FINAL REPORT
Mercury Total Maximum Daily Load Implementation Plan Framework for Wetlands San Francisco Bay Estuary, California

October 13, 2003
001-09084-00

Prepared for
Applied Marine Sciences, Inc.
On behalf of
San Francisco Bay Clean Estuary Partnership

LFR
LEVINE • FRICKE

October 13, 2003

001-09084-00

Dr. Khalil E. Abu-Saba
Senior Aquatic Chemist
Applied Marine Sciences, Inc.
117 Fern Street, Suite 150
Santa Cruz, California 95060

Subject: Final Report: Mercury Total Maximum Daily Load Implementation Plan Framework for Wetlands, San Francisco Bay Estuary, California

Dear Khalil:

Per our discussion on October 9, 2003, attached with this letter are ten copies of the "Final Report: Mercury Total Maximum Daily Load Implementation Plan Framework for Wetlands, San Francisco Bay Estuary, California."

Thank you for inviting LFR to assist the Clean Estuary Partnership in addressing mercury issues in the Bay.

Please call me at 510-596-9588 if you have any questions.

Sincerely,

Phillip A. Lebednik, Ph.D.
Principal Scientist

Enclosure

CONTENTS

TABLE

FIGURE

1.0 INTRODUCTION

A total maximum daily load (TMDL) report for mercury in the San Francisco Bay Estuary ecosystem (“the Estuary”) was prepared by the California Regional Water Quality Control Board San Francisco Bay Region (RWQCB) and submitted to the United States Environmental Protection Agency (U.S. EPA) in 2000 (Abu-Saba and Tang 2000). A source assessment and mercury TMDL strategy recently have been prepared (Abu-Saba 2001, Abu-Saba 2002, Mumley and Abu-Saba [in press]). The next step in the TMDL process is to develop an Implementation Plan (“the Plan”) for control (load reduction) of mercury in the Estuary. Because of its physical and biological complexities and uncertainties regarding pathways of mercury within the Estuary, RWQCB has determined that the first step in developing the Plan should be to obtain additional information. This report presents an approach for developing a framework to identify data that will be useful for developing the Plan for one habitat of the Estuary ecosystem: tidally influenced wetlands (“tidal wetlands” or “wetlands”).

2.0 SCOPE AND PURPOSE

The geographical extent of Estuary wetlands, for the purposes of this report, includes all tidal wetlands associated with San Francisco Bay (“the Bay”) waters from the Golden Gate east to the Antioch Bridge. Within this area, tidal wetlands encompass a variety of habitat types, ranging from salt marshes of the Bay shoreline to estuarine marshes in the lower Sacramento/San Joaquin River Delta (“the Delta”) and Bay tributaries. Tidal wetlands are defined to include all physical and biotic elements within the geographical boundaries of the wetlands, as well as biota that utilize the wetlands for feeding and other activities but that may not reside within the wetlands at all times.

For the purposes of this report, “mercury transport” (transport) is defined to mean transport of mercury into, out of, and within (e.g., between the compartments of) the Estuary. “Mercury cycling” is defined to mean alterations in the chemical form of mercury in the environment. “Mercury loading” and associated terms refer to the movement of mercury that proximally results in an exceedance of a water quality standard or objective. “Mass loading of mercury” (mass loading) refers to the net transport of all forms of mercury into the Estuary. Although mercury loading occurs as a result of transport, not all transport in the Bay may contribute to mercury loading. Those transport pathways that contribute directly and substantially to mercury loading are referred to in this report as “links” or “linkages.” These linkages must be identified and quantified to understand the mechanism(s) of mercury loading in the Estuary. Focusing load reduction actions on the linkages will enable the Plan to efficiently accomplish its objectives.

Tidal wetlands (i.e., those wetlands that have a direct ebb and flood connection to the Bay) are involved in mercury transport and cycling in the Estuary. Of particular importance, tidal wetlands may contribute substantially to cycling of methyl mercury within the Estuary. Methyl mercury is currently considered to be the primary chemical form of mercury in the environment that is taken up (bioaccumulated and sometimes biomagnified) by aquatic and associated biota. Accordingly, this report places special emphasis on methyl mercury processes in wetlands.

To accomplish the purpose of the Plan, this framework will identify sources of information that will assist in determining:

- the current mercury and mass loading to the system
- the allowable loads based on understanding of loading linkages
- the means by which mercury loads could be reduced

This report focuses on existing regulatory programs and requirements and how those requirements may be employed to obtain information pertinent to Plan development. Key sources of information are wetland creation, restoration and management activities associated with dredged sediment beneficial re-use. This report addresses the following five topics:

- summary of regulatory oversight of dredging and beneficial sediment reuse
- summary of existing and proposed wetland restoration projects
- identification of uncertainties
- identification of activities to reduce uncertainties
- integration and coordination of monitoring data

3.0 SUMMARY OF REGULATORY OVERSIGHT OF DREDGING AND BENEFICIAL SEDIMENT REUSE

Regulatory oversight of beneficial reuse associated with dredging in San Francisco Bay is provided in the LTMS Management Plan (U.S. Army Corps of Engineering [USACE] et al. 2001). Based on that plan, this section summarizes the regulatory oversight (e.g. permits and processes) conducted by a variety of agencies.

3.1 Regional Water Quality Control Board, San Francisco Bay Region

RWQCB generally is responsible for oversight of surface water hydrology, surface water quality, groundwater hydrology, groundwater quality, sediment quality, sediment placement, sediment elevation control, channel morphology, and associated biological resources (RWQCB 1999).

The above areas of oversight include a large number of specific monitoring requirements currently in place for large-scale beneficial re-use projects (LFR 2000).

These requirements are too numerous to list completely in this report. The following specific requirements are potentially most relevant to mercury TMDL monitoring:

1) cover sediments:

- physical characteristics (including grain size)
- chemical characteristics
- placement
- final elevation
- movement (wind driven)
- channel formation
- erosion control

2) water quality:

- make-up water pond
- shallow groundwater
- surface water in placement cells
- point discharges

3) biological:

- contaminant bioaccumulation (wetland plants, submerged macrophytes, invertebrates)
- shorebird and waterfowl habitat monitoring
- native plant population establishment
- sensitive species monitoring
- fish screens
- sensitive species habitat development (including channels)

3.2 San Francisco Bay Conservation and Development Commission (BCDC)

BCDC has extensive regulatory oversight of Bay shoreline development that occurs within 100 feet inland of the high tide line under authority of the McAteer-Petris Act, which primarily is concerned with minimizing Bay fill and facilitating public access. BCDC generally is responsible for oversight of geotechnical engineering, surface water hydrology, groundwater hydrology, sediment quality, sediment placement, sediment elevation control, channel morphology, associated biological resources, visual resources, and public access.

3.3 U.S. Army Corps of Engineers

USACE generally is responsible for oversight of geotechnical engineering, surface water hydrology, surface water quality, groundwater hydrology, sediment placement, sediment elevation control, channel morphology, associated biological resources, and cultural resources.

3.4 State Lands Commission (SLC)

SLC is responsible for managing the State's tidelands and submerged lands based on the historical entitlement of the State of California to sovereign lands when statehood was enacted by Congress. Tidelands extend up to the current or historical high water mark. SLC oversight typically manages resources and placement of structures. Generally, SLC issues lease agreements and permits for structures placed and other activities affecting lands under its jurisdiction.

3.5 California Department of Fish and Game (DFG)

DFG has oversight of streambeds and other biological resources and habitats under state law. DFG typically works closely with RWQCB in oversight of aquatic habitats (including tidal wetlands).

DFG is also a designated state Natural Resource Trustee.

3.6 U.S. Fish and Wildlife Service (FWS)

FWS has oversight for non-marine/anadramous federal threatened or endangered species (T&E species) and their habitats. Governmental actions are subject to review by FWS. FWS provides biological consultation with the involved federal agency and, if needed, may issue "take" permits for activities that could involve take of T&E species.

It is important to note that FWS would potentially review any proposals for TMDL implementation that could affect T&E species or their habitats. Most or all Bay wetlands may be considered habitat for one or more T&E species. FWS is also a designated federal Natural Resource Trustee.

3.7 National Marine Fisheries Service (NMFS)

NMFS has oversight for marine/anadramous federal T&E species and their habitats. Governmental actions are subject to review by NMFS. NMFS provides biological consultation with involved federal agency and if needed, may issue "take" permits for activities that could involve take of T&E species.

It is important to note that NMFS would potentially review any proposals for TMDL implementation that could affect T&E species or their habitats. Most or all Bay wetlands may be considered potential habitat for one or more T&E species. NMFS/National Oceanographic and Aeronautics Administration is also a designated federal Natural Resource Trustee.

3.8 Delta Levee Flood Control Program, Department of Water Resources (DLFCP-DWR)

DLFCP-DWR has review oversight for projects with potential for impacting state Water Project facilities.

3.9 State Reclamation Board

The State Reclamation Board has review oversight for projects with potential for restricting flows, altering flood stage, etc.

3.10 Local Reclamation Districts

Local Reclamation Districts have review oversight for projects involving levee and flood control.

3.11 Local Mosquito Abatement/Vector Control Districts

Local Mosquito Abatement/Vector Control Districts have oversight for projects that involve vector habitats, including tidal wetlands in the Bay. The districts generally review projects affecting surface water flow and standing water.

4.0 SUMMARY OF EXISTING AND PROPOSED WETLAND RESTORATION PROJECTS

A comprehensive listing and maps of potential restoration projects in Suisun, North, Central and South Bays was compiled by the Goals Project (2000, pp. A-75 to A-84). USACE et al. (2001) and NMFS (2002) includes a listing of major beneficial re-use projects in the Bay. San Francisco Bay Joint Venture (2002) has also compiled a list of habitat acquisition, restoration, and enhancement projects in the Bay. An updated map of wetland restoration and enhancement projects in the North Bay was prepared by Siegel (2001). These and other sources could be used to categorize wetland projects in the Bay suitable for involvement in the mercury TMDL process. The following key parameters should be used in categorizing the projects:

- tidal wetlands type (exclude non-tidal wetlands)
- area of tidal wetlands
- beneficial re-use project

- spatial relationship to mercury exceedances
- habitat use by mercury impaired biota
- RWQCB permit oversight
- project activity status (completed, current, future)

The results of this tabulation would enable the RWQCB to focus on those projects that could most effectively contribute to development of the Plan.

5.0 IDENTIFICATION OF UNCERTAINTIES

Factors affecting mercury contamination in Bay wetlands are complex and not completely understood. Data pertaining to the distribution of mercury and particularly methyl mercury in wetlands are limited. The factors affecting methylation of mercury and its movement into the wetland food web are not completely defined with a high degree of certainty. Thus, with the current state of knowledge, there are substantial uncertainties associated with development of an Implementation Plan for mercury in Bay wetlands. Without resolution of critical uncertainties, it is possible that some or all implementation actions designed for wetlands may not achieve their desired objectives. However, resolution of all uncertainties prior to initiating the formulation of a Plan is not feasible given the regulatory schedule. Furthermore, not all uncertainties may need to be resolved to develop an effective plan. A viable approach to proceeding with development of the Plan is to use an adaptive management approach. In this report, "adaptive management" is taken to mean the interactive resolution of uncertainties in parallel with development of implementation actions, as mediated by a conceptual model.

Figure 1 presents a highly simplified hypothetical example of how adaptive management could be applied to the Plan process for wetlands. The framework includes three major elements:

- uncertainty reduction options
- mercury processes and pathway to biota (conceptual model)
- implementation options

Figure 1 is intended to represent a dynamic assessment and development process (i.e., adaptive management) whereby refinement of the three elements proceeds in parallel; therefore, the details in the framework will change as new information is incorporated. The controlling element, mercury processes and pathway to biota, is presented in the middle column. The process element is a highly condensed classical conceptual model for mercury in the wetland system. The model, as employed in the framework, may be expanded or contracted as a result of new information, uncertainty resolution and/or implementation option selection. For example, "methylation-facilitating conditions" incorporates a number of parameters that could be depicted in greater detail. The framework could also be applied simultaneously at different levels of conceptual model detail (i.e., by creating "layers" with different degrees of detail). Each model item (process or compartment) is depicted on its own vertical segment in the figure (defined by horizontal dashed lines). By horizontal scanning, the reader will see the uncertainty reduction and implementation options identified with each model item. In the left hand column, key uncertainties are identified as potential options for uncertainty reduction. For example, "determine active thresholds" refers to a determination of the level of the parameter in the environment below which mercury methylation is substantially reduced. Once a threshold becomes established, it and its uncertainty value would replace the text. In the right hand column, implementation options are identified. For example, "maintain conditions below thresholds" means that a plan could be developed to maintain wetland conditions below the value provided for the parameter in the left column. Once the technical information has been incorporated into the framework, a decision-maker can evaluate the effectiveness of maintaining conditions below thresholds by examining the numerical uncertainty values. Ranking of all implementation options can provide a basis for development of the Plan for wetlands. The end result will be to identify the linkages for mercury exceedances in Bay wetlands.

A key feature of this framework is that the potential implementation options are an integral part of the assessment process. Change (or change in emphasis or an addition) of one item will directly affect related items in other elements as dictated by the relationships established in the mercury processes element.

The conceptual framework has the benefit of directly associating implementation actions with scientific information and its associated uncertainties as well as providing documentation of the basis for any endpoint (decision) reached by the process. Therefore, the complete rationale for actions eventually adopted in the Plan would be available for examination and easily visualized at any time. Furthermore, the process would provide an objective basis for development of implementation actions. Development and application of the framework should incorporate stakeholder input to ensure that the process addresses feasible implementation actions.

Figure 1 presents a two-dimensional image; however, the system that the conceptual model is intended to represent is multi-dimensional. Among the other dimensions of the system that may be most important in mercury cycling and related implementation actions in Bay wetlands are the following:

- time
- geographical space
- vertical space
- habitat

Each of these dimensions should be incorporated into the framework elements as appropriate. Time is an important dimension because estuaries are not in a steady-state condition, although certain wetland biotic elements may exhibit little detectable population change over many years. Time elements fall into two major categories: predictable and unpredictable events. Predictable events include, for example, daily, lunar month, and six-month tide cycles (daily high and low, neap/spring, and solstitial/equinoctial tide cycles, respectively). Unpredictable (episodic) events include, for example, tidal forcing (barometric pressure and storm surge), annual precipitation and related runoff, inter-annual variation in precipitation, Delta runoff and sea level changes. These factors may affect not only the instantaneous mass loading and/or cycling of mercury in wetlands, but also other parameters (e.g., salinity and redox potential) related to methylation of mercury. Of particular importance may be the unpredictable coincidence of extreme events (e.g., extreme tide range and high precipitation or low local precipitation and low Delta outflow) that trigger processes leading to substantial alteration of loading and/or cycling of mercury in wetlands. These events affect not only the model, but also provide opportunities for potential implementation actions (e.g., episodic event load management).

Geographical space is an important dimension primarily because of transport pathways and feasible implementation options. The importance of this dimension on a large scale was recognized in the proposal to compartmentalize the Bay into different segments (Abu-Saba and Tang 2000).

Vertical space may be important on a very small scale, especially as it relates to methylation and bioaccumulation processes in wetlands. In contrast to the geographical dimension, which is measured in miles or kilometers, vertical dimension is important on a scale of inches or centimeters. Of particular importance is refinement of the specific sediment horizons within which methylation is facilitated and further understanding of the exposure points (i.e., physical locations) associated with bioaccumulation (e.g., top 3 feet of sediment, oxic/anoxic layers, sediment/water interface).

Habitats are closely related to the geographical dimension; however, habitats are defined by physical/biological attributes. Understanding of variations in methylation and loading/cycling in different wetland habitats is important in developing implementation options (e.g., effectiveness, exposure of sensitive species).

Incorporation of the above dimensions into the framework elements will enable an evaluation of their importance in identifying uncertainties and implementation options.

6.0 IDENTIFICATION OF ACTIVITIES TO REDUCE UNCERTAINTIES

Depending on the nature of a specific uncertainty, a range of reduction activities is available. Uncertainty reduction activities could include (in approximate ascending order of level of effort):

- tabulation of existing monitoring data

- review of published literature
- evaluation/analyses of existing technical information
- collection and evaluation of monitoring data
- performance of detailed research projects

The reduction process could directly select an activity or could proceed in a phased manner where the possibility exists that a high level of effort may be needed to address the uncertainty (i.e., evaluate the results of an initial low-level effort before deciding to conduct a more extensive effort).

To obtain the greatest benefit and efficiency, uncertainty reduction activities will be determined by utilizing the conceptual framework. Examples of the suggested process are presented in Table 1. Once the conceptual framework has been developed, implementation options are ranked according to potential feasibility. Next, an evaluation can be made by ranking the uncertainties based on the greatest potential for effective implementation. The level of effort to be expended in any uncertainty reduction activity would be determined by the ranking scores. Table 1 also includes hypothetical results to assist in visualizing the potential outcome of the process.

There are several potential sources of funding for uncertainty reduction and framework evaluations. Funding may be obtained directly by RWQCB or by other organizations that could conduct work on behalf of the RWQCB. Other organizations could include private companies (e.g., permit applicants or holders); local, state or joint-power agencies; federal agencies; and NGOs (e.g., non-profits, stakeholder groups). Potential mechanisms for funding or otherwise obtaining results include:

- National Pollutant Discharge Elimination System (NPDES) permit fees
- NPDES permit conditions
- WDR permit fees
- WDR permit conditions
- storm-water permit fees
- storm-water permit conditions
- 401 permit fees
- 401 permit conditions
- U.S. EPA Region 9 State-Tribal-Local Governments Wetland Program Grants

The above should be considered as an initial list. Additional sources of funding may be available through private, local, state and federal mechanisms.

7.0 INTEGRATION AND COORDINATION OF MONITORING DATA

A wide variety of data may be obtained from numerous sources and evaluated in developing the Plan for Bay wetlands. Because the data and resulting conclusions will be used to make decisions regarding implementation actions, they should have a high level of scientific integrity, data quality and documentation. The following elements are recommended for obtaining and processing relevant data:

- identify needs using the conceptual framework
- develop generic sampling and analysis plan(s)
- develop a quality assurance plan
- develop a data management plan

Data to be obtained for the Plan should be identified through the conceptual framework to ensure relevance to the overall objectives and efficient use of available resources. Additionally, consideration should be given to how the data collection process for mercury may be efficiently coordinated with the data collection needs of other TMDLs (e.g., polychlorinated biphenyls [PCBs]). For example, sediment collection efforts for PCB analysis may require only a minor additional effort if collected simultaneously with sediment samples obtained for mercury analysis. However, the other TMDL processes need to be sufficiently developed to provide confidence that the resulting samples will produce useful data. One or more sampling and analysis plans (SAPs) should be developed to ensure that all appropriate information is obtained. For example, if sediment methyl mercury measurements are to be made, related data should also be collected (e.g., salinity, redox potential). The SAP(s) should be generic (i.e., one plan should be developed for similar data collection activities). Requirements in the SAP(s) should be tiered based on the size of the project that is being monitored. Data collection activities should also be controlled by a Quality Assurance Plan (e.g., QAPP). Such a plan will establish quality requirements suitable for the objectives of the evaluations and will also establish documentation requirements. Collection, transmittal and management of data should be accomplished in accordance with a Data Management Plan. The data management plan will specify data formats, digital formats, transmission protocols, database platform, etc. The plan should also incorporate consideration of data tabulation, analysis, and graphical display outputs. The three plans identified in this section may be developed in the form of guidance for wetland project planners, thus providing consistent monitoring data. Production of consistent data would most effectively contribute to development of the mercury Implementation Plan. Because these plans would be based on the conceptual framework, they may be modified as adaptive management generates changes to the framework.

The Bay Protection and Toxic Cleanup Program (BPTCP) provides a potential example for development of the plans described above (Hunt et al. 1998, Stephenson et al. 1994). This program involved Bay-wide data collection for many toxic chemicals, including mercury. The highly qualified scientific team included several state agencies as well as university scientists. Although BPTCP objectives differ from TMDL objectives and new information and technology are available, the plans developed by that program may serve as a useful starting point for development of the mercury TMDL monitoring plans.

The funding sources for this activity would be similar to those identified in the previous section.

8.0 RECOMMENDATIONS

As described briefly in this report, there is sufficient information available to indicate that tidal wetlands associated with San Francisco Bay contribute substantially to mercury loading. Of particular importance is the likelihood that such wetlands play a key role in the impairment of indigenous biota by facilitating mercury methylation. Therefore, substantial reduction of mercury bioaccumulation in biota may be achieved by instituting load reduction actions in wetlands.

There is little information available for Bay wetlands that would assist in establishing implementation options for reducing mercury loading. Consequently, any implementation options that might be developed based on existing information would have a high degree of uncertainty of success. To reduce this uncertainty to an acceptable level, additional information on Bay wetlands is needed for the following topics:

- confirmation of the primary mercury methylation pathway(s)
- identification of the physical locations of the methylation process
- identification of the key parameters affecting methylation
- quantification of the effects of the key parameters
- development of a conceptual model describing the distribution of key parameters in wetlands
- determination of “natural” events/actions in wetlands that affect key parameters
- identification of design/engineering/restoration/management elements that affect the key parameters
- pilot testing of design/engineering/restoration/management elements
- development of proposed design/engineering/restoration/management implementation options
- development of monitoring requirements following implementation

It is recommended that RWQCB adopt an adaptive management action plan for wetlands (AMAP/WET) as the initial step in the implementation plan for load reduction of mercury in wetlands. The objective of the AMAP/WET would be to reduce uncertainties to a level that would enable development of appropriate implementation actions. The methodology would include the conceptual model approach discussed in this report applied to the major information gap topics listed above. The results of technical studies would include a series of potential implementation actions that address design, engineering, restoration, management and monitoring of wetlands to achieve mercury load reduction. It is recommended that these steps be accomplished via a technical study project. The final step in the AMAP/WET would be to incorporate the results of the study project into appropriate regulatory vehicle(s) (i.e., the Basin Plan) to obtain the desired load reduction.

9.0 REFERENCES

Abu-Saba, K. E. 2001. The View from Downstream: the Past, Present and Future of Mercury in San Francisco Bay. p. 15. in: Anon., San Francisco Estuary: Achievements, Trends and the Future. 5th Biennial State of the Estuary Conference. Palace of Fine Arts, San Francisco, October 9-11, 2001. Abstract.

———. 2002. Mercury Source Assessment for San Francisco Bay. 35 pp. Draft. Applied Marine Sciences, Inc. August 19.

Abu-Saba, K. E., and L. W. Tang. 2000. Watershed Management of Mercury in the San Francisco Bay Estuary: Total Maximum Daily Load Report to U.S. EPA. 154 pp. June 30.

Bay Conservation and Development Commission (BCDC). 1994. Applying for a Project Approval from BCDC. 11 pp. San Francisco Bay Conservation and Development Commission, San Francisco, California. September.

California Regional Water Quality Control Board, San Francisco Bay Region (RWQCB). 1999. Order 99-030. Reissuance of Waste Discharge Requirements for: U.S. Army Corps of Engineers, San Francisco District Three Year Dredging Cycle, 1999 through 2001 Maintenance Dredging. May 25.

Goals Project. 1999 (First Reprint June 2000). Baylands Ecosystem Habitat Goals. A Report of Habitat Recommendations Prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project. San Francisco and Oakland, California. U.S. EPA/RWQCB.

Hunt, J. W. , B. S. Anderson, B. M. Phillips, J. Newman, R. S. Tjeerdema, K. M. Taberski, C. J. Wilson, M. Stephenson, H. M. Puckett, R. Fairey, and J. Oakden. 1998. Sediment Quality and Biological Effects in San Francisco Bay. Bay Protection and Toxic Cleanup Program. Sacramento, California. Calif. State Water Res. Cont. Bd. Final Technical Report. August.

LFR. 2000. Mitigation, Monitoring and Reporting Plan, Montezuma Wetlands Project, Solano County, California. June 20.

Mumley, T. E., and K. E. Abu-Saba. The View from Downstream: a TMDL Strategy to Attain Water Quality Standards for Mercury in San Francisco Bay. 23 pp. Paper accepted for publication by Water Environment Federation, based on a presentation at the National Conference on TMDLs, Phoenix, Arizona, November 2001.

National Marine Fisheries Service (NMFS). 2002. San Francisco Bay Environmental Work Windows for Dredging and Disposal. Interactive website. http://swr.ucsd.edu/overview/overview.htm. Accessed September 3, 2002.

San Francisco Bay Joint Venture. 2002. Habitat Acquisition, Restoration, and Enhancement Projects. Interactive website. http://www.sfbayjv.org/. Accessed September 3, 2002.

Siegel, S. W. 2001. Inventory and Status of North Bay Wetland Restoration Projects. p. 25. in: Anon., San Francisco Estuary: achievements, Trends and the Future. 5th Biennial State of the Estuary Conference. Palace of Fine Arts, San Francisco, October 9-11, 2001. Abstract. Display included large format map.

Stephenson, M., M. Puckett, N. Morgan, and M. Reid. 1994. Quality Assurance Project Plan. Bay Protection and Toxic Cleanup Program. 1-1 to 12-7 pp. Sacramento, California. State Water Res. Cont. Bd.

U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (U.S. EPA), San Francisco Bay Conservation and Development Commission (BCDC), and San Francisco Bay Regional Water Quality Control Board (RWQCB). 2001. Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region Management Plan. Report available at <http://www.spn.usace.army.mil/ltms/>.

Table 1. Hypothetical Examples of the Process for Determining Uncertainty-Reducing Priorities

Process/pathway	Implementation Option	Feasibility Ranking[a]	Uncertainty	Effectiveness Ranking[a]	Decision	Result
Methylation-facilitating conditions	Maintain conditions below thresholds	1	Determine redox threshold	1	Conduct study to determine redox threshold for mercury methylation	When redox potential falls below XX, methyl mercury production is reduced by 3 orders of magnitude – evaluate redox management
Transport of methyl mercury into wetlands	Reduce sediment transport into wetlands	3	Determine concentration of methyl mercury in transported sediments	3	Review literature	Methyl mercury transport is minor compared to in situ production – no further action
Transport and exposure of methyl mercury within wetlands	Manage exposure	2	Determine exposure parameters	3	Assess fish distribution in channels	Vegetation-associated fish populations have lower mercury concentrations – consider vegetating channels

Notes: [a] 1=most, 2=moderately, 3=least feasible or effective

Uncertainty Reduction Options	Mercury Processes and Pathway to Biota: Processes/Conditions	Mercury Processes and Pathway to Biota: Pathway Compartments	Implementation Options
• Determine sources of mercury • Determine conditions favorable for transport • Determine spatial distribution • Determine methyl mercury loading	Transport of Mercury into Wetland Sediments		• Reduce sediment transport • Reduce mercury concentration in sediment • Manage spatial extent of mercury
• Determine spatial distribution of mercury		Mercury in Wetland Sediments	• Remove Sediment
• Identify facilitator parameters • Determine active thresholds • Evaluate spatial distribution • Consider Episodic Events	Methylation-Facilitating Conditions (e.g., salinity, dissolved oxygen)		• Maintain conditions below thresholds • Manage spatial distribution • Manage episodic events
• Evaluate spatial distribution • Determine distribution in media		Methyl Mercury in Wetland Sediments and Water	• Remove sediment
• Determine exposure parameters • Evaluate bioaccumulation factors • Evaluate biomagnification factors • Evaluate food web pathway	Transport and Exposure Bioaccumulation/ Biomagnification		• Manage exposure • Manage habitat conditions • Change species distribution • Modify food web interactions
• Determine effects thresholds • Evaluate bioavailability • Evaluate exposure		Mercury in Biota	• Modify target levels • Manage exposure • Increase populations with low-mercury body burdens

Note: This Framework is Presented for Illustrative Purposes.
Further Evaluation is Needed to Develop a Working Model and Framework.

Example Framework for Evaluating and Reducing Mercury Contamination in Bay Wetlands

San Francisco Bay, California

LFR
LEVINE•FRICKE

Figure 1

G/9084/9084-conceptual-framework.ai 050903