common sense, not excessive or extreme; fair moderate (American Heritage Dictionary of English Language, New College Edition 1976).

The objective of this program since 2002 has been to develop SQOs and robust indicators in conjunction with a program of implementation that protects two beneficial uses, aquatic life and human health. The goals of this program are

- *Establish narrative receptor-specific SQOs.*
- *Establish a condition that is considered protective for each targeted receptor.*
- *Identify appropriate lines of evidence for each receptor that when integrated can support a confident interpretation of the narrative objective.*
- *Develop and or refine and validate specific indicators for each line of evidence so that the condition of each station can be measured relative to the protected condition.*
- *Build a program of implementation based upon these tools and the current level of scientific understanding to promote the protection of sediment quality related beneficial uses.*
- *Define a process that will result in better management and more effective restoration of polluted sediments*

Staff believes the approach developed to assess aquatic life via benthic communities for Southern California's enclosed bays and marine lagoons and polyhaline San Francisco has met these goals. For other bays on the central and north coast such as Morro Bay Humboldt Bays, Tomales Bay, and all estuaries including the San Sacramento Joaquin Delta [sic] *lack of available data prevented the staff and technical team from achieving these goals in these waters. In response Board staff have proposed a less robust means to determine if sediment quality is meeting the narrative aquatic life - benthic community SQO in these waters. However, Water Board staff believe that work conducted in the next phase will provide superior indicators that could replace these tools if adopted and be comparable to those developed for Southern California Bay and polyhaline San Francisco Bay in Phase II of the SQO program.*

Although extensive progress was also made on developing an approach to interpret the human health based narrative objective, Staff are proposing in this first phase to use existing site-specific human health risk methodology to interpret the narrative. As State Water Board staff stated in the May 2003 Workplan, developing sediment quality objectives that protect human health from consumption of contaminated fish is extremely complex for several reasons.

- *The fate and transport of pollutants from sediment to tissue and the water column pollutants is highly site specific.*
- *Indirect exposure to pollutants from sediments transported up the food web is difficult to relate directly to specific sites or stations of area of a waterbody.*

- *The home range, habitat, feeding strategies, and lipid content of each fish species may vary seasonally and as the fish matures, all of which affects the rate of contaminant accumulation in the tissue.*
- *The type and size of prey-fish targeted by sport-fisherman and subsistence fisherman also varies considerably as do the methods of preparation, types of tissue consumed and consumption rates.*

A more detailed approach to support the human health based SQOs will require greater time and effort. Staff expects this effort to be completed in the next phase, which would trigger a new proposed methodology for Board consideration."

Appendix A of the staff report presents "Staff Proposal Draft Water Quality Control Plan for Enclosed Bays and Estuaries of California Part 1 Sediment Quality." This section states in the "Intent and Summary,"

> *"It is the goal of the State Water Board to comply with the legislative directive in Water Code §13393 to adopt sediment quality objectives (SQOs). Part 1 integrates chemical and biological measures to determine if the sediment dependent biota are protected or degraded as a result of exposure to toxic pollutants* in sediment and to protect human health.* ***This plan is not intended to address low dissolved oxygen, pathogens or nutrients including ammonia.*** [Bold added for emphasis – see discussion below.] *This Draft Plan represents the first Phase of the State Water Board's Developmental Effort and focuses primarily on the protection of benthic* communities in enclosed bays* and estuaries*. The State Water Board has committed in Phase II to the refinement of benthic community protection indicators for estuarine waters and the development of an approach to address sediment quality related human health risk associated with consumption of fish tissue."*

The SWRCB staff proposed an integrated approach to developing an evaluation of sediment quality through SQO development involving multiple lines of evidence. Page 8 of Appendix A states,

> *"Section V. Benthic Community Protections*
>
> *A. Multiple Lines of Evidence Approach*
>
> *The methods and procedures described below shall be used to implement the Narrative Objective described in Section IV.A. These tools are intended to assess the condition of benthic communities relative to potential for exposure to toxic pollutants in sediments. Exposure to toxic pollutants at harmful levels will result in some combination of a degraded benthic community, presence of toxicity, and or elevated concentrations of pollutants in sediment. The assessment of sediment quality shall consist of the measurement and integration of three lines of evidence (LOE). The LOE are:*
>
> ***Sediment Toxicity****: Sediment toxicity is a measure of the response of invertebrates exposed to surficial sediments under controlled laboratory conditions. The sediment toxicity LOE is used to assess both pollutant related biological effects and exposure. Sediment toxicity tests are of short durations and may not duplicate exposure conditions in natural systems. This LOE provides a*

measure of exposure to all pollutants present, including non-traditional or unmeasured chemicals.

***Benthic Community Condition**: Benthic community condition is a measure of the species composition, abundance and diversity of the sediment-dwelling invertebrates inhabiting surficial sediments. The benthic community LOE is used to assess impacts to the primary receptors targeted for protection under Section IV.A. Benthic community composition is a measure of the biological effects of both natural and anthropogenic stressors.*

***Sediment Chemistry**: Sediment chemistry is the measurement of the concentration of chemicals of concern* in surficial sediments. The chemistry LOE is used to assess the potential risk to benthic organisms from toxic pollutants in surficial sediments. The sediment chemistry LOE is intended only to evaluate overall exposure risk from chemical pollutants. This LOE does not establish causality associated with specific chemicals."*

As discussed in these comments, as proposed the so-called "sediment chemistry" component of the triad is not technically valid for assessing the potential impacts of a chemical(s) on sediment quality or benthic organisms, or for assessing the impairment of beneficial uses of a waterbody.

"B. Limitations

None of the individual LOE is sufficiently reliable when used alone to assess sediment quality impacts due to toxic pollutants. Within a given site, the LOEs applied to assess exposure as described in Section V.A. may underestimate or overestimate the risk to benthic communities and do not indicate causality of specific chemicals. The LOEs applied to assess biological effects can respond to stresses associated with natural or physical factors, such as sediment grain size, physical disturbance, or organic enrichment.

Each LOE produces specific information that, when integrated with the other LOEs, provides a more confident assessment of sediment quality relative to the narrative objective. When the exposure and effects tools are integrated, the approach can quantify protection through effects measures and also provide predictive capability through the exposure assessment.

Table 12 Tools for Use in Evaluation of LOEs

LOE TOOLS METRICS

Chemistry

Bulk sediment chemistry to include existing list plus other chemicals of concern CA LRM Pmax

Concentration on a dry weight basis

Sediment Toxicity

10-Day amphipod survival using a species tolerant of the sample salinity and grain size characteristics. E.g., Hyalella azteca or Eohaustorius estuarius Percent of control survival

Benthic Community Condition

Invertebrate species identification and abundance
Species richness Presence of sensitive indicator taxa Dominance by tolerant indicator taxa Presence of diverse functional and feeding groups Total abundance"

The statement about including "*other chemicals of concern*" in the CA LRM Pmax co-occurrence-based approach for the "chemistry" (more properly, chemical concentration) is a superficial attempt to try to make this technically invalid approach appear more reliable. Repeatedly at staff-organized meetings to discuss SQO development, and in his writings Lee has pointed out that there is a vast array of chemicals that could be causing toxicity in a sediment but that are not considered in the Long and Morgan, MacDonald, or Field et al., co-occurrence-based approaches. Misguided focus on a chemical based on its total concentration can result in failure to address the primary cause of the sediment toxicity. This issue is discussed further below.

Appendix C states,

*"**Direct Effects Station Assessment Example Calculation***

This document describes the calculations needed to evaluate sediment with respect to the sediment quality objective for aquatic life-benthic community protection. The evaluation process consists of 5 steps, as shown in Figure 1. Step 1 consists of sediment sampling and laboratory measurement of three Lines of Evidence (LOE): chemistry, toxicity, and abundance of benthic infauna. The data from each LOE are then summarized, interpreted using multiple indices, and integrated in Steps 2-4 in order to determine a LOE condition category. The final step of the evaluation process is to combine the three LOE category classifications to determine the station assessment category.

The data used in the example are typical of those likely to be encountered in California embayments. Steps 2-4 are described separately for each LOE. The thresholds used to evaluate the data were obtained from Appendix A (Draft Enclosed Bays and Estuaries Sediment Quality Plan). The data analyses described in this example have been broken down into a number of intermediate steps to allow the reader who is unfamiliar with these analyses to follow the calculations. In practice, many of these steps are accomplished with a single calculation and the calculations are easily automated using readily available computer software.

Figure 1. Steps in the sediment evaluation process.
Step 1 Collect and analyze samples Chemistry, Toxicity, Benthos
Step 2 Compile and summarize data QA review, means, sums
Step 3 Apply Indicators for each LOE Indices and thresholds
Step 4 Determine LOE Category Integrate indicators
Step 5 Station impact assessment Integrate LOEs

The steps involved in analysis of the chemistry LOE are gathering the data and getting them into the appropriate units, calculating the Logistic Regression Model values, calculating the Chemical Score Index values, and integrating these values to determine the chemistry LOE category. All of the calculations can be done with a standard desk calculator, but can be more easily accomplished using a spreadsheet program, such as Excel.

<u>Data preparation</u>
The first step in the process is to gather the appropriate sediment chemistry data and put it into the proper units for analysis. The chemical constituents needed for the chemistry LOE analysis and the sample data are listed in Table 1. Note that all constituents are expressed on a dry weight basis, metals in mg/dry kg and organic constituents in mg/dry kg. For any chemicals that were measured but not detected, an estimated concentration (e.g., ½ of the detection limit) should be used for calculation purposes.

<u>California Logistic Regression Model Calculation</u>
The California Logistic Regression Model (CA LRM) uses logistic regression models to predict the probability of sediment toxicity based on chemical concentration. The concentration data for each chemical, along with chemical-specific regression slope and intercept are used in the following equation to predict the probability of toxicity (p).”

According to the staff report, on page 77,

“Logistic Regression Model (National LRM)
The Logistic Regression Model (LRM) approach was based on the statistical analysis of paired chemistry and amphipod toxicity data from studies throughout the U.S. (Field et al. 1999, 2002). A logistic regression model is developed for each chemical to estimate the probability of toxicity at a given concentration. LRM models for 18 chemicals having low rates of false positives were selected for use in this study. The LRM method does not establish specific concentration values for each chemical, but rather describes the relationship between contaminant concentrations and the probability of toxicity. The maximum probability of effects obtained from the individual chemical models (Pmax) was selected to represent the chemical mixture present in a sample (Field et al. 2002).”

Comments on SQO Development Approach

The SWRCB staff’s effort to develop sediment quality objectives that can be used in sediment quality evaluation has made significant advances in documenting the complexity of aquatic sediments, especially in the relationship (more appropriately lack of relationship) between the bulk chemical composition of sediments and sediment toxicity and benthic organism assemblages. The incorporation of sediment toxicity and benthic organism assemblage information in an evaluation of the *impact* of chemicals on sediment quality is normally appropriate. Finding sediment toxicity and altered benthic organism assemblages compared to the population that should be present based on habitat characteristics should trigger further investigation to evaluate the cause of the toxicity and/or altered benthic organism populations. Of particular concern is whether the toxicity is causing the altered benthic organism assemblages. However, the staff's proposed incorporation of the California Logistic Regression Model, a **co-occurrence**-based component, with those otherwise valid effects-based parameters, invalidates the proposed evaluation scheme.

The principles of aqueous environmental chemistry, as well as the extensive empirical evidence from site-specific research, attest irrefutably to the fact that the bulk sediment chemical composition is not relatable to the potential or actual impact of that sediment. A detailed discussion of this issue has been presented by Lee and Jones-Lee (2002, 2004) in their reviews,

> 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," Presented at the 2002 Fifth International Conference on Sediment Quality Assessment (SQA5), In: Munawar, M. (Ed.), *Aquatic Ecosystem Health and Management* 7(3):351-356 (2004). http://www.gfredlee.com/BPJWOEpaper-pdf

> Lee, G. F., Jones-Lee, A., "Appropriate Incorporation of Chemical Information in a Best Professional Judgment 'Triad' Weight of Evidence Evaluation of Sediment Quality" poster at the 5th International Conference on Sediment Quality Assessment, Aquatic Ecosystem Health and Management Society Chicago, IL, October (2002). http://www.gfredlee.com/BPJ_Poster.pdf

as well as in

> Jones-Lee, A. and Lee, G. F., "Unreliability of Co-Occurrence-Based Sediment Quality Guidelines for Contaminated Sediment Quality Evaluation at Superfund/Hazardous Chemical Sites," J. *Remediation*, 15(2):19-33, Spring (2005). http://www.members.aol.com/annejlee/SQGSuperfund2.pdf

and other papers and reports provided on Lee and Jones-Lee's website, http://www.gfredlee.com/psedqual2.htm. Their papers and reports contain numerous references to the wider professional literature that further documents the unreliability of co-occurrence-based approaches for evaluation of sediment quality and the potential for a chemical(s) to cause sediment toxicity.

The first of the papers listed above was presented at the Fifth International Conference on Sediment Quality Assessment. That conference included a series of papers by internationally recognized authorities on sediment quality evaluation. As would be expected from principles of aqueous environmental chemistry, there was agreement by the presenters and many of the conference participants that co-occurrence-based sediment quality evaluation is technically invalid since the total concentration of a chemical or group of chemicals is not evidence of the impact of the chemicals on aquatic life or the potential for excessive bioaccumulation of a chemical in aquatic organism tissue.

Review of the list of references provided by the staff in its report discussing the proposed SQO approach reveals that the staff has relied exclusively upon authors who advocate for co-occurrence-based approaches, to the exclusion of the vast technical literature that substantiates the technical unreliability of the approach. Notably absent is reference to the presentations at the 2002 Fifth International Conference on Sediment Quality Assessment, as well as countless papers in the literature that address why co-occurrence-based approaches should not be used in sediment quality evaluation. Such unbalance in a review, especially in advocacy of a technically unreliable position, is not serving the SWRCB or the public interest well.

The inclusion of chemical concentrations in the proposed SQO methodology in the manner advocated by the staff, is a contrivance to incorporate what the staff mistakenly calls "chemistry" into a triad approach for sediment quality evaluation. As discussed by Lee and Jones-Lee (2002, 2004) and Jones-Lee and Lee (2005) referenced above, aquatic sediment chemistry involves the evaluation of the chemical reactions – their kinetics and thermodynamics – that control whether a chemical exists in forms that affect aquatic life in a sediment. Jones-Lee and Lee (2007) recently discussed the assessment of sediment chemistry (chemical reactions that influence the impact of chemicals on aquatic life and other beneficial uses of waterbodies) in the modeling of water quality impacts of chemicals in stormwater runoff.

> Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff-Associated Pollutants," Report of G. Fred Lee & Associates, El Macero, CA, September (2007).
> http://www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf

Lee and Jones-Lee (2002, 2004) and Jones-Lee and Lee (2005) discussed how sediment chemistry can be reliably incorporated into sediment quality evaluation. This is done through a toxicity identification evaluation framework to determine whether and which chemicals present in a sediment are causing sediment toxicity (stressor identification). It is this type of evaluation that should serve as the "chemical" component of a triad approach for sediment quality evaluation.

The staff report indicates that the proposed SQO development approach is restricted to a limited number of classical potential pollutants that are considered in developing California Logistic Regression Model Calculations, and does not include the wide variety of other sediment-associated chemicals that can cause toxicity to aquatic life. The staff stated explicitly, as quoted above in bold typeface, that this SQO development approach does not consider the impact of low-DO or ammonia as causes of sediment toxicity. While not specifically mentioned by the staff, it also does not consider the impacts of hydrogen sulfide as a toxicant in sediments. As discussed by Lee and Jones-Lee (2007a,b,c) and as has been known for more than three decades, low DO, ammonia, and hydrogen sulfide are the most common causes of sediment toxicity. While those chemicals are well-known toxicants in aquatic systems, their full potential impact on aquatic resources is often not understood. If those issues are not addressed, it makes little sense to pursue contrivances to address chemicals that are of comparatively less significance to sediment quality. The failure of the SQO staff report to even discuss the significance of not including the potential toxicity associated with low-DO, ammonia, and hydrogen sulfide derived from aquatic sediments as part of the cause of sediment toxicity is a major, fundamental flaw with the proposed approach.

In an effort to address this issue, Lee and Jones-Lee published three newsletters that discussed various aspects of this issue, and developed the information into the following reports.

> Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part I – Origin of Rapid Sediment Oxygen Demand," Report of G. Fred Lee & Associates, El Macero, CA, May (2007a). http://www.members.aol.com/LFandWQ/NutrientSOD1RapidOD.pdf
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> Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part II – Sediment Oxygen Demand," Report of G. Fred Lee & Associates, El Macero, CA, June (2007b). http://www.members.aol.com/LFandWQ/NutrientSOD2SOD.pdf
>
> Lee, G. F., and Jones-Lee, A., "Role of Aquatic Plant Nutrients in Causing Sediment Oxygen Demand Part III – Sediment Toxicity," Report of G. Fred Lee & Associates, El Macero, CA, June (2007c). http://www.members.aol.com/LFandWQ/NutrientSOD3Tox.pdf

Those three reports discuss the potential role of aquatic plant nutrients (nitrogen and phosphorus compounds) derived from natural, as well as anthropogenic, sources in contributing to, or being the underlying cause of, aquatic sediment toxicity. Aquatic plant nutrients stimulate the growth of algae in a water column. The algae die, settle, and are decomposed in sediments. This anoxic environment leads to the sediments' containing significant concentrations of chemicals that exert an oxygen demand. Of particular importance are ferrous iron and sulfide species. Both of those chemical species, when stirred or suspended in a water column, can cause a very rapid depletion of DO that is well-documented to have caused fish kills.

By ignoring low-DO, ammonia, and hydrogen sulfide in the protocols for assessing the causes of adverse impacts on aquatic life in sediments, major adverse impacts on benthic organism assemblages could go unaddressed. Further, the public and other dischargers could find themselves chasing "ghosts" of alleged sediment quality problems and stressors so-identified based on technically unreliable and invalid approaches. Failure to address these issues in a technically valid manner can be expected to result in large amounts of public and private expenditures for sediment "remediation" and "source control" without alleviating the real sediment quality problems.

Other Chemicals of Concern

In addition to the staff's approach being significantly deficient in providing guidance on evaluating the role of chemicals in sediments in causing toxicity to benthic organisms due to low DO, ammonia, and hydrogen sulfide, there is a vast array of other chemicals that need to be considered in identifying the causes of sediment toxicity. One such group of chemicals is the pyrethroid-based pesticides. In the mid- to late 1990s, G. F. Lee and S. Taylor of RBF Consulting, Irvine, CA, conducted a comprehensive study of aquatic life toxicity in Upper Newport Bay (Orange County, California) on behalf of the Santa Ana Regional Water Quality Control Board. They sampled urban, highway, agricultural, and open-space stormwater runoff from 10 different subwatersheds in the Upper Newport Bay watershed. As discussed by Lee and Taylor (2001a,b,c) and as summarized in several Stormwater Runoff Water Quality Newsletters (www.gfredlee.com/newsindex.htm), they found that the stormwater runoff from all of the watersheds investigated was toxic to the standard test organism *Ceriodaphnia*. The toxicity was not due to heavy metals as had previously been hypothesized based on total concentrations, but rather was due to the organophosphate-based pesticides diazinon and chlorpyrifos. Through directed TIE investigations with the assistance of the University of California, Davis, Aquatic Toxicology Laboratory staff and Dr. Jeff Miller of AquaScience in Davis, CA, they tentatively identified part of this toxicity as being due to pyrethroid-based pesticides.

> 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 (2001a).
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> Lee, G. F. and Taylor, S., "Results of Heavy Metal Analysis Conducted During 2000 in the Upper Newport Bay Orange County, CA Watershed," Report of G. Fred Lee & Associates, El Macero, CA (2001b). http://www.members.aol.com/apple27298/Heavy-metals-319h.pdf
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> Lee, G. F. and Taylor, S., "Results of Aquatic Toxicity Testing Conducted During 1997-2000 within the Upper Newport Bay Orange County, CA Watershed," Report of G. Fred Lee & Associates, El Macero, CA (2001c). http://www.members.aol.com/apple27298/295-319-tox-paper.pdf

At the time of the studies a decade ago, the manufacturers of pyrethroid-based pesticides and the USEPA Office of Pesticide Programs believed that the pyrethroid-based pesticides were bound so tightly to soils that they would not be toxic to aquatic life. The pyrethroid-based pesticides were not on the list of chemicals of potential concern in water quality investigations even though more than 25,000 pounds (ai) of pyrethroid-based pesticides were being used in the Upper Newport Bay watershed each year. Now, some 10 years later, through studies such as those of Weston and his associates at the

University of California Berkeley, it is beginning to be realized that pyrethroid-based pesticides are a common cause of aquatic life toxicity in urban and some agricultural stormwater runoff. These issues have been discussed in several issues of Lee's Stormwater Newsletters including NL 8-1/2, 8-6, 9-3, 9-4, 9-6, 9-7, 9-8, 10-3, and 10-8. Those studies brought to light the fact that pyrethroid-based pesticides, which have been widely used in agriculture and more recently in urban areas, should be recognized as a cause of sediment toxicity by inclusion in the SWRCB staff's list of chemicals of concern.

The pyrethroid-based pesticides are just one type of unregulated or inadequately regulated chemical that can cause water quality impacts. As discussed in NL 7-3, 8-5, 9-3, and 10-7 under "unrecognized pollutants," of the millions of chemicals in commerce today only a very small number of chemicals of potential concern are regulated. These issues are discussed further in,

> Lee, G. F. and Jones-Lee, A., "Unrecognized Environmental Pollutants," In: Water Encyclopedia: Surface and Agricultural Water, Wiley, Hoboken, NJ, pp 371-373 (2005).
> http://www.members.aol.com/annejlee/WileyUnrecognizedPollutants.pdf

This situation highlights the need for water quality, and especially sediment quality, evaluations to be truly effects-based. The evaluations should not be distorted by incorporating the notoriously unreliable co-occurrence-based approaches as is now proposed by the SWRCB staff for developing SQOs.

Elevating Stature of Unreliable, Invalid Approaches

One of the insidious aspects of the use of the co-occurrence-based California Logistic Regression Model in the proposed SQO development is that this use, to some, gives the appearance credibility to a demonstrably invalid methodology for evaluating sediment quality. Although it has been known since the Long and Morgan co-occurrence approach was developed in the early 1990s that it was technically invalid for application in sediment quality guidelines, it has been widely used by federal and state regulatory agencies and others because it provides a mechanical, low-effort use for readily measurable total chemical concentrations, and existing data. Others then blindly cite prior use as justification for continued use without facing the reality that it is not reliable.

In the July 2006 Scientific Steering Committee meeting, Ed Long (one of the originators of the co-occurrence-based approach for sediment quality evaluation) stated,

> *"My lingering concern is that, based on my experience with the values that I published, that despite any large-font, bold-print warnings against doing so, people will tend to use your single chemical values in a regulatory framework. I was aghast to find after I retired from NOAA and got into the reality of working with industrial clients, that there are state and federal judges in this country that are using my values as regulatory values on a single chemical basis."*

"In the publication I put out in 1995 I stated it very clearly in bold, … and it was summarily ignored."

Despite such admonitions, some of the California Regional Water Boards and the SWRCB are using co-occurrence-based approaches to classify sediment quality and to designate impaired waterbodies, thereby ignoring the literature, basic principles of aquatic chemistry/toxicology, as well as Long's own recommendations of not using this approach in a regulatory program. For example, the SWRCB's 2006 Clean Water Act Section 305b report, "Water Quality Assessment of the Condition of California Coastal Waters and Wadeable Streams," October 2006 (available at, http://www.swrcb.ca.gov/swamp/docs/factsheets/305breport2006.pdf) states the following,

"Sediment Contamination

Sediment concentration measurements of approximately 80 contaminants, including 24 PAHs, 22 PCBs, 19 pesticides, and 15 metals were taken at each site. Homogenized samples were analyzed using standard wet chemistry and mass spectroscopy. Sediment condition related to contamination was rated moderate if five or more ERLs were exceeded and high if one or more ERMs were exceeded. Based on the literature evaluated, these values identify threshold concentrations that, if exceeded, are expected to produce ecological or biological effects. The sediment contaminant index for the West Coast excluded nickel and the PAH phenanthrene. Phenanthrene was excluded because values were not included from all West Coast sites. Nickel was excluded because the ERM value has a low reliability for West Coast conditions where high natural crustal concentrations of nickel exist (Long, MacDonald, Smith and Calder, 1995).

Seven percent of California's estuarine sediments had high sediment contamination. Moderate contamination (exceeding ERL guidance values for at least five contaminants) was observed in 57% of estuaries. Areas of California with the highest sediment contamination were in Southern California, particularly Los Angeles Harbor.

Sediment Toxicity

Sediment toxicity depends on the biological availability of contaminants in sediments. Sediment toxicity is determined by tests that expose organisms to sediments from each location and evaluate the effects on the organisms' survival. Sediment toxicity tests (10-day static tests) were conducted using the benthic amphipod Ampelisca abdita. Sediments were determined to be toxic if there was more than 20% mortality, corrected for controls. Less than 1% of estuarine sediments in California were found to be toxic (greater than 20% mortality). Toxic sediments were observed in the Dominguez Channel leading into Los Angeles Harbor, as well as in some of the northern California small river mouths. No sediments from San Francisco Bay were found to be toxic to Ampelisca, though sediment toxicity tests run with other species of test organisms indicated that some sediments from San Francisco Bay were toxic. Other test species, such *as Eohaustorius estaurius, may be more representative test species for California."*

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentration in marine and estuarine sediments. Environmental Management 19(1): 81-97.

It is disturbing and disheartening to find that the SWRCB staff used co-occurrence-based ERL and ERM values in 2006 to evaluate the quality of California's water and sediments. It was obvious even then that what should have been done was to base the sediment quality evaluation on toxicity information and not incorporate what were recognized to be technically invalid co-occurrence-based ERM and ERL values into the evaluation. In order for the State Board and Regional Board staffs to rectify this error, additional staff resources and expertise would be required to properly conduct the TIEs to determine the chemical(s) responsible for the sediment toxicity that should have been conducted long ago. Since this back tracking and reworking is unlikely, it is unlikely that the SWRCB and Regional Board staffs will stop using co-occurrence-based approaches to evaluate sediment quality. Thus, inappropriate and unreliable evaluations of sediment quality will continue in California, and remediation and source control programs misdirected toward perceived (but not confirmed) sediment quality problems.

Compliance with CEQA

The California Environmental Quality Act (CEQA) requires that full disclosure be provided as to the environmental consequences of a proposed action. The staff report does not meet the CEQA-equivalent requirement in that regard. It does not provide, for example, a reliable discussion of the consequences of ignoring low-DO, ammonia, hydrogen sulfide, and other toxicants, in sediment quality evaluation. As discussed by Lee and Jones-Lee (2007c), and above, ignoring those factors in the sediment quality objectives process could trap the public into very expensive sediment "remediation" and "source control," such as controlling urban stormwater runoff, directed to controlling chemicals identified by the invalid co-occurrence-based approach while not addressing the ultimate cause of sediment toxicity; thus the sediment would be expected to remain toxic after the "remediation." Sediment remediation could be similarly misdirected by not considering many other constituents such as pyrethroid-based and other pesticides. This issue should have been discussed in any credible CEQA-equivalent discussion of the SQO development approach.

Stressor Identification

The staff provided a section devoted to stressor identification in its report. That section is evidently part of the staff's guidance on SQO implementation; the stressor identification results are to be used to correct the errors associated with use of total concentration co-occurrence-based chemical information. While the staff report mentions that the co-occurrence-based approach (*California Logistic Regression Model Calculation)* should not be used to try to identify the cause of sediment toxicity or altered benthic organism assemblages, the staff's recommended approaches for identification of the stressor(s) states,

"F. Stressor Identification
If sediments fail to meet the narrative SQOs in accordance with Section V and VI, a sequential approach is necessary to manage the sediment appropriately. The sequential approach consists of development and implementation of a work plan to seek confirmation and characterization of pollutant-related impacts, pollutant identification and source identification. The workplan shall be submitted to the Regional Board for approval. Stressor identification consists of the following studies:
1. Confirmation and Characterization of Pollutant Related Impacts.
Exceedance of the direct effects SQO at a site indicates that pollutants in the sediment are the cause but does not identify the specific pollutant responsible. The MLOE assessment establishes linkage to sediment pollutants; however, the lack of confounding factors (e.g., physical disturbance, non-pollutant constituents) should be confirmed. There are two generic stressors that are not related to toxic pollutants that may cause the narrative to be exceeded:

2. Pollutant Identification
Methods to help determine cause may be statistical, biological, chemical or a combination. Pollutant identification studies should be structured to address site specific conditions, and may be based upon the following:
a. Statistical methods: Correlations between individual chemicals and biological endpoints (toxicity and benthic community)."

This statistical approach is not valid for identification of the pollutant responsible for a biological effect such as sediment toxicity and/or altered benthic organism assemblages compared to the assemblages that should be present based on habitat characteristics. It is another manifestation of the invalid co-occurrence-based approaches in that it contrives to relate total concentrations of a chemical(s) to a biological response. As with sediment concentration/impact co-occurrence, it has long been well-established that the total concentration of a chemical cannot be relied upon for inferring or predicting impacts. A variety of factors influence a chemical's availability to, and hence impact on, organisms.

The statistical approach described in the staff report assumes that the concentration of a bioavailable form of a chemical is constant in a sediment; i.e., that the detoxifying chemicals that cause part (and possibly all) of a chemical to be non-toxic occur at constant composition in all samples of the sediment. This is highly unlikely. This approach contradicts the basic principles of aquatic chemistry. (See the discussion of basic aquatic chemistry in Jones-Lee and Lee's (2007) discussion of modeling of chemicals as pollutants that impair water quality.)

Jones-Lee, A. and Lee, G. F., "Modeling Water Quality Impacts of Stormwater Runoff-Associated Pollutants," Report of G. Fred Lee & Associates, El Macero, CA, September (2007).
http://www.members.aol.com/GFLEnviroQual/StormwaterWQModeling.pdf

Several of the university graduate-level aquatic chemistry texts such as Stumm and Morgan (latest edition) discuss the issues that need to be considered in reviewing the aquatic chemistry of chemicals in aquatic systems that influence the species composition of a chemical and therefore the relationship between the total concentration and the toxic forms. Dr. G. F. Lee taught graduate-level aquatic chemistry courses for more than 30 years at several major US universities. He has conducted several million dollars in research which has been published in several hundred professional papers and reports devoted to aquatic chemistry water quality issues. Dr. Lee had approximately 100 graduate students conduct their MS theses and PhD dissertations under his supervision. He pioneered in developing approaches that reveal and demonstrate the importance of incorporating aquatic chemistry into water quality evaluations through considering the thermodynamics and kinetics of the reactions that influence the chemical species composition and therefore its impact on aquatic life. In the early 1980s he developed the "Aquatic Chemistry Wheel" which diagrammatically represents the types of reactions that should be considered in determining the role of a chemical(s) in a water quality/sediment quality evaluation. This is discussed in Jones-Lee and Lee (2007) referenced above, and in a recent Newsletter. Lee and Jones-Lee (2002, 2004) discussed how chemical information should be used in a best professional judgment (BPJ) triad weight-of-evidence approach for sediment quality evaluation.

The discussion of the unreliability of the statistical approach presented above is equally applicable to gradient analysis. The proposed SQO approach states,

> *"b. Gradient analysis. Comparisons are made between different samples taken at various distances from a chemical hotspot to examine patterns in chemical concentrations and biological responses. The concentrations of causative agents should decrease as biological effects decrease."*

"Biological responses" cannot be directly related to the total concentration of chemicals in sediment. Furthermore, the "co-occurrence" of a potentially toxic chemical and some impact cannot be presumed to be cause-and-effect related. Therefore, the "gradient analysis" approach is also unreliable for identification of a chemical that is responsible for sediment toxicity.

The staff report states,

> *"c. Additional Toxicity Identification Evaluation efforts: A toxicological method for determining the cause of impairments is the use of toxicity identification evaluations (TIE). Sediment samples are manipulated chemically or physically to remove classes of chemicals or render them biologically unavailable. Following the manipulations, biological tests are performed to determine if toxicity has been removed. TIEs should be conducted at limited number of stations, preferably those with strong biological or toxicological effects."*

Reliable identification of the chemical(s) and/or conditions responsible for toxicity to aquatic life in sediments is done through a properly conducted TIE. This is, therefore, the appropriate mechanism for incorporation of chemical information into a triad sediment quality evaluation approach. These issues are discussed in detail in Lee and Jones-Lee (2002, 2004).

In addressing the issue of bioavailability, the staff report states,

> *"d. Bioavailability*: Chemical pollutants may be present in the sediment but not biologically available to cause toxicity or degradation of the benthic community. There are several measures of bioavailability that can be made.*
> *Chemical and toxicological measurements can be made on pore water to determine the availability of sediment pollutants. Metal compounds may be naturally bound up in the sediment and rendered unavailable by the presence of sulfides. Measurement of acid volatile sulfides and simultaneously extracted metals analysis can be conducted to determine if sufficient sulfides are present to bind the observed metals. Similarly, organic compounds can be tightly bound to sediments. Solid phase microextraction (SPME) or laboratory desorption experiments can be used to identify which organics are available to animals."*

Detoxification reactions are not restricted to the formation of particulate forms of chemicals. This discussion of bioavailability is significantly deficient in considering the types of chemical reactions that can render a chemical non-toxic. Complexation reactions are often responsible for detoxification of potentially toxic chemicals; chemical complexes are often in the dissolved phase. Complexation reactions can take place in solution (e.g., in pore water) or on the surfaces of solids. In addition it is known that very fine particles, including colloidal forms, appear to be in solution but are non-toxic.

The proposed approach states with respect to verification of findings,

> *"e. Verification: After specific chemicals are identified as likely causes of impairment, analysis should be performed to verify the results. Sediments can be spiked with the suspected chemicals to verify that they are indeed toxic at the concentrations observed in the field. Alternately, animals can be transplanted to suspected sites for in situ toxicity and bioaccumulation testing."*

Again, this approach reflects a lack of understanding of aquatic chemistry/toxicity; those familiar with this topic know that spiking sediments cannot be relied upon for determining if a chemical in the sediments is the cause of observed sediment toxicity. Over time, the form of chemical binding with sediment changes, causing the chemical to be increasingly less available – less toxic. While the form of the chemical used to spike the sediment would be toxic, the chemical as it is present in the sediments may not be toxic. This phenomenon is well-known for pesticide residues; over time a portion of the pesticide becomes a bound residue that is not extractable and is non-toxic.

Also, transplanting organisms to measure bioavailability is not necessarily reliable to identify a toxic species in sediments. Non-toxic forms of some chemicals such as organic complexes can be taken up by organisms in sediments without causing toxicity to them, or to other organisms, in the sediment. Further, the partitioning between a sediment-bound chemical and organism tissue is significantly different from the partitioning between a sediment-bound chemical and water. This means that semi-bound chemicals can be absorbed into aquatic organism tissue without being toxic to aquatic organisms.

Overall, except for the appropriate use of TIEs, the recommended stressor identification presented in the staff report is flawed and can readily lead to incorrect assessments of the chemical(s) responsible for sediment quality impairment. Unreliable stressor identification can lead to large expenditures for misdirected and hence ineffective sediment "remediation" and source control.

The inadequate and unreliable incorporation of aquatic chemistry and aquatic toxicology into the SQO development and implementation approach seriously damages the credibility of the high-quality work that was done in developing SQOs based on biological effects (sediment toxicity and altered benthic organism assemblages).

Sediment Cleanup Objectives

The staff report contains a section providing guidance for establishing sediment cleanup objectives. The staff report states,

> *"G. Development of Site Specific Management Guidelines*
> *In those cases where development of site-specific management guidelines is appropriate (i.e. where toxic stressors have been identified and controllable sources of these stressors exist or remedial goals are desired), guideline development should be considered.*
>
> *Development of site-specific management guidelines is the process to estimate the level of the stressor pollutant that will meet the narrative sediment quality objective. The guideline could serve as the basis for cleanup goals or revision of effluent limits described in C. 4 above depending upon the situation or sources. Guideline development should only be initiated after the stressor has been identified. The goal is to establish a relationship between the organism's exposure and the biological effect. Although this relationship is not always easy identify, once this relationship is established a pollutant specific target may be designated that corresponds with minimum biological effects. The following approaches can be applied to establish these relationships:*
> *a. Correspondence with sediment chemistry. An effective target can best be derived based upon the site-specific, or reach- specific relationship between the stressor pollutant exposure and biological response. Therefore the correspondence between the bulk sediment stressor concentration and biological effects should be examined."*

Once again, this discussion reflects the mistaken equating of "sediment chemistry" and sediment chemical composition. Bulk sediment stressor concentration is not a reliable basis for establishing sediment cleanup objectives. Detailed, comprehensive studies of the concentrations of those chemicals reliably determined to be responsible for impairment of sediment quality are needed in order to establish the sediment cleanup objectives. As discussed previously, co-occurrence-based approaches do not establish the cause-and-effect relationship necessary for identifying problem areas and for developing sediment cleanup objectives.

The proposed approach states,

> *"b. Correspondence with bioavailable pollutant concentration. The concentration of the bioavailable fraction of the stressor pollutants is likely to show a less variable relationship to biological effects that bulk sediment chemistry. Interstitial water analysis, SPME, desorption experiments, selective extractions, or mechanistic models may indicate the bioavailable pollutant concentration. The correspondence between the bioavailable stressor concentration and biological effects should be examined."*

As discussed above, claims of analytically measuring "bioavailable forms" of a chemical are misleading at best; measurements as recommended would be unreliable for establishing stressor identification and are not a reliable basis for establishing sediment cleanup objectives.

The proposed approach states,

> *"c. Correspondence with tissue residue. The concentration of the stressor accumulated by a target organism may provide a measure of the stressor dose for some chemicals (e.g., those that are not rapidly metabolized). The tissue residue threshold concentration associated with unacceptable biological effects can be combined with a bioaccumulation factor or model to estimate the loading or sediment concentration guideline."*

There is often no relationship between the tissue residues in organisms and sediment toxicity. It is well-known that a variety of factors influence tissue residue bioaccumulation and sediment toxicity and that these factors act independent of one another. The guidance provided above is unreliable for establishing sediment cleanup objectives.

The proposed approach states,

> *"d. Literature review. If site-specific analyses are ambiguous or unable to determine a guideline then the results of similar development efforts for other areas should be reviewed. Scientific credible values from other studies can be combined with mechanistic or empirical models of bioavailability, toxic potency, and organism sensitivity to estimate targets for the area of interest."*

While those establishing sediment cleanup objectives should be familiar with the literature, especially the aquatic chemistry and sediment toxicology literature, work done at a particular site in establishing sediment cleanup objectives would rarely have applicability to another site. The statement, "*Scientific credible values from other studies can be combined with mechanistic or empirical models of bioavailability, toxic potency, and organism sensitivity to estimate targets for the area of interest,"* is nonsense and provides misdirection for developing sediment cleanup objectives. The SWRCB should ask members of the Regional Board staff what that statement means to them and how they would use it to develop sediment cleanup objectives.

Overall, as with other sections of the staff report that attempt to provide guidance for establishing sediment cleanup objectives involving chemical issues, this section is flawed and can readily provide unreliable information and thereby lead to unreliable cleanup objectives compared to those that should be used to remediate polluted sediments in a technically valid, cost-effective approach.

Establishing contaminated sediment cleanup objectives involves more than just SQO evaluation; it necessitates incorporation of engineering feasibility. These issues have been discussed in,

> Lee, G. F., "Issues in Establishing Contaminated Sediment Clean-Up Objectives," Proc. Sediment Remediation '95 International Conference, Wastewater Technology Centre, Burlington, Ontario, Canada, May (1995).

As indicated above, the SWRCB should instruct its staff to revise the proposed approach to focus the development of SQOs on biological effects – sediment toxicity and altered benthic organism assemblages. All references to the application of co-occurrence-based evaluations and use of total concentrations of chemicals in sediment for any evaluation purpose should be deleted. The SWRCB should see to it that individuals with high degrees of expertise in aquatic chemistry relative to water quality assessment become integral parts of the staff team responsible for formulating guidance on evaluation of sediment chemical stressor and sediment remediation objectives.

Application to Dredged Sediments

The staff report Appendix A, in section VII. PROGRAM OF IMPLEMENTATION, states,

> *"A. Dredge Materials*
>
> *1. This Plan shall not apply to Dredge material suitability determinations. Suitability determinations shall be based upon USACE and U.S. EPA methodologies developed for ocean, inland and upland disposal, and guidance developed by regional dredging teams and approved by the Regional Water Boards.*
> *2. The Regional Water Boards shall not approve a dredging project that involves the dredging of sediment that exceeds the objectives in this plan, unless the Regional Water Boards determine that:*
> *a. The polluted sediment is removed in a manner that prevents or minimizes water quality degradation.*
> *b. The polluted sediment is not deposited in a location that may cause significant adverse effects to aquatic life, fish, shellfish, or wildlife or may harm the beneficial uses of the receiving waters, or does not create maximum benefit to the people of the State.*

c. The activity will not cause significant adverse impacts upon a federal sanctuary, recreational area, or other waters of significant national importance."

In the mention of the USEPA/USACE open-water disposal of Dredged Material regulatory program in the staff report, key information was omitted. As discussed in the summary of Drs. G. F. Lee and Anne Jones-Lee's qualifications to undertake this review, in the 1970s they were highly involved in working with the USACE in conducting research to develop regulatory criteria governing open-water disposal of dredged sediments. That activity involved dredging shallow-water sediments and transporting them either by a hopper dredge (boat), clamshell dredge/barge, or pipeline to deeper waters for disposal. Open water disposal would be expected to provide the greatest potential for contaminants in the dredged sediments to cause adverse effects to aquatic life at a disposal site. Dr. Lee and his graduate students conducted more than a million dollars in laboratory and field research devoted to evaluating the water quality impacts of open-water disposal of highly contaminated dredged sediments. That work included laboratory studies of the chemical composition, leaching, and aquatic life toxicity of about 100 sediments from navigation channels across the US. It also included comprehensive field studies that were designed to investigate and compare results of laboratory studies with what actually happens under field conditions. The results of their studies were published in two USACE reports,

Jones, R. A. and Lee, G. F., "Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release during Open Water Disposal of Dredged Sediment and Environmental Impact of Open Water Dredged Material Disposal, Vol. I: Discussion," Tech Report D-78-45, US Army Engineer Waterway Experiment Station, Vicksburg, MS, August (1978).

Lee, G. F., Jones, R. A., Saleh, F. Y., Mariani, G. M., Homer, D. H., Butler, J. S. and Bandyopadhyay, P., "Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release during Open Water Disposal of Dredged Sediment and Environmental Impact of Open Water Dredged Materials Disposal, Vol. II: Data Report," Technical Report D-78-45, US Army Engineer Waterway Experiment Station, Vicksburg, MS, 1186 pp., August (1978).

Summaries of those studies were published as,

Lee, G. F. and Jones-Lee, A., "Water Quality Aspects of Dredging and Dredged Sediment Disposal," In: Handbook of Dredging Engineering, Second Edition, McGraw Hill, New York, NY, pp. 14-1 to 14-42 (2000).
http://www.gfredlee.com/dredging.html

Jones-Lee, A. and Lee, G. F., "Water Quality Aspects of Dredged Sediment Management," In: Water Encyclopedia: Water Quality and Resource Development, Wiley, Hoboken, NJ, pp 122-127 (2005).
http://www.members.aol.com/annejlee/WileyDredging.pdf

Those studies convincingly demonstrated that, as would be expected based on principles of aquatic chemistry, the total concentration of a chemical or group of chemicals in sediments is not a reliable predictor of the water quality impacts of the chemical(s) on aquatic life. They demonstrated the parameters and characteristics that needed to be considered and accounted for in assessing the potential leaching and impacts of sediment-associated contaminants. Based on the results of those and other studies, the USEPA and USACE developed a biological effects-based approach for regulating the open-water disposal of dredged sediments. That approach has been reviewed on several occasions since it was first adopted in the late 1970s. Each review has concluded that that approach is technically valid and that co-occurrence-based approaches (such as Long and Morgan, MacDonald, etc.) are not technically valid for evaluating the potential impacts of contaminants in sediments when either suspended in the water column during disposal or present in bedded sediments after disposal.

This experience has demonstrated that biological effects-based sediment quality evaluation can be used reliably in a regulatory program to manage highly contaminated sediments to protect aquatic life, public health, and environmental quality. A similar approach should be developed for SQO development and implementation in California.

Inadequate Consideration of Implementation

Fundamental to the development of technically valid regulations is that they be based on a scientifically sound foundation, and that a clear and reliable path for implementation be provided. Regulatory programs that are based on pseudoscience approaches such as that proposed to the SWRCB for SQO development, can only led to technically invalid assessments of the approach that should be followed to manage water quality problems (see discussion by Lee and Jones-Lee, 2002).

There are numerous examples of the problems caused by basing the initial phase of a regulatory program on technically invalid approaches. For example, the Los Angeles Regional Water Quality Control Board, with the concurrence of the SWRCB and the USEPA Region 9, adopted a $42-million Santa Monica Bay Restoration Program to control lead in urban stormwater runoff to the Bay because of the finding that the lead concentration in Bay sediment exceeded a co-occurrence-based so-called "sediment quality guideline." Lee and Jones-Lee (2004), and Lee (1998, 2005) pointed out that the Santa Monica Bay Restoration Plan corrective action program is based on a technically invalid approach, and that detailed studies should be conducted to determine if the lead that exceeds the co-occurrence-based guideline is, in fact, toxic or if it is inert as would be expected based on its aqueous environmental chemistry. The regulatory agencies at the regional, state, and federal levels all decided, without further study, that the lead must be toxic because it exceeded sediment quality guidelines. Studies conducted after the regulatory program was adopted, however, showed that the lead in the Santa Monica Bay sediments was, as expected based on its aquatic chemistry, not toxic. Nonetheless, even with that new site-specific information documenting the lack of toxicity of the lead that exceeded the co-occurrence-based guideline, the regulatory agencies have not changed the Bay's restoration program. The public in the Santa Monica Bay watershed are trapped into a technically invalid Bay "restoration" program to correct a "problem" that does not exist. Clearly the "implementation phase" does not correct for faulty SQOs.

Such misdirection of the limited resources available can be expected to continue if the SWRCB adopts the staff's recommended SQO development approach. Any identification of a water quality or sediment quality "problem," especially one based in any way on co-occurrence-based concentrations, should be followed by properly conducted, true chemistry and toxicity studies to reliably determine if a real water quality impairment such as toxicity exists, the cause of the impairment (not simply what "co-occurs" with measured concentrations) as well as the role of aquatic nutrient-caused sediment toxicity (such as episodic low-DO) in affecting the aquatic life resources of the waterbody. Based on past experience, the statements in the staff report regarding the need to do follow-up stressor identification studies can be expected to be ignored, as long as the regional boards continue to follow technically invalid approaches for developing and using sediment quality evaluation and remediation approaches.

Having unreliable scientific foundation for the SQOs can lead to endless controversy between regional boards' staff members and the regulated community over the chemical(s) responsible for the toxicity, etc. This can lead to the regional board staff members' becoming disillusioned with the attempts to regulate sediment quality using the approach currently recommended. Inappropriate regulatory approaches can ultimately result in the regulated community's having to take the issues to the court to find remedy from implementation of their unreliable results. Using the SWRCB database used to develop the SQOs, it can be demonstrated that the chemical concentration component of the SQO can be in error and mislead the identification of chemicals as causing impaired sediment quality.

One of the most vulnerable groups that will be subject to inappropriate application of the SWRCB staff's proposed SQO-based sediment quality evaluation is the urban stormwater runoff water quality managers and the public they represent. Urban stormwater runoff from streets and highways has long been known to contain a variety of particulate heavy metals and other chemicals that will accumulate in receiving water sediments. While it has been well-established that such metals are largely non-toxic and do not convert to toxic forms under most receiving water conditions, the total concentrations of the metals will likely continue to exceed co-occurrence-based sediment quality guidelines, including those proposed for the SQO development approach. (These issues have been extensively discussed in Stormwater Newsletters available on the Lee and Jones-Lee website.)

This situation illustrates the fallacy and misleading quality of the co-occurrence-based approach; while the heavy metals commonly considered in stormwater runoff are largely in non-toxic forms, the sediments in their receiving waters will likely exhibit toxicity due to chemicals (such as pesticides, ammonia, etc.) that are not included in the SWRCB staff's list of chemicals that they propose to consider in evaluating sediment toxicity. Further, the aquatic organism assemblages in areas where the runoff-derived heavy metals and other particulate potential pollutants settle can be found to be altered due to physical disturbance of the sediments that causes rapid-acting oxygen-demanding substances (derived from processes influenced by nutrient inputs) to kill the normal benthic organism assemblages. Under the proposed, technically invalid approach for incorporating chemical concentration information in sediment quality evaluation, the sediments impacted by urban stormwater runoff would be classified, albeit incorrectly, as highly impacted by heavy metals. While the staff proposed that such errors in sediment classification could be corrected though the use of one or more of the proposed approaches for stressor identification, such as statistical correlation, as discussed above, those approaches would not likely correctly evaluate that situation or correct the misdiagnosis.

Overall the staff's proposed approach for SQO development can trap the public and private entities into spending large amounts of money only to find they are chasing phantom sediment quality "problems." Members of the Scientific Advisory Panel repeatedly stated that the total chemical concentration co-occurrence-based SQOs should not be used in a regulatory program. Yet clearly the co-occurrence-based SQO is a key component of the proposed sediment quality evaluation approach and, therefore, likely a component of the regulatory program that will evolve from the staff's proposed approach for sediment quality evaluation.

One of key implementation issues is the need to incorporate a reliable TIE procedure to identify the cause of true sediment toxicity. As discussed by Jones-Lee and Lee (2007), while there may be no "cookbook" TIEs that can be reliably used by those with limited understanding and experience in the aquatic chemistry of sediments as it relates to sediment toxicity, it is possible for those with this knowledge to conduct TIEs to potentially identify causes of sediment toxicity. This situation points to the need to focus the initial sediment quality evaluation on biological effects (toxicity and benthic organism assemblages) without trying to force-fit total chemical concentration information into the evaluation.

Repeatedly during the course of SQO development, G. F. Lee and others urged the SWRCB staff to fully develop the implementation approach for the use of the SQO-based sediment quality evaluation. Without development and reliable evaluation of the implementation approach, the full significance of the fundamental technical deficiencies with the staff's recommended approach cannot be appreciated.

In order to understand the implementation problems with the staff's proposed SQO develop approach, G. F. Lee suggested to staff members that they needed to develop several example situations, and step through the implementation approach through to making decisions on the need for sediment remediation/source control. While the staff did not conduct this type of evaluation, it would be prudent for the SWRCB to require that this type of exercise be conducted. The SWRCB should not adopt the staff's proposed SQO development approach until a detailed, technically valid, implementation approach has been developed and demonstrated. Involving the regional board staff that will have to try to implement this approach is key to evaluating the implementability of the proposed SQO-based sediment quality evaluation.

Comments on SWRCB November SQO Hearing

On November 19, 2007 the SWRCB held a public hearing devoted to review of the SWRCB staff's proposed SQO development approach. Various interested parties were given the opportunity to make five-minute presentations to summarize their views on the proposed SQOs. Several representatives of environmental groups expressed a number of concerns about the deficiencies in the proposed approach, including the fact that the proposed approach did not include public health impacts of sediment-associated chemicals that accumulate in the food web to cause excessive concentrations of hazardous chemicals in edible fish. This is a particularly significant deficiency since excessive bioaccumulation of hazardous chemicals in edible organisms is one of the greatest concerns for managing chemicals in aquatic sediments.

Several representing "dischargers" indicated overall support for the SWRCB staff's "multiple lines of evidence" approach. That support, however, should not be interpreted to indicate that they support the chemical component of the proposed approach. Rather, it is an acknowledgement that including toxicity and altered benthic organism assemblages is an important improvement over the co-occurrence-based approach currently being used by the State and Regional water boards to evaluate sediment quality. There was general agreement that the proposed SQO development approach is deficient for not including detailed information on implementation of the SQO development approach into a regulatory program. Without such information it is not possible to adequately evaluate the SQO development approach.

Dr. Gary Wolff, hearing chairperson and vice-chair of the SWRCB, asked Shelia Vassey of the SWRCB Office of Chief Counsel responsible for working with SWRCB staff in SQO development, whether information on implementation of the SQO into a regulatory program was a necessary component of the SQO development. Attorney Vassey confirmed that information on implementation of the SQO into a regulatory program is required. This means that the current SQO staff report should be considered to be a "work in progress" and should not be adopted by the SWRCB without detailed, properly reviewed, information on how the SQOs will be used in a regulatory program. This, coupled with the fact that the staff's proposed implementation section on Stressor Identification and Sediment Cleanup Objective is largely technically invalid, makes the current SQOs inadequate for adoption by the SWRCB.

During questioning of the staff, Dr. Wolff requested that information that the staff had provided to SWRCB members on how well the use of a single line of evidence, such as the chemical component, predicted the results of the SQOs developed based on all three lines of evidence, be presented to the hearing audience. Dr Wolfe stated that the chemical line of evidence was not necessarily reliable for predicting the results of the all three lines of evidence. This is to be expected owing to the unreliability of using a total concentration co-occurrence-based approach for including chemical information in the SQO development. It is somewhat circular to try to evaluate the proposed SQO development using two components that contain chemical concentration-based components that are known to be unreliable. What should be done to evaluate the reliability of the proposed SQO development approach is compare the outcome of a total concentration co-occurrence-based approach with that of a properly developed sediment quality evaluation using the biological effects-based components of toxicity and benthic organism assemblage information that include a properly evaluated chemical component based on TIEs that show the chemical(s) responsible for toxicity and altered benthic organism assemblages.

These comments on the deficiencies in the SWRCB staff's proposed SQO development approach include reference and links to Newsletters and Lee and Jones-Lee reports that are on the Internet, and discuss topics and issues that should be considered in developing technically valid sediment quality evaluations that can be reliably used in a regulatory program. The information, concerns, and admonitions presented in these comments regarding the proposed SQO development approach are not new; they have been brought to the attention of SWRCB and many of its staff, and have been incorporated into papers and Newsletters for several years.

Additional References

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