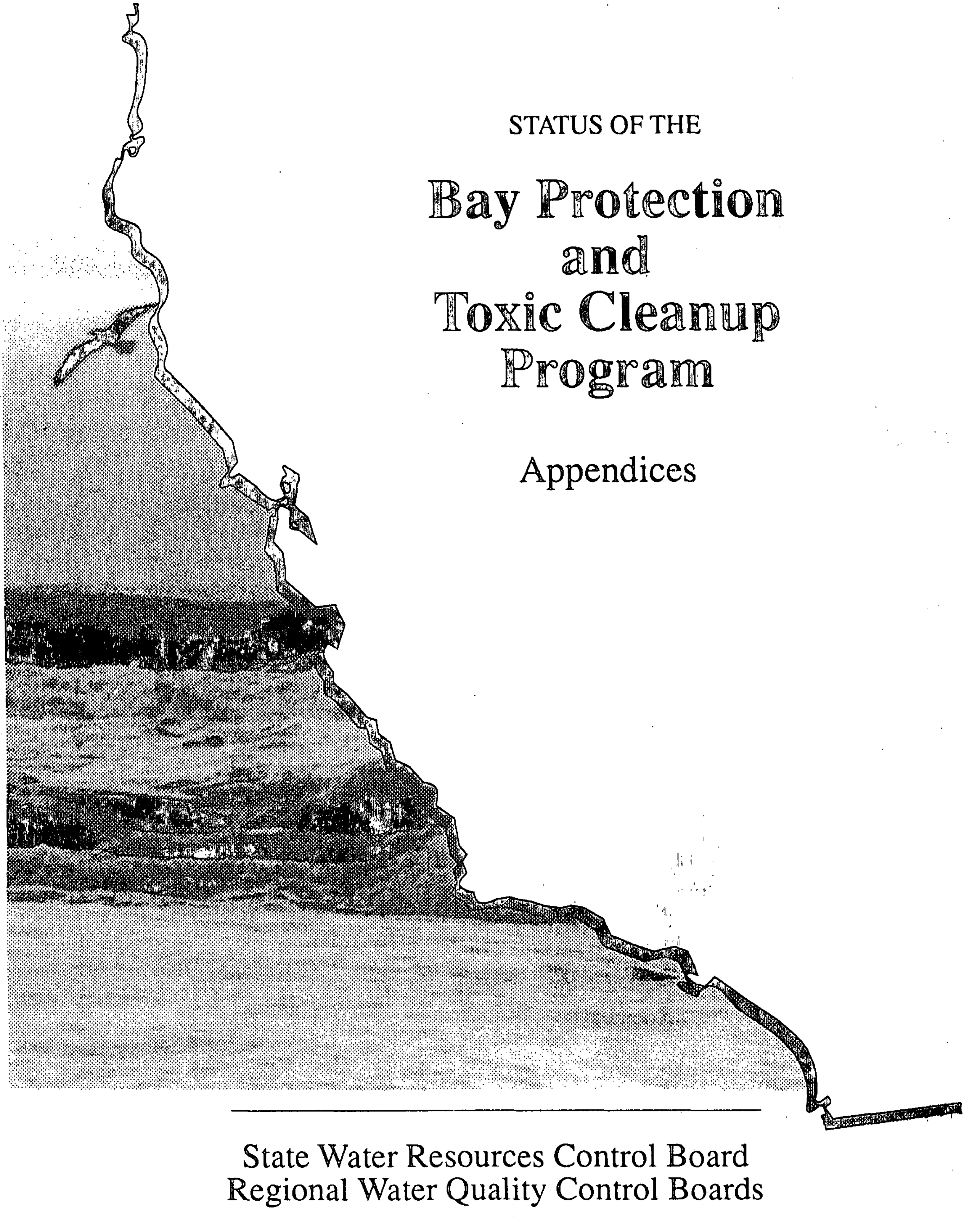

STATUS OF THE

Bay Protection and Toxic Cleanup Program

Appendices

State Water Resources Control Board
Regional Water Quality Control Boards

STATE OF CALIFORNIA
Pete Wilson, Governor

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
James M. Strock, Secretary

STATE WATER RESOURCES
CONTROL BOARD
P.O. Box 100
Sacramento, CA 95812-0100
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STATUS OF THE
BAY PROTECTION AND TOXIC CLEANUP PROGRAM

STAFF REPORT

APPENDICES

STATE WATER RESOURCES CONTROL BOARD

STATE OF CALIFORNIA

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APPENDIX A

Bay Protection and Toxic Cleanup Program
Water Code Sections

Chapter 5.6 of the Water Code
Sections 13390 et seq.

by the defendant personally, cannot be attributed to the defendant.

(e) Any person who knowingly makes any false statement, representation, or certification in any record, report, plan, or other document filed with a regional board or the state board, or who knowingly falsifies, tampers with, or renders inaccurate any monitoring device or method required under this division shall be punished by a fine of not more than twenty-five thousand dollars ($ 25,000), or by imprisonment for not more than two years, or by both. If a conviction of a person is for a violation committed after a first conviction of the person under this subdivision, punishment shall be by a fine of not more than twenty-five thousand dollars ($ 25,000) per day of violation, or by imprisonment of not more than four years, or by both.

(f) For purposes of this section, a single operational upset which leads to simultaneous violations of more than one pollutant parameter shall be treated as a single violation.

(g) For purposes of this section, "organization," "serious bodily injury," "person," and " hazardous substance" shall have the same meaning as in Section 309(c) of the Federal Water Pollution Control Act, as amended.

(h) Funds collected pursuant to this section shall be paid to the State Water Pollution Cleanup and Abatement Account.

HISTORY: Added Stats 1987 ch 1189 § 14.
[Former Section: Former § 13387, similar to the present section, Added Stats 1972 ch 1256 § 1, effective December 19, 1972; Amended Stats 1978 ch 746 § 11; Stats 1984 ch 1541 § 8; Repealed Stats 1987 ch 1189 § 13.]

§ 13388. Board member eligibility

Notwithstanding any other provision of this division or Section 175, no person shall be a member of the state board or a regional board if he receives or has received during the previous two years a significant portion of his income directly or indirectly from any person subject to waste discharge requirements or applicants for waste discharge requirements pursuant to this chapter. This section shall become operative on March 1, 1973.

HISTORY: Added Stats 1972 ch 1256 § 1, effective December 12, 1972.

§ 13389. Exemption of boards from certain provisions of the California Environmental Quality Act

Neither the state board nor the regional boards shall be required to comply with the provisions of Chapter 3 (commencing with Section 21100) of Division 13 of the Public Resources Code prior to the adoption of any waste discharge requirement, except requirements for new sources as defined in the Federal Water Pollution Control Act or acts amendatory thereof or supplementary thereto.

HISTORY: Added Stats 1972 ch 1256 § 1, effective December 12, 1972.

CHAPTER 5.6. Bay Protection and Toxic Cleanup

§ 13390. Intent

It is the intent of the Legislature that the state board and the regional boards establish programs that provide maximum protection for existing and future beneficial uses of bay and estuarine waters, and that these programs include a plan for remedial action at toxic hot spots. It is also the intent of the Legislature that these programs further compliance with federal law pertaining to the identification of waters where the protection and propagation of shellfish, fish, and wildlife are threatened by toxic pollutants and contribute to the development of effective strategies to control these pollutants. It is also the intent of the Legislature that these programs be structured and maintained in a manner which allows the state board and the regional boards to make maximum use of any federal funds which may be available for any of the purposes specified in this chapter.

HISTORY: Added Stats 1989, ch 269, § 50, effective August 3, 1989.

§ 13391. Formulation, adoption and implementation of California Enclosed Bays and Estuaries Plan

(a) The state board shall formulate and adopt a water quality control plan for enclosed bays nd estuaries, which shall be known as the California Enclosed Bays and Estuaries Plan, in accordance with the procedures established by this division for adopting water quality control plans.

(b) As part of its formulation and adoption of the California Enclosed Bays and Estuaries Plan, the state board shall review and update the Water Quality Control Policy for Enclosed Bays and Estuaries of California, as adopted in 1974 pursuant to Article 3 (commencing with Section 13140) of Chapter 3, and incorporate the results of that review and update in the California Enclosed Bays and Estuaries Plan.

(c) State and regional offices, departments, boards and agencies shall fully implement the California Enclosed Bays and Estuaries Plan. Pending adoption of the California Enclosed Bays and Estuaries Plan by the state board, state and regional offices, departments, boards and agencies shall fully implement the Water Quality Control Policy for Enclosed Bays and Estuaries of California.

(d) Each regional board shall review and, if necessary, revise waste discharge requirements that are inconsistent with those policies and principles.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 3, 1989; Amended Stats 1989 ch 1032, § 30, effective September 29, 1989.

§ 13391.5. Definitions

The definitions in this section govern the construction of this chapter.

(a) "Enclosed bays" means indentations along the coast which enclose an area of oceanic water within distinct headlands or harbor works. "Enclosed bays" include all bays where the narrowest distance between the headlands or outermost harbor works is less than 75 percent of the greatest dimension of the enclosed portion of the bay. "Enclosed bays" include, but are not limited to, Humboldt Bay, Bodega Harbor, Tomales Bay, Drake's Estero, San Francisco Bay, Morro Bay, Los Angeles-Long Beach Harbor, Upper and Lower Newport Bay, Mission Bay, and San Diego Bay. For the purposes of identifying, characterizing, and ranking toxic hot spots pursuant to this chapter, Monterey Bay and Santa Monica Bay shall also be considered to be enclosed bays.

(b) "Estuaries" means waters, including coastal lagoons, located at the mouths of streams which serve as mixing zones for fresh and ocean waters. Coastal lagoons and mouths of streams which are temporarily separated from the ocean by sandbars shall be considered as estuaries. Estuarine waters shall be considered to extend from a bay or the open ocean to a point upstream where there is no significant mixing of fresh water and sea water. Estuarine waters include, but are not limited to, the Sacramento-San Joaquin Delta, as defined in Section 12220, Suisun Bay, Carquinez Strait downstream to the Carquinez Bridge, and appropriate areas of the Smith, Mad, Eel, Noyo, Russian, Klamath, San Diego, and Otay Rivers.

(c) "Health risk assessment" means an analysis which evaluates and quantifies the potential human exposure to a pollutant that bioaccumulates or may bioaccumulate in edible fish, shellfish, or wildlife. "Health risk assessment" includes an analysis of both individual and population wide health risks associated with anticipated levels of human exposure, including potential synergistic effects of toxic pollutants and impacts on sensitive populations.

(d) "Sediment quality objective" means that level of a constituent in sediment which is established with an adequate margin of safety, for the reasonable protection of the beneficial uses of water or the prevention of nuisances.

(e) "Toxic hot spots" means locations in enclosed bays, estuaries, or any adjacent waters in the "contiguous zone" or the "ocean," as defined in Section 502 of the Clean Water Act (33 U.S.C. Sec. 1362), the pollution or contamination of which affects the interests of the state, and where hazardous substances have accumulated in the water or sediment to levels which (1) may pose a substantial present or potential hazard to aquatic life, wildlife, fisheries, or human health, or (2) may adversely affect the beneficial uses of the bay, estuary, or ocean waters as defined in water quality control plans, or (3) exceeds adopted water quality or sediment quality objectives.

(f) "Hazardous substances" has the same meaning as defined in subdivision (f) of Section 25281 of the Health and Safety Code.

HISTORY: Added Stats 1989 ch 269 § 50, effective Aug. 3, 1989; Amended Stats 1989 ch 1032, § 30, effective Sept. 29, 1989; Stats 1991 ch 1091 § 162.

§ 13392. Toxic hot spots program

The state board and the regional boards, in consultation with the Office of Environmental Health Hazard Assessment and the Department of Fish and Game, shall develop and maintain a compre-hensive program to (1) identify and characterize toxic hot spots, as defined in Section 13391.5, (2) plan for the cleanup or other appropriate remedial or mitigating actions at the sites, and (3) amend water quality control plans and policies to incorporate strategies to prevent the creation of new toxic hot spots and the further pollution of existing hot spots. As part of this program, the state board and regional boards shall, to the extent feasible, identify specific discharges or waste management practices which contribute to the creation of toxic hot spots, and shall develop appropriate prevention strategies, including, but not limited to, adoption of more stringent waste discharge requirements, onshore remedial actions, adoption of regulations to control source pollutants, and development of new programs to reduce urban and agricultural runoff.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 3, 1989; Governor's Reorganization Plan, No. 1, 1991, § 197.

§ 13392.5. Data base identifying and describing toxic hot spots; Monitoring and surveillance task force

(a) Each regional board which has regulatory authority for one or more enclosed bays or estuaries shall, by January 1, 1992, develop for each enclosed bay or estuary, a consolidated data base which identifies and describes all known and suspected toxic hot spots. Each regional board shall, in consultation with the state board, also develop an ongoing monitoring and surveillance program that includes, but is not limited to, the following components:

(1) Establishment of a monitoring and surveillance task force that includes representation from agencies, including, but not limited to, the Office of Environmental Health Hazard Assessment and the Department of Fish and Game, that routinely monitor water quality, sediment, and aquatic life.

(2) Suggested guidelines to promote standardized analytical methodologies and consistency in data reporting.

(3) Identification of additional monitoring and analyses that are needed to develop a complete toxic hot spot assessment for each enclosed bay and estuary.

(b) Each regional board shall make available to state and local agencies and the public all information contained in the consolidated data base, as well as the results of new monitoring and surveillance data.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 2, 1989; Amended Stats 1989 ch 1032 § 32, effective September 29, 1989; Governor's Reorganization Plan, No. 1, 1991, § 198.

§ 13392.6. Workplan for adoption of sediment quality thresholds for toxic pollutants

(a) On or before July 1, 1991, the state board shall adopt and submit to the Legislature a workplan for the adoption of sediment quality objectives for toxic pollutants that have been identified in known or suspected toxic hot spots and for toxic pollutants that have been identified by the state board or a regional board as a pollutant of concern. The workplan shall include priorities and a schedule for development and adoption of sediment quality objectives, identification of additional resource needs, and identification of staff or funding needs. The state board is not prohibited from adopting sediment quality objectives in the workplan for a constituent for which the workplan identifies additional research needs.

(b) In preparing the workplan pursuant to subdivision (a), the state board shall conduct public hearings and workshops and shall consult with persons associated with municipal discharges, industrial discharges, other public agencies, research scientists, commercial and sport fishing interests, marine interests, organizations for the protection of natural resources and the environment, and the general public.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 2, 1989; Amended Stats 1989 ch 1032 § 33, effective September 29, 1989.

§ 13393. Sediment quality objectives

The state board shall adopt sediment quality objectives pursuant to the workplan submitted pursuant to Section 13392.6. The state board shall adopt the sediment quality objectives pursuant to the procedures established by this division for adopting or amending water quality control plans. The sediment quality objectives shall be based on scientific information, including, but not limited to, chemical monitoring, bioassays or established modeling procedures, and shall provide adequate protection for the most sensitive aquatic organisms. The state board shall base the sediment quality objectives on a health risk assessment if there is a potential for exposure of humans to pollutants through the food chain to edible fish, shellfish, or wildlife.

HISTORY: Added Stats 1989 ch 1032 § 35, effective September 29, 1989. [Former Section: Former § 13393, similar to the present section, was added Stats 1989 ch 269 § 50, effective August 2, 1989, and repealed Stats 1989 ch 1032 § 34, effective Sept. 29, 1989].

§ 13393.5. Assessment and priority ranking of toxic hot spots

On or before July 1, 1992, the state board, in consultation with the Office of Environmental Health Hazard Assessment and the Department of Fish and Game, shall adopt general criteria for the assessment and priority ranking of toxic hot spots. The criteria shall take into account the pertinent factors relating to public health and environmental quality, including, but not limited to, potential hazards to public health, toxic hazards to fish, shellfish, and wildlife, and the extent to which the deferral of a remedial action will result or is likely to result in a significant increase in environmental damage, health risks, or cleanup costs.

HISTORY: Added Stats 1989 ch 269, § 50, effective Aug. 3, 1989; Amended Governor's Reorganization Plan, No. 1, 1991, § 199.

§ 13394. Toxic hot spot cleanup plans

On or before July 1, 1993, each regional board shall complete and submit to the state board a toxic hot spots cleanup plan. On or before January 1, 1994, the state board shall submit to the Legislature a consolidated statewide toxic hot spots cleanup plan. The cleanup plan submitted by each regional board and the state board shall include, but not be limited to, the following information:

(a) A priority ranking of all hot spots, including the state board's recommendations for remedial action at each toxic hot spot site.

(b) A description of each hot spot site including a characterization of the pollutants present at the site.

(c) An estimate of the total costs to implement the plan.

(d) An assessment of the most likely source or sources of pollutants.

(e) An estimate of the costs that may be recoverable from parties responsible for the discharge of pollutants that have accumulated in sediment.

(f) A preliminary assessment of the actions required to remedy or restore a toxic hot spot.

(g) A two-year expenditure schedule identifying state funds needed to implement the plan.

(h) A summary of actions that have been initiated by the regional board to reduce the accumulation of pollutants at existing hot spots and to prevent the creation of new hot spots.

(i) The plan submitted by the state board shall include findings and recommendations concerning the need for establishment of a toxic hot spots cleanup program.

HISTORY: Added Stats 1989 ch 269, § 50, effective Aug. 3, 1989.

§ 13394.5. Annual Expenditure Plan

The state board, as part of the annual budget process, shall prepare and submit to the Legislature a recommended annual expenditure plan for the implementation of this chapter.

HISTORY: Added Stats 1989 ch 269, § 50, effective Aug. 3, 1989.

§ 13395. Reevaluation of waste discharge requirements for discharge into toxic hot spots

Each regional board shall, within 120 days from the ranking of a toxic hot spot, initiate a reevaluation of waste discharge requirements for dischargers who, based on the determination of the regional board, have discharged all or part of the pollutants which have caused the toxic hot spot. These reevaluations shall be for the purpose of ensuring compliance with water quality control plans and water quality control plan amendments. These reevaluations shall be initiated according to the priority ranking established pursuant to subdivision (a) of Section 13394 and shall be scheduled so that, for each region, the first reevaluation shall be initiated within 120 days from, and the last shall be initiated within one year from, the ranking of the toxic hot spots. The regional board shall, consistent with the policies and principles set forth in Section 13391, revise waste discharge requirements to ensure compliance with water quality control plans and water quality control plan amendments adopted pursuant to Article 3 (commencing with Section 13240) of Chapter 4, including requirements to prevent the creation of new toxic hot spots and the maintenance or further pollution of existing toxic hot spots. The regional board may determine it is not necessary to revise a waste discharge requirement only if it finds that the toxic hot spot resulted from practices no longer being conducted by the discharger or permitted under the existing waste discharge requirement, or that the discharger's contribution to the creation or maintenance of the toxic hot spot is not significant.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 2, 1989.

§ 13395.5. Contracts and Other Agreements

The state board may enter into contracts and other agreements for the purpose of evaluating or demonstrating methods for the removal, treatment, or stabilization of contaminated bottom sediment. For the purpose of preparing health risk assessments pursuant to Section 13393, the state board shall enter into contracts or agreements with the Office of Environmental Health Hazard Assessment, or with other state or local agencies, subject to the approval of the office. The costs incurred for work conducted by other state agencies, including, but not limited to, the office and the Department of Fish and Game, pursuant to this chapter shall be reimbursed according to the terms of an interagency agreement between the state board and the agency.

HISTORY: Added Stats 1989, ch 269, § 50, effective August 3, 1989; Governor's Reorganization Plan, No. 1, 1991, § 200.

§ 13396. Certification or approval to dredge or disturb toxic hot spots

No person shall dredge or otherwise disturb a toxic hot spot site that has been identified and ranked by a regional board without first obtaining certification pursuant to Section 401 of the Clean Water Act (33 U.S.C. Sec. 1341) or waste discharge requirements. The state board and any regional board to which the state board has delegated authority to issue certification shall not waive certification for any discharge resulting from the dredging or disturbance unless waste discharge requirements have been issued. If the state board or a regional board does not issue waste discharge requirements or a certification within the period provided for certification under Section 401 of the Clean Water Act. The certification shall be deemed denied without prejudice. On or after January 1, 1993, the state and regional boards shall not grant approval for a dredging project that involves the removal or disturbance of sediment which contains pollutants at or above the sediment quality objectives established pursuant to Section 13393 unless the board determines all of the following:

(a) The polluted sediment will be removed in a manner that prevents or minimizes water quality degradation.

(b) Polluted dredge spoils will not be 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 project or activity will not cause significant adverse impacts upon a federal sanctuary, recreational area, or other waters of significant national importance.

HISTORY: Added Stats 1989 ch 269 § 50, effective August 2, 1989; Amended by Stats 1989 ch 1032 § 36, effective September 29, 1989.

§ 13396.5. Fees

(a) The state board shall establish fees applicable to all point and nonpoint dischargers who discharge into enclosed bays, estuaries, or any adjacent waters in the contiguous zone or the ocean as defined in Section 502 of the federal Clean Water Act (33 U.S.C. Sec. 1362), which shall be collected annually.

(b) The fees shall create incentives to reduce discharges to the ocean, bays, and estuaries and shall be based on the relative threat to water quality from point and nonpoint dischargers. The schedule of fees shall be set at an amount sufficient to fund the responsibilities and duties of the state board, the State Department of Health Services, and the Department of Fish and Game established by this chapter. The total amount of fees collected pursuant to this section shall not exceed four million dollars ($ 4,000,000) per year. Nothing in this section limits or restricts the funding of activities required by this chapter from sources in addition to the fees established by this section.

(c) Fees collected pursuant to this section shall be deposited in the Bay Protection and Toxic Cleanup Fund which is hereby created, and shall be available for expenditure by the state board, upon appropriation by the Legislature, for the purposes of carrying out this chapter.

(d) Fees collected pursuant to this section shall be in addition to fees established pursuant to Section 13260 and shall not be subject to the maximum fee established in subdivision (d) of Section 13260, provided that the annual fee under this section shall not exceed the amount of thirty thousand dollars ($ 30,000) per discharger.

(e) Any person failing to pay a fee established under this section when so requested by the state board is guilty of a misdemeanor and may be liable civilly in accordance with subdivision (d) of Section 13261.

(f) On or before January 1, 1993, the State Board shall report to the Legislature on the progress made toward meeting the requirements of this chapter and the adequacy of the fee levels established in subdivisions (b) and (d).

(g) This section shall remain in effect only until January 1, 1994, and as of that date is repealed, unless a later enacted statute, which is enacted before January 1, 1994, deletes or extends that date.

HISTORY: Added Stats 1990, ch 1294, § 1.

CHAPTER 6. State Financial Assistance

ARTICLE 1. State Water Quality Control Fund

§ 13400. Definitions

As used in this chapter, unless otherwise apparent from the context:

(a) "Fund" means the State Water Quality Control Fund.

(b) "Public agency" means any city, county, city and county, district, or other political subdivision of the state.

(c) "Facilities" means:

(1) facilities for the collection, treatment, or export of waste when necessary to prevent water pollution,

(2) facilities to reclaim waste waters and to convey reclaimed water,

(3) facilities or devices to conserve water, or

(4) any combination of the foregoing.

HISTORY: Added Stats 1969 ch 482 § 18, operative January 1, 1970; Amended Stats 1978 ch 436 § 1.

§ 13401. State Water Quality Control Fund; Appropriation of moneys

The State Water Quality Control Fund is continued in existence. The following moneys in the fund are appropriated, without regard to fiscal years, for expenditure by the state board in making loans to public agencies in accordance with the provisions of this chapter:

(a) The balance of the original moneys deposited therein.

(b) Any money repaid thereto.

(c) Any remaining balance of the money in the fund deposited therein after the specific appropriations for loans to the South Tahoe Public Utility District, the North Tahoe Public Utility District, the Tahoe City Public Utility District,

APPENDIX B

List of Reports Prepared Fully or in Part by the BPTCP (including Contractor Reports)

List of Reports Prepared Fully or in Part by the BPTCP (including Contractor Reports)

Becker, D.S., R.C. Barrick, and L.B. Read. 1990. Evaluation of the AET Approach for Assessing Contamination of Marine Sediments in California. State Water Board Report No. 90-3WQ.

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Division of Water Quality, State Water Resources Control Board. 1990. Staff Report: Proposed Authorization to Negotiate and Execute Contracts and Advise of Staff Action for the Bay Protection and Toxic Cleanup Program.

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Flegal, A.R., R.W. Risebrough, B. Anderson, J. Hunt, S. Anderson, J. Oliver, M. Stephenson, and R. Packard. 1992. Second Draft Final, Pilot Regional Monitoring Program San Francisco Estuary Sediment Study.

Gunther, A., S.G. Lorenzato, and J.M. O'Connor. 1991. Summary of a Workshop Concerning Sediment Quality Assessment and Development of Sediment Quality Objectives.

Lorenzato, S.G. and C.J. Wilson. 1991. Workplan for the Development of Sediment Quality Objectives for Enclosed Bays and Estuaries of California. State Water Board Report No. 91-14WQ.

Montoya, B.L. 1991. An Analysis of the Toxic Water Quality Impairments in the Sacramento-San Joaquin Delta/Estuary.

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Regional Water Quality Control Board, San Diego Region. 1992. BPTCP Regional Monitoring Plan.

Regional Water Quality Control Board, San Francisco Bay Region. 1992. BPTCP Regional Monitoring Plan.

Regional Water Quality Control Board, Santa Ana Region. 1992. BPTCP Regional Monitoring Plan.

State Water Resources Control Board. 1991a. Final Statement of Reasons Title 23, Division 3, Chapter 9, Article 6, Section 2236, California Code of Regulations: Bay Protection and Toxic Cleanup Annual Fees.

State Water Resources Control Board. 1991b. Final Functional Equivalent Document for Amendment of the Water Quality Control Plan for Enclosed Bays and Estuaries of California. State Water Board Resolution No. 91-33. (Prepared with the Freshwater Standards Unit).

State Water Resources Control Board. 1992a. Draft Functional Equivalent Document, Amendments of the Water Quality Control Plan for Enclosed Bays and Estuaries of California.

State Water Resources Control Board. 1992b. Final Functional Equivalent Document for Amendment of the Water Quality Control Plan for Enclosed Bays and Estuaries of California. State Water Board Resolution No. 92-100.

State Water Resources Control Board. 1992c. Regulations to Implement the Bay Protection and Toxic Cleanup Program Annual Fees. Section 2236, Article 6, Chapter 9, Division 3, Title 23 of the California Code of Regulations. State Water Board Resolution No. 92-102.

State Water Resources Control Board and California Environmental Protection Agency. 1991. National Estuary Program: The Nomination of Morro Bay. (Prepared with assistance of Central Coast Regional Water Board and the Friends of the Morro Bay Estuary).

State Water Resources Control Board and California Environmental Protection Agency. 1992. National Estuary Program: The Nomination of Morro Bay, Addendum. (Prepared with the assistance of the Central Coast Regional Water Board and the Friends of the Morro Bay Estuary).

State Water Resources Control Board and National Oceanic and Atmospheric Administration. 1991. Proposal for a cooperative Agreement Measures of Bioeffects Associated with Toxicants in Southern California. (Los Angeles-Long Beach Harbor). First Year.

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APPENDIX C

San Francisco Bay Pilot Regional Monitoring Program 1991-1992 Summary Progress Report

SAN FRANCISCO BAY PILOT REGIONAL MONITORING PROGRAM 1991-1992

SUMMARY PROGRESS REPORT

BY

KAREN TABERSKI

MICHAEL CARLIN

JESSICA LACY

SAN FRANCISCO BAY REGIONAL WATER QUALITY CONTROL BOARD

DECEMBER 1992

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PROGRESS REPORT

This report summarizes the data collected in the San Francisco Bay 1991-1992 Regional Monitoring Program. This is a progress report describing the work that has been completed to date. There were five different contracts written for the San Francisco Bay Regional Monitoring Program that were funded by the Bay Protection and Toxic Cleanup Program. Each deal with different components of the monitoring program or wasteload allocation studies: 1) sediment analysis, 2) bioaccumulation, 3) water column toxicity, 4) water column chemistry (organics) and 5) wasteload allocation. The Sediment Report and Water Column Toxicity Report are submitted with this summary as draft finals. All of the chemical analysis for the sediment study is not yet completed. The Bioaccumulation Report is submitted in final form. Analysis of the water column samples for organic chemistry is not yet complete. The wasteload allocation studies are on a four year time schedule. Progress on these studies is included in this report.

In addition, since the Regional Monitoring Program had many contracts and many subcontractors in each contract (the sediment contract had six contractors) the final reports do not analyze the data in a fully integrated fashion. We are currently trying to hire statisticians to thoroughly analyze all of the data collected in the program so that we can extract the most information from the enormous amount of data we have. An integrated approach to data analysis is necessary in order to use this information to guide our decisions in the future. Once all of the monitoring reports are final and an integrated statistical analysis of the data is completed, a final version of this summary report will be issued.

EXECUTIVE SUMMARY

This report is a summary of the progress to date on the San Francisco Bay Regional Water Quality Control Board's Pilot Regional Monitoring Program (RMP). The RMP was funded by the Bay Protection and Toxic Cleanup Program. The main goal of this program was to develop a regional monitoring and surveillance program that could be used as a prototype in other bays and estuaries in the state. This was accomplished by setting up monitoring programs and special studies to evaluate various techniques and protocols used to sample water, sediment and tissue and to measure chemical contamination and toxicity. A second purpose of the program was to identify toxic hot spots in the Bay and in critical habitats (marshes, creeks and mudflats) around the Bay.

This was a multi-media program in which chemical contamination and toxicity was measured in water and sediments and bioaccumulation of contaminants was measured in tissues. The program was divided into two major monitoring programs two special study programs and a data management component. The two monitoring components were the Bay Monitoring Surveys and the Critical Habitat Investigations.

In the Bay Monitoring Surveys, chemistry and toxicity was measured in the water and sediments at stations ranging from the South Bay to the Sacramento and San Joaquin Rivers. The purposes of the Bay Monitoring Surveys were to: 1) monitor stations that in a longterm monitoring program would indicate spatial and temporal trends in toxicity and chemistry throughout the Estuary, 2) determine background for different basins in the Estuary and 3) determine if there was toxicity or high levels of contaminants at Bay stations.

Critical Habitat Investigations were conducted primarily to determine if there were high levels of contaminants or toxicity " hot spots" in the marshes, mudflats or creeks surrounding the Estuary. Toxicity was measured in the sediments. Chemical analyses was performed on sediment samples for a suite of metals and organics. Investigations of toxicity in the water column of critical habitats focused on stormwater runoff in two systems: 1) The Crandall Creek and Demonstration Urban Stormwater Treatment (DUST) marsh (DUST system) which retains stormwater in a freshwater marsh and 2) Arrowhead Marsh where stormwater is discharged into San Leandro Bay.

A special study was performed on a sediment gradient to: 1) determine which toxicity tests or type of toxicity tests (solid phase, elutriate, or pore water) could best distinguish between highly contaminated, moderately contaminated, and relatively uncontaminated sites, 2) evaluate the degree to which field replication increases the ability to distinguish between sites, 3) determine the effect of sample depth, 4) determine the relationship between toxicity and factors that may effect toxicity including the levels of chemical contaminants, total organic carbon, grain size, ammonia and sulfides and 5) determine the relationship between toxicity test results and benthic community analysis. Shallow and deep samples were collected at stations in Castro Cove, which has been historically contaminated with effluent from an oil refinery. Five field replicates were collected at each station. Toxicity tests were performed on whole sediment, elutriates and porewater. Chemical analyses were performed on whole sediment and porewater. Samples for benthic community analysis were collected from these stations. In addition, for another program, biomarkers were measured in fish exposed to the sediment in the laboratory.

A bioaccumulation study was performed in order to: 1) describe the distribution of trace metals and organics in organisms in the San Francisco Estuary, 2) determine the differences in contaminants in organisms collected in wet and dry seasons, 3) determine the differences between mussels transplanted to shallow and deep water column depths at the same station, 4) determine the effect of depurating sediment from the guts of organisms on the contaminant levels in the whole bodies, 5) determine the optimum length of exposure for transplant organisms and 6) determine the differences in uptake in three species, each with their own salinity tolerances.

To manage the data for the entire RMP a common format was developed for all laboratories participating in the program. This allowed data to be more easily interpreted, analyzed and thoroughly checked for quality assurance. All laboratories in the program were provided with consistent formats with QA programs integrated into the data input system to insure accurate data entry. Data were generated at each of the laboratories and sent to EcoAnalysis for review.

For the sediment portion of the Bay Monitoring Surveys and Critical Habitat Investigations, stations were identified where sediment was toxic or showed elevated levels of metals or organics (see results). Sediment was monitored at 15 stations baywide during wet and dry seasons. For the Critical Habitat Investigations 32 sediment stations were monitored. Preliminary studies and data from the monitoring programs indicated that: 1) for the amphipod test Eohaustaurius estuarius seemed more sensitive than Hyalella azteca and Rhepoxinius abronius, even when a 28 day growth test was conducted with Hyalella, 2) the Menidia growth and survival test, using an elutriate, is not sensitive and should not be used in a monitoring program, 3) diver cores seemed to be the best way to collect undisturbed sediment samples, next best was the box core and 4) chemical analysis indicated that the technique used for homogenizing samples was adequate. Eohaustaurius seems to be an excellent organism for estuarine monitoring because it is tested in solid phase, is sensitive and can be tested at ambient salinity.

Only preliminary analyses have been completed on data from the gradient study but these analyses seem to indicate that: 1) toxicity was greater in deep samples, 2) this toxicity was not caused by high levels of ammonia or hydrogen sulfide, 3) toxicity tests were able to distinguish between stations, 4) field replicates were more variable than laboratory replicates, 5) three laboratory replicates may be sufficient to distinguish between stations, 6) in the bivalve larvae test, porewater samples were much more toxic than elutriate samples from the same sediment, 7) abnormality in the bivalve larvae test was highly correlated with abnormality in the sea urchin test, 8) abnormality in neither the urchin or bivalve test were correlated with the sea urchin fertilization test, and 9) sampling cores may be suitable containers for conducting amphipod tests.

For the water column portion of the Bay Monitoring surveys, monitoring of organic contaminants and toxicity was conducted at 15 and 12 stations, respectively, within the Estuary in June 1991 and April 1992. The results of the organic contaminant monitoring will be available in January 1993. Toxicity testing indicated statistically significant toxicity during the first sampling event at two stations. Each station had significant toxicity in one toxicity test. There was no significant toxicity in the second sampling event.

Investigations of toxicity in the water column of critical habitats detected toxicity in both the DUST system and Arrowhead Marsh following storm events. The DUST system was further investigated to study the fate of toxicity in the receiving waters following storm events of different intensity.

Bioaccumulation results indicated that: 1) bivalves at most of the stations within San Francisco Bay accumulated contaminant levels that were significantly higher than the controls collected at sites in more pristine locations outside of the Bay, 2) stations in the South Bay, especially Coyote Creek, were significantly higher than the Central or Northern Bay stations for DDT, PCBs, chlordane and PAHs, 3) Stations in the South and Central Bays were significantly higher than the North Bay for silver, 4) there were no significant differences in contaminant levels between wet and dry seasons, 5) there were no significant differences between mussels deployed near the surface and those deployed near the bottom, 6) a small number of metals at each station were significantly different between depurated and undepurated mussels, 7) an equilibrium appeared to be reached in mussels during the three and four month transplants for copper, mercury, lead, selenium, and chlordane, but no equilibrium was reached for silver, PCBs and possibly DDT after 120 days, 8) the patterns exhibited for DDTs, PCBs, and chlordanes for deploment time experiments were similar indicating a similar source of these compounds and 9) oysters and mussels exhibited similar concentrations of chlordane, DDT and PCBs but PAHs differed and all metals differed greatly between the two species.

Although all of the data from the program has not been thoroughly analyzed, there are already several major accomplishments of the RMP: 1) a Baseline Monitoring Program has been established which will start in 1993, using the techniques and protocols evaluated during the RMP, to measure temporal and spatial trends in chemistry, toxicity and bioaccumulation throughout the San Francisco Estuary on an ongoing basis, 2) toxic hot spots were identified throughout the Bay and in critical habitat areas, 3) most of the marshes and mudflats in the Estuary were surveyed for chemical contamination and toxicity, 4) as the first step in setting up a statewide database, a format was generated for data and laboratories in the Bay Protection Program were trained to use these formats so that data could be easily checked for quality assurance, and integrated for statistical analysis, 5) data generated in this program can be combined with other data to generate Apparent Effects Threshold (AET) values for San Francisco Bay and 6) problems in identifying toxic hot spots and generating sediment quality criteria were identified and future studies were recommended to make the program more scientifically rigorous and provide more certainty in the final results (see Recommendations for Future Studies).

Besides the Regional Monitoring Program, studies are also underway supporting the development of a wasteload allocation for South San Francisco Bay. In the first phase, a predictive water quality model was developed based on available water quality and hydrodynamic data, using the EPA model WASP4. The second phase includes collection of time series of suspended sediment data to improve the ability to model transport of pollutants associated with sediments.

INTRODUCTION

The State Water Resources Control Board established the Bay Protection and Toxic Cleanup Program in April 1990 in order to implement Sections 13390-13396 of the California Water Code (Chapter 5, Division 7). One of the requirements under the Water Code is to develop an ongoing monitoring and surveillance program in bays and estuaries of the state. The primary goal of the Pilot Regional Monitoring Program (RMP) was to develop a monitoring and surveillance program for the San Francisco Estuary that could be used as a prototype for the rest of the state. In addition, this program was designed to identify toxic hot spots in the Bay and in marshes surrounding the Bay and to collect data that can be used to develop sediment quality objectives. In a second part of this report, the progress of wasteload allocation studies is described.

The RMP was primarily a monitoring program but special studies were also undertaken to determine the best methods and stations to use to monitor the Estuary. A multi-media approach was used in order to evaluate the ultimate fate and effects of contaminants in this complex estuarine system. Measurements of chemical contaminants, exposure of organisms to these contaminants and toxic effects of contaminants on organisms were all measured. In the water column, chemistry, toxicity and bioaccumulation were measured. In the sediments, chemistry, and toxicity in both whole sediment and in pore water were measured. In addition, biomarkers were measured in fish exposed in the laboratory to sediment samples synoptically collected for chemistry and toxicity.

Chemical measurements included a suite of metals and organics. At least three different toxicity tests were used to evaluate the effects of contaminants in both water and sediment. Bioaccumulation was measured in three different species of shellfish deployed in the water column. These data will not only be used for the immediate needs of the Bay Protection and Toxic Cleanup Program but also to determine background concentrations in the Estuary and to evaluate spatial and temporal trends in chemistry, bioaccumulation and toxicity.

Included in the program was a data management component. Under this part of the program, a common format was developed so that data could be more easily interpreted, analyzed and thoroughly checked for quality assurance. Although analysis is included in this report for each component of the program, a thorough statistical analysis integrating all portions of the program is currently being planned. All of the data previously mentioned are included in this report except for water column metals analysis and biomarker measurements, which were funded under another program and are on a different time schedule. For a more thorough description of methods and results consult the original reports.

PART I. REGIONAL MONITORING PROGRAM

The RMP included two major monitoring components: Bay Monitoring Surveys and Critical Habitat Investigations. The purposes of the Bay Monitoring Surveys were to: 1) monitor stations that in a longterm monitoring program would indicate spatial and temporal trends in toxicity and chemistry throughout the Estuary, 2) determine background for different basins in the Estuary and 3) determine if there was toxicity or high levels of contaminants at Bay stations. The Bay Monitoring Surveys included chemical and toxicity measurements in the water column and in the sediment. In the water column, metals were analyzed at 27 stations, organics at 14 stations and toxicity at 12 stations. Sediment chemistry and toxicity were measured at 15 stations. Bioaccumulation in shellfish was measured at 8 stations. Each group of stations was a subset of the 27 water column stations. However some sediment stations, although located in the same general vicinity as the water column stations, were changed due to the composition of the sediment. The stations ranged geographically from the South Bay to the Sacramento and San Joaquin Rivers.

Critical Habitat Investigations were conducted primarily to determine if there were high levels of contaminants or toxicity " hot spots" in the marshes and mudflats surrounding the Estuary. Sediment chemistry and toxicity were measured in most critical habitats around the Estuary, except for the South Bay which has been extensively monitored in the recent past. Water column toxicity was measured in several of these marshes, although most of the work relating to water column toxicity concentrated on the effect of runoff on the Demonstration Urban Stormwater Treatment (DUST) marsh in the South Bay and Arrowhead Marsh in San Leandro Bay.

Special studies on sediment toxicity and bioaccumulation were also conducted and are described in those sections below. In addition, a data management component was included so that all of the data would be consistent and could be integrated for quality assurance and statistical analysis.

SEDIMENT

Study Design

Several preliminary studies were conducted for the sediment monitoring programs to determine: 1) the most appropriate amphipod species and endpoints to use in an estuary with a wide range of salinities and 2) a fine grain reference site. These studies are discussed in more detail in the Sediment Report. Tests exposed the amphipod Hyalella azteca to two freshwater reference sediments (Del Valle Reservoir and Lake Mendocino) and two contaminated sediments (Coyote Creek and Mayfield Slough). The duration of the tests were 14 and 28 days. Endpoints were 14 day survival and for the 28 day test three growth measurements. Eohaustaurius estuarius was exposed to two estuarine reference (Brazil Beach in Tomales Bay, and Drakes Estero) and two estuarine contaminated sediments (Oakland Inner Harbor and Castro Cove). The duration of the test was 10 days and the endpoint was survival. In addition, both Hyalella and Eohaustaurius were exposed to low salinity sediments (3-4 ppt) from Lake Mendocino, Blanco Drain, Mayfield Slough and Stockton Harbor to determine if Eohaustaurius could be used at low salinities. The results of these studies indicated that 1) the most appropriate amphipod test to use for the sediment monitoring programs was the 10 day amphipod test, using Eohaustaurius and measuring survival, 2) Eohaustaurius could be run in estuarine sediment down to 4 ppt but it had low survival in freshwater sediment that was salted up and 3) the best fine grain reference site out of those tested was Brazil Beach in Tomales Bay. However, after testing with Brazil Beach sediment showed toxicity in consecutive studies, including the first Critical Habitat survey, the site was changed to Marconi Cove in Tomales Bay. Still, throughout the study Marconi Cove sediments exhibited sporadic toxicity.

Additional samples were collected at Drakes Estero, Tomales Bay, Oakland Inner Harbor, Del Valle Reservoir, Mayfield Slough, Lake Mendocino and Coyote Creek for pore water analysis. Samples were taken with a sampling core. Pore water was extracted with syringes inserted at different depths. Pore water was analyzed for ammonia, nitrite plus nitrate, phosphate, dissolved oxygen,silicate, manganese, silver, iron and lead.

Bay Monitoring Surveys

Composite samples of the depositional layer were collected at 15 stations during the dry season (August 1991) and 14 during the wet season (April 1992) (Figure 1 and 2; Table 1 and 2). A fine grain sample could not be collected at Davis Point during the wet season. The depositional layer was defined by being brown in color, loosely compacted and lacking the smell of hydrogen sulfide. Because of the highly dynamic nature of the San Francisco Estuary, due to wind, tides and currents, sediment is constantly resuspended and redeposited. In this program we decided not to sample the top 2 cm, as is done in most sediment surveys, because we felt that in most areas that depth was constantly in a state of flux. To truly characterize a site we decided to sample a deeper layer. We sampled down to the interface where the existence of hydrogen sulfide was evident. The sulfide layer was not sampled because of possible confounding effects in toxicity test results.

Sediment was homogenized and analyzed for concentrations of metals and organics and for toxicity. Three toxicity tests were used in the dry weather run. These were the solid phase 10 day amphipod test using Eohaustaurius and two elutriate tests, the bivalve larvae test measuring development, and the Menidia beryllina test measuring growth and survival. The Menidia test was deleted from the wet weather run because after much testing it proved to be less sensitive than the other tests.

Critical Habitat Investigations

Composite samples of the depositional layer were collected at 32 stations located in marshes or mudflats around the Estuary (Figure 3; Table 3). Four separate surveys were conducted, each in a separate part of the Estuary. The sediment was analyzed for metals and organics and tested for toxicity using the same three toxicity tests used for the Bay Monitoring samples. However, several tests from freshwater stations were conducted using the 7 day test for Daphnia magna, which measures reproduction.

Gradient Study

The main purposes of the gradient study were to: 1) determine which toxicity tests or type of toxicity tests (solid phase, elutriate, or pore water) could best distinguish between highly contaminated, moderately contaminated, and relatively uncontaminated sites, 2) evaluate the degree to which field replication increases the ability to distinguish between sites, 3) determine the effect of sample depth, 4) determine the relationship between toxicity and factors that may effect toxicity including the levels of chemical contaminants, total organic carbon, grain size, ammonia and sulfides and 5) determine the relationship between toxicity test results and benthic community analysis.

Castro Cove was chosen as the study site. There were four station locations on a distance gradient away from an historic outfall from a petroleum refinery (Figure 4). Station locations were chosen based on historic data and a reconnaissance survey. At three of the four stations, including the most contaminated and the least contaminated, samples were taken at two depths (the depositional layer, referred to as shallow, and one foot, referred to as deep). The depositional layer at station GD23, the third station from the source, could not be sampled because of an intense infestation of tube worms at the station that was not there during the reconnaissance survey five weeks before. In addition, sediment from Carr Inlet in Puget Sound, Washington was also sampled at two depths and used as an additional clean control for all of the toxicity tests, including pore water tests, in the study. A full chemical analysis was conducted on the sediment and pore water from Carr Inlet. At all seven stations (each depth was considered a separate station) five field replicates were collected. Each field replicate was a composite made up of at least five cores.

Twelve liters of sediment were collected for each field replicate and homogenized. Sediment was then separated for pore water or whole sediment/elutriate analysis. Whole sediment was analyzed for metals, organics, grain size and total organic carbon. The 10 day amphipod test, using Eohaustaurius was conducted with whole sediment. In addition, speckled sanddabs, Citharichthys stigmaeus , were exposed to this sediment for 60 days in the laboratory, after which a series of biomarkers were measured (these results will be reported in a separate report). The bivalve larvae development test was also conducted on an elutriate of the sediment using the same techniques that were used in the monitoring portion of the program.

Pore water was squeezed from the sediment and used for chemical analysis and toxicity tests. Pore water was analyzed for organics, metals, ammonia, sulfides, pH and dissolved oxygen. Pore water toxicity tests measured: 1) bivalve larval development, 2) sea urchin fertilization, development, cytologic and cytogenic effects, 3) nematode broodsize and mutagenic effect and 4) bacterial mutagenicity. In addition, a different pore water sampler was used to extract pore water at different depths. Concentrations of ammonia, hydrogen sulfide, dissolved oxygen, nitrite plus nitrate, silicate and manganese were measured in each sample.

In addition to chemical measurements, toxicity tests and biomarker measurements, samples were collected at each of the four station locations (GD10/20, GD11/12, GD23 and GD12/22) for benthic community analysis. Five field replicates were collected at each location.

A dilution experiment was also conducted on sediment from the gradient study to determine: 1) whether Eohaustaurius or Rhepoxinius was more sensitive to Castro Cove sediments and 2) if salinity effected toxicity to Eohaustaurius. The 10 day amphipod test was performed for both species on dilutions of Carr Inlet and a mix of GD10 and GD20 sediments (sediments from the most toxic site). Sediment was mixed to achieve six concentrations: 100, 80, 60, 40, 20, and 0 % . Eohaustuarius was tested at 10 and 25 ppt. Rhepoxinius was tested at 28 ppt.

Methods

Sampling

Sediment was sampled by four different methods: 1) a modified Gray-Ohara box core, 2) diver operated cores, 3) diver operated scoops, and 4) hand held scoops. The method used depended on the environment being sampled. For the Bay Monitoring Surveys the box core was always used. For the Critical Habitat Investigations one of the other three methods was used depending on whether the sediment was exposed or underwater. Diver operated cores or scoops were used if the sediment was underwater. Hand held scoops were used if the tide was out and the sediment was not underwater. Diver operated scoops were considered the least effective in maintaining the integrity of the top layer of sediment. These were used for the first of four Critical Habitat Investigations but after this were only used for collecting reference sediment. For the Gradient Study, except for Carr Inlet sediment, only diver cores were used. Diver cores were the best method for maintaining the integrity of the top layer of sediment.

All sampling equipment was made of Teflon, polyethylene, or polycarbonate and was pre-cleaned and protectively packaged prior to entering the field. New sampling equipment, except for the sampler, was used at each station. All sampling equipment (excluding the sediment sampler) was cleaned by: a 2-day soak and wash in Micro brand detergent, 3 Milli-Q water rinses, 3 deionized water rinses, a 3-day soak in 10% HCL or HNO3, 3 Milli-Q water rinses, air dry, 3 petroleum ether rinses, and air dry. The sediment sampler was cleaned prior to entering the field by: a vigorous Micro brand detergent wash and scrub, a tap-water rinse, a 10% HCL rinse, and a petroleum ether rinse. To avoid cross-contamination, the sediment sampler was thoroughly cleaned between sampling at each station with a seawater rinse, scrubbing with Micro brand detergent, a seawater rinse, 1% HCl rinse and a methanol rinse.

The San Francisco Estuary is a highly dynamic system. Wind, currents and tides constantly resuspend and redeposit sediment. Organisms reburrow and are exposed to deeper sediment when it is resuspended. In most sediment studies, the top 2 cm of sediment is sampled. A decision was made in this study that the top 2 cm was not deep enough to characterize a site in this Estuary. Yet, at that time it was unclear how much effect ammonia and hydrogen sulfide would have on toxicity tests if we sampled the sulfide layer. Also, it was felt that the mobilization of sulfides could create artificial conditions by either extracting metals from the pore water during homogenization or releasing metals during bioassay exposure. For these reasons the decision was made to measure as deep as possible without sampling the sulfide layer. For all studies, except the deep samples in the Gradient Study, the depositional layer was sampled. This layer was characterized by being brown in color, relatively noncompacted and lacking the smell of hydrogen sulfide.

This layer ranged, depending on the site from 1 cm to 20 cm. The average depth for the Bay Monitoring Surveys was 10 cm.

Most samples were a composite of grabs. The amount of grabs varied from 1 to 20 depending on the depth of the depositional layer at that site, the greater the depth the fewer the grabs. The Bay Monitoring Surveys averaged 6 grabs. Sediment was placed in a tub and homogenized. It was then divided up for the various types of analyses conducted in the study.

For the Gradient Study whole sediment was sampled from the depositional layer and to a depth of one foot using a diver core. Pore water was collected from each sample. For every field replicate homogenized sediment was divided into sediment that would be used for whole sediment analysis and sediment that would be used for pore water analyses. The sediment to be used for pore water analyses was squeezed by a whole core squeezing method developed by Bender et al. (1987). This method utilizes mechanical force to squeeze pore water from interstitial spaces. The pore water was then divided for the various types of chemical analyses and toxicity tests.

A second method was used for sampling pore water at various depths. This method used a pore water squeezer to collect dissolved (<0.45um) pore water samples, in replicate, from depths of 0, 1, 2, 4, 6, 8, 10, 14, 18, 22 and 26 cm. Filtered water samples were drawn directly into acid-cleaned polyethylene (LDPE) syringes; the syringe contents were filtered through a 0.45um teflon syringe filter into an acid-cleaned LDPE bottle. The samples were then acidified with sub-boiling quartz distilled (2x) acids in a trace element clean laboratory. Samples collected by this technique at Drakes Estero, Tomales Bay, Oakland Inner Harbor, Del Valle Reservoir, Mayfield Slough, Lake Mendocino and Coyote Creek were analyzed for ammonia, nitrite plus nitrate, phosphate, dissolved oxygen, silicate, manganese, silver, iron and lead. Castro Cove samples were also collected by this method. These samples were analyzed for ammonia, hydrogen sulfide, dissolved oxygen, nitrite plus nitrate, silicate and manganese.

Organic Chemistry

Organic contaminants were measured in sediments and pore waters. Concentrations of PAHs, PCBs, and chlorinated pesticides in sediments were measured with established techniques. All sediment values are reported in dry weight. Concentrations of the same compounds in pore waters were measured with experimental techniques, due to the sensitivity limitations of the small volumes available.

Sediments were freeze-dried, mixed with kiln-fired sodium sulfate, and soxhlet-extracted with methylene chloride. The methylene chloride was then replaced by hexane. Lipids were removed by florisil-column chromatography. Sediment extract volumes were concentrated to approximately 1-4 ml and analyzed by both electron-capture gas chromatography (Varian 3400 GC with 8100 autosampler) and by GC/MS (Saturn II, also with 8100 autosampler).

Pore water samples in the gradient study, about 50 ml, were extracted three times with methylene chloride in a separatory funnel. The methylene chloride was reduced and replaced by hexane. Pore water extract volumes were reduced to 5-10 microliters before analysis by GC/ECD and GC/MS to achieve the necessary sensitivity.

For total organic carbon analysis, aliquots of freeze-dried or oven-dried sediments were prepared by agitation in 1N HCl, repeating the process until there was no further evolution of carbon dioxide. After centrifugation and decanting, sediments were rinsed with Milli-Q treated water, centrifuged again, and dried at 60 degrees. Subsequent steps in the analysis were undertaken by using established methods (Froelich, 1980; Hedges and Stern, 1983; and suggested procedures of the manufacturer). The methods are comparable to those of the recent validation study of the EPA method MARPCPN conducted by the Chesapeake Biological Laboratory of the University of Maryland.

Metals Chemistry

Two different methods were used to prepare whole sediment samples for chemical analysis. The first involved a near total (aqua regia) digestion consistent with the recommended procedures of the United States Environmental Protection Agency for sediment analyses (EPA, 1974). This procedure provides a conservative measure of trace element concentrations in sediment and can be used to compare concentrations with historical measurements and numerical sediment guidelines and standards. The second procedure extracted "biologically available" trace elements by using a dilute acid (0.5 N HCl) extraction procedure (Flegal et al., 1981). This procedure was developed for the State Water Resources Control Board to monitor trace element concentrations in marine sediments and wastewater sludge. Research has indicated that this extraction method is consistent with the extraction for acid volatile sulfides (Ditoro, 1990).

The first method of digestion was used to prepare samples that were analyzed for aluminum, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, phosphorus, silver, vanadium and zinc. The second method was used to prepare samples that were analyzed for aluminum, cadmium, iron, magnesium, manganese, phosphorous and vanadium. Elemental concentrations were measured by Graphite furnace atomic absorption spectrometry (GFAAS), flame atomic absorption spectrometry (AAS), and/or inductively coupled plasma atomic emission spectrometry (ICP-AES). All samples were measured in duplicate.

Total arsenic, mercury, and selenium were analyzed by American Environmental Corporation. Methods used for these metals were: arsenic (EPA Method 7061), mercury (EPA Method 7471) and selenium (EPA Method 7741). The instrument used for detection was in all cases a GFAAS. Tributyltin was analyzed by Toxscan, Incorporated using a gas chromatograph with a flame photometric detector. All metals values for the project are reported in dry weight.

Pore water samples were concentrated with an APDC/DDC organic extraction, which was based on the procedures described by Bruland et al. (1985). This method was necessary because of the small volumes of pore water that could be extracted. The total dissolved (< 0.45um) concentrations of pore water samples were measured with microtechniques based on procedures used to measure total dissolved trace element concentrations in surface waters in the San Francisco estuary (Flegal et al., 1991). Therefore, this set of data may be compared to other measurements of trace element concentrations in surface waters. Pore water samples were analyzed for cadmium, cobalt, copper, iron, lead, manganese, silver and zinc. Concentrations were measured by GFAAS and by ICP-AES.

Additional pore water measurements collected at various depths and analyzed for dissolved ammonia, phosphate, silicate, and nitrate plus nitrite used the procedures described by Gieskes and Peretsman (1986).

Toxicity Tests

For the first Bay Monitoring Survey and the Critical Habitat Investigations three sediment toxicity tests were performed: the amphipod, bivalve larvae and Menidia test. The 10 day amphipod test measuring survival was performed on whole sediment (ASTM, 1992). The amphipod Eohaustaurius estuarius was used so that all tests could be conducted at ambient salinity. Rhepoxinius abronius was tested at a subset of stations to compare the sensitivity of the two species. Control (home) sediment was used in all tests. In addition, fine grain sediment from Tomales Bay was run as a reference sediment.

Elutriate tests were performed with bivalve larvae measuring development and with the inland silverside, Menidia beryllina, measuring growth and survival. The Menidia test was used because 1) it has been shown to be sensitive in water column tests, 2) we wanted to determine possible toxic effects on fish and 3) Menidia has a broad salinity tolerance. Elutriates were prepared by mixing sediment with dilution water in a sediment-to-water ratio of 1:4 by volume (EPA/ACOE, 1991) and shaken vigorously for 10 seconds (Tetra Tech, 1986). The one liter mixture was allowed to settle for 24 hours and then carefully decanted into a one liter Erlenmeyer flask.

Toxicity tests with bivalve larvae were conducted following ASTM guidelines (ASTM, 1991) with adaptations for elutriate testing given in the Puget Sound Protocols (Tetra Tech, 1986). Pacific oysters, Crasssostrea gigas, were used in all tests except the third marsh run, which was run in December when spawnable oysters were unavailable. At that time, oysters were replaced by bay mussels, Mytilus edulis. Toxicity tests measuring growth and survival in Menidia beryllina followed the EPA protocol (Weber et al., 1988). A subset of stations were also tested measuring growth and survival in the topsmelt Atherinops affinis (Anderson et al., 1990). Both tests are growth and survival tests in which young larvae are exposed to test solution for 7 days. However, Atherinops is a local species and Menidia is imported. For the second Bay Monitoring Run, which was the last monitoring run to be conducted, larval fish tests were dropped from the tests because they were insensitive in the previous tests. Several tests from freshwater stations were conducted using the 7 day test for Daphnia magna measuring reproduction described by Nebeker et al. (1988).

In the gradient study both the amphipod test using Eohaustaurius and the elutriate bivalve larvae test were performed on test sediment. Protocols were the same as described above. In addition, other toxicity tests were performed on whole sediment and on pore water. The amphipod test using Eohaustaurius was performed within cores used to collect sediment in the field. At three stations in the gradient study, five separate core tubes (10 cm diameter) were taken in to the field and used to sample sediment at each field replicate (5 per station) to a depth of 10 cm. These cores were capped, top and bottom, in the field with 10 cm of overlying water which was retained throughout transport. The actual collection cores were then used as the test containers.

Several toxicity tests were performed in pore water extracted from the sediment. The bivalve larvae test was performed using the same methods as in the elutriate tests (ASTM, 1991). The echinoderm fertilization test was conducted according to methods described by Anderson et al. (1990). Development scoring, cytogenic analysis and cytologic analysis were all conducted on the same samples. Cytogenic and cytologic evaluations were conducted according to the methods of Hose and Puffer (1983). The echinoderm, Strongylocentrotus purpuratus was used for all echinoderm tests. A bacterial mutagenicity test was conducted on Salmonella according to the methods of Kado et al., (1983, 1986). This assay is a simple modification of the Salmonella/microsome test of Ames et al. (1975). The nematode (C. elegans) broodsize and mutagenicity assay was performed using methods of Rosenbluth et al. (1983) and Anderson et al. (submitted MS). This test assesses alterations in broodsize in the F1 and F2 generations as well as mutations in a specific target region of the genome.

All toxicity tests had five laboratory replicates except in the gradient study. After statistically analyzing data from the previous studies, we determined that laboratory variability was so low that using three laboratory replicates instead of five did not effect the ability to distinguish between stations. Field variability was expected to be much greater than laboratory variability, therefore, five field replicates were collected at each station. Positive reference toxicants were used for all tests. Dissolved oxygen, pH, temperature and ammonia were monitored in the tests. Grain size was also measured to evaluate the amphipod tests. In the gradient study sulfides were also measured.

Benthic Analysis

For the gradient study five replicate cores (.018m2/core) were collected from each of the four main gradient stations (GD10/20, GD11/21, GD23 and GD12/22). Cores were immediately screened through .5mm mesh, and fixed in 10% formalin. Samples were transferred four days later into 70% isopropyl alcohol, sorted, identified to the lowest possible taxon, and counted under a dissecting microscope.

Results/Discussion

A thorough, integrated, statistical analysis of the sediment results has not been completed. Although toxicity test results are complete, all of the chemical analyses are not. Therefore, toxicity test results are described, but the results for chemical analysis and the integration of chemical analysis with toxicity test results is considered preliminary. The results for each study and each type of analysis are discussed in that section.

Bay Monitoring

Organic Chemistry

For sediment samples from the Bay Monitoring surveys, PAH concentrations ranged from 81 to 6300 ng/g with a median value of 810 ng/g. A review of PAH residue data previously obtained from San Francisco Bay by the Status and Trends program of NOAA (NOAA, 1988) provided a mean (arithmetic) of about 2.5 ppm dry weight.

In almost all samples, the combustion profile dominated the petroleum profile. In only one of the Dumbarton Bridge samples and one of the Redwood creek samples did most of the PAHs derive from petroleum rather than combustion sources. Combustion residues derive primarily from the atmosphere (the principal local source is probably automobile exhaust) and surface runoff during rainstorms. PAH residues that derive from petroleum and petroleum products are generally from spills, those released into disposal systems and as components of surface runoff.

Metals Chemistry

In general, distributions of the chemicals measured could be classified into two principal groups. These were 1) the elements which show some anthropogenic enrichment in some locations (Ag, Cd, Cu, Pb, and Zn) and 2) those with less pronounced perturbations (Co, Cr, Ni, and V). This was true for both Bay and Critical Habitat surveys.

All trace elements, except V, showed a significant difference with season at several stations. However, when stations were pooled there was no significant difference between seasons.

In order to evaluate the potential for toxicity based on sediment chemistry, trace element concentrations were compared to concentrations which caused toxic effects in previous studies and the enrichment of the element relative to its natural abundance. The Effects Range-Low (ER-L) and Effects Range-Median (ER-M) values of Long and Morgan (1990) are presented to provide a basis for evaluating the potential adverse effects of contamination. The average continental crustal abundance (CA) of each element (Lof, 1987) has been included to provide a measure of the enrichment or depletion of each element relative to its average natural concentration. Figures 5-12 show concentrations of trace elements (Ag, Cd, Cr, Cu, Ni, Pb, and Zn) measured in the Bay Monitoring runs along with ER-L, ER-M and CA values. Table 4 illustrates the mean, standard deviation, median, maximum and minimum concentrations for trace elements in the Bay Monitoring surveys.

The ER-L value of 35 ppm lead was exceeded by stations BB31 (Oyster Point), BD20 (Petaluma River), and BD51 and BD52 (Napa River) during both wet and dry monitoring runs. Lead concentrations in sediments at BC50 (Stauffer) exceeded the ER-L during the wet weather run. BC10 (Yerba Buena Island), BC30 (Richardson Bay), BD40 (Davis Point), BD30 (Point Pinole), BF10 (Pacheco Creek) and BF20 (Grizzly Bay) exceeded the ER-L during the dry weather sampling. The highest concentration of lead in the bay sediments was at Davis Point (BD40), where the lead concentration was equal to the ER-M of 110 ppm.

Most stations which exceeded the ER-L values for lead also exceeded the ER-L values for zinc. This is reflected by the highly significant correlation between lead and zinc concentrations. Sediment concentrations of zinc and lead in San Francisco Bay are greater than their average crustal abundances.

Only Davis Point had silver concentrations which exceeded its ER-L value of 1 ppm. But, all stations sampled were enriched with respect to the average crustal abundance of silver, some as much as ten-fold.

The only station that exceeded the ER-L value for copper was a boat yard in Richardson Bay (BC30). Copper concentrations were four times higher than samples collected outside of the boat yard (BC31) during wet weather. These concentrations appear to be due to contamination of sediments due to boat yard activities.

None of the Bay sediments exceeded the ERL for cadmium (5 ppm). That value is 50 times greater than the average crustal abundance of cadmium. The ERL for chromium was exceeded at many stations and the ER-M for nickel was exceeded in sediments at every station. The ER-M for nickel is much higher than its average crustal abundance.

The chemical concentrations of replicate samples collected from each homogenate were highly precise. This indicates that the homogenization of composite samples at each station was successful.

Toxicity Tests

Amphipod tests - Due to sporadic toxicity in the fine grain reference sediment, it was difficult to determine what actually constituted a toxic response. In the dry weather Bay Monitoring survey the reference site was not significantly different than the controls but in the wet weather survey it was. Contractors statistically compared test sediment to both home and reference sediment (Table 5). This approach makes sense except that some of the response of the organisms in test sediment, when statistically compared to home sediment due to the lack of an adequate reference sediment, may be due to fine grain size rather than toxicity. In this summary, since these data are being used to identify toxic hot spots, a consistent 25% effect level compared to home sediment will be used to identify stations that were toxic. This issue is more thoroughly discussed in the Recommendations for Future Studies section.

In the August 1991 dry weather Bay Monitoring survey, stations that showed a 25% reduction in survival compared to home sediment included:

BA20 - Extreme South Bay
BA30 - Dumbarton Bridge
BA40 - Redwood Creek
BB31 - Oyster Point Marina

BC30 - Richardson Bay, Anderson's Boat Yard
BD20 - Petaluma River, Lt. 18
BD51 - Napa River, West Bank, Mare Island
BF10 - Pacheco Creek
BF20 - Grizzly Bay

These stations were the same stations that had significantly less survival than both the home and reference sediment in statistical tests.

In the April wet weather Bay Monitoring survey stations showing a 25% reduction compared to home sediment included:

BA20 - Extreme South Bay
BA30 - Dumbarton Bridge
BA40 - Redwood Creek
BB31 - Oyster Point Marina
BC31 - Richardson Bay, outside channel
BC50 - Staufer
BD20 - Petaluma River, Lt. 18
BD52 - Napa River, East Bank, Vallejo
BF20 - Grizzly Bay
BG21 - Sacramento River in Sherman Lake

These stations and BF10 (Pacheco Creek) and BC10 (Yerba Buena Island) had significantly less survival than home sediment in statistical tests.

In addition, Rhepoxinius was exposed to sediment from BA20, BA40, BB30, BC30, BC50 and BD40 for the dry weather run. Using the same method that was used for Eohaustaurius to determine toxicity, only BA20, Extreme South Bay, was toxic. This was also the only station with significantly reduced survival compared with both the reference site and controls (Table 6).

Grain size was significantly correlated to survival for Eohaustaurius but not for Rhepoxinius. However, grain size may not be all that is directly effecting the amphipods. Sediment with larger grain size probably also has a lower concentration of contaminants. Ammonia did not exceed 6 ppm in any test, therefore, it is not expected that ammonia contributed to toxicity.

Differences in survival were not significant for tests run with sediments collected in the wet weather versus those collected in the dry weather run. This is consistent with the results of chemical analysis, which showed no significant differences in trace metal concentrations between pooled wet and dry weather samples.

Daphnia Test - The Daphnia test was run on samples from stations BG21 and BG31. There was no significant difference in reproduction when compared to sediment from Lake Mendocino, the freshwater reference site (Table 7).

Bivalve Larvae Tests - For the August 1991 dry weather run, BA40 (Redwood Creek) and BF 10 (Pacheco Creek) were significantly different than seawater controls. Reference sediments were not tested at the same time as test sediments for this run. For the April 1992 wet weather run BD20 (Petaluma River,Lt. 18), BG21 (Sacramento river at Sherman Lake) and BG32 (San Joaquin River at Kimball Island) were significantly different than both the seawater control and the reference sediment. See Table 8 for the means and standard deviations at each station.

Menidia Tests - The Menidia test was only performed on sediments collected in the August 1991 monitoring run. There were no samples that were significantly different than either the seawater controls or the reference sediment (Table 8b). This test was dropped from the April 1992 monitoring run because of its lack of sensitivity.

Critical Habitat Investigations

Organic Chemistry

In the sediment samples from this part of the study PAH concentrations ranged from 35 to 9,100 ng/g, with a median of 1,200. Higher concentrations in these areas may reflect both proximity to runoff input sources and higher organic carbon/silt levels.

Metals Chemistry

Figures 13-21 show concentrations of trace elements (Ag, Cd, Cr, Cu, Ni, Pb, and Zn) measured in the Critical Habitat surveys along with ER-L, ER-M and CA values. By far the highest metals concentrations were found at Peyton Slough (MF22). The concentration of copper in this sample exceeded the TTLC (2.5 g/kg). The concentration of zinc (4.39 g/kg) approached the TTLC (5.0 g/kg). The concentration of cadmium was the highest found in the entire study (19.51 mg/kg). All of these concentrations far exceed the ER-M for these metals. Yet, there were no toxic effects in the bivalve larvae test, a test that is particularly sensitive to metals. In the amphipod test, although there was significant toxicity, survival was 60%. This illustrates the importance of being able to estimate the bioavailable fraction of metals. Additional analysis is being conducted on this sample. Historically the site was used for copper slag. See the Recommendations section for a further discussion of this issue.

Sediments from San Leandro Bay (MB11) and Cordinices Creek were above the ER-M levels for lead (110 ppm) and zinc (260 ppm), as well as the ER-L for copper (70 ppm). Sediments from Cordinices Creek also exceeded the ER-L value for silver (1 ppm). Silva Island Marsh (MC61) exceeded the ER-M value for lead and the ER-L value for zinc. Emeryville Marsh exceeded the ER-M value for zinc and the ER-L value for lead. All of these samples were collected near urban storm drains.

In Tomales Bay, sediment concentrations exceeded the ER-M value for chromium (80ppm) and the ER-L value for nickel (50 ppm). In fact, the chromium and nickel concentrations of sediments in Tomales Bay were the highest in the entire data set. Yet, chromium concentrations were below the average crustal abundance. Serpentine deposits in the area may account for elevated levels of chromium and nickel, although almost all sediments sampled in the RMP exceeded the ER-M for nickel (Fig.3-A-4 and Fig.3-B-4). The ER-M for nickel is well below its average crustal abundance.

Toxicity Tests

Amphipod Tests - In two out of the four marsh surveys, survival in the reference sediment was poor. Therefore, the same method for reporting toxicity as was used in the Bay Monitoring runs will be used for the Critical Habitat Surveys. Table 9 shows mean survival and statistical analysis for each station, comparing results from each station to both the home and reference sediment.

Stations showing a 25% reduction in survival compared to home sediment included:

MF10 - Boynton Slough C1
MF11 - Boynton Slough C3
MF12 - Boynton Slough C4
MF20 - Hill Slough, below bridge
MF21 - Hill Slough, above bridge
MF22 - Peyton Slough, back end of slough
MD31 - Tolay Creek mouth
MD32 - Napa Slough at bridge
MD33 - Sonoma Creek at Tubbs
MD34 - Sonoma Creek at bridge
MC30 - Emeryville Marsh at EBMUD storm drain
MC50 - Corte Madera Marsh S of Industrial Rd.
MD20 - Gallinas Cr. at John F. McInnis County Park
MD21 - Novato Creek at Lock

Regression analysis indicated that the percent sand of samples from critical habitat sediments accounted for little of the variability in survival for the Eohaustaurius tests.

Daphnia Test - The Daphnia test was run on stations MF10 (Boynton Slough C1), MF11 (Boynton Slough C3), MF20 (Hill Slough, below bridge) and MF21 (Hill Slough, above bridge). The only station that showed a significant decrease compared to reference sediment, which had high reproduction, was MF20. The Daphnia test was less sensitive than the amphipod test in detecting toxicity.

Bivalve Larvae, Menidia and Atherinops Tests - Results for these three tests are summarized in Table 10a and 10b. The reference sediment was toxic in two out of the four marsh runs for the bivalve larvae test. These were the same samples that were toxic in the amphipod test. Since the runs where the reference site was toxic were the only runs where test sample toxicity was observed, only samples that were significantly more toxic than seawater controls will be listed. These stations for the bivalve test are:

MF10 - Boynton Slough, C1
MF11 - Boynton Slough, C3
MF12 - Boynton Slough, C4
MF13 - Chadbourne Slough, CR2
MF23 - Peyton Slough, mouth of slough
MD10 - Miller Creek at Las Gallinas discharge
MD11 - Miller Creek upstream from discharge at fence
MC61 - Silva Island Marsh at Seminary Dr. storm drain

MF20 and MF21 were not tested.

The only sample that was toxic to Menidia, besides the Lake Mendocino reference sediment, was MC61 (Silva Island Marsh at Seminary Dr. storm drain). Atherinops was used to test for toxicity on the 8 Suisun Marsh stations. Only MF21 (Hill Slough, above bridge) was toxic to this species. Due to the general insensitivity of the elutriate fish tests they were dropped from the final Bay Monitoring survey.

Gradient Study

Organic Chemistry

The highest concentrations of PAHs in the entire Regional Monitoring Program were measured in Castro Cove. At the station closest to the source, PAH concentrations were 21 and 8.4 ppm, geometric means, in deep and shallow sediments, respectively. At the intermediate stations the geometric mean total PAHs in deeper sediments were 1.1 and 0.9 ppm, and at the Point Pinole Pilings (PPP) station, the station farthest from the source, concentrations were 0.6 and 0.9 in deep and shallow sediments respectively. With the exception of PPP, the PAHs in the Castro Cove stations derived principally from petroleum, and were associated with complex mixtures of other petroleum hydrocarbons. The "fingerprint" of PAH compounds in the surface sediments at PPP was the typical combustion profile characteristic of most areas of San Francisco Bay.

In the gradient study, contaminant variables were highly and significantly correlated with each other, and with related variables such as the organic carbon and nitrogen content. Thus mortality in the amphipod test was significantly correlated with all of the contaminant variables measured. Development of oyster larvae in the elutriates, however, was most significantly associated with the organic carbon and nitrogen content of the sediments, rather than with the contaminants, suggesting that variables such as small particulate material in the elutriate might be contributing to the measured effects.

Metals Chemistry

Concentrations of trace metals in pore waters collected for the gradient are displayed in Table 11. Concentrations of trace metals in sediments are displayed in Table 12. Comparisons of bulk aqua regia extractable concentrations of trace metals in sediments were poor predictors of pore water concentrations. Dilute acid leach extractions, which are not yet completed, may provide a better measurement of the "labile" concentration of particulate metals.

Toxicity Tests

Amphipod Tests - Three types of amphipod tests were conducted in the gradient study that were described in the Study Design. They were: 1) the standard amphipod test using Eohaustaurius, 2) a test exposing Eohaustaurius to sediment in cores that were used for sediment collection and 3) an experiment with dilutions of Castro Cove and Carr Inlet sediment using Rhepoxinius and Eohaustaurius at two different salinities.

For the standard amphipod toxicity test, results yield evidence of a toxicity gradient related to chemical concentrations. Toxicity and chemistry did not show a distance gradient except that the least toxicity was observed at the station farthest from the source and the greatest toxicity was observed closest to the source. In the middle stations hydrodynamics and possibly dredging may have mixed sediments in a way that the toxicity and chemistry of the two middle stations were reversed. Trace metal assays for chromium, zinc, copper, nickel, lead, cadmium, and silver were highest in the station closest to the source. Conversely, the lowest trace metal concentrations were in the deep core farthest from the source, the only station to not differ significantly from the controls. In general, the ranking of toxicity from most toxic to least toxic for this test was: GD10 deep, GD20 shallow (both of these station were closet to the outfall), GD23, GD12 (PPP shallow), GD11 and GD21 (which showed no difference between the shallow and deep at the same station), and GD22 (PPP deep). Statistical tests have not yet been done to determine if stations differed significantly from each other.

All stations except PPP (deep) differed significantly from the control. Variance among field replicates was low. Regression analysis indicated that toxicity was significantly correlated with (most metals), PAHs, total organic carbon (TOC) and grain size. Particle size of the sediments is critical in determining toxicity not only because of its mechanical effect on burrowing ability but also effects on contaminant and TOC concentration and bioavailability.

The amphipod tests using sampling cores showed the same trend although they seemed to show less sensitivity. Amphipod mortality was 5% in samples of home sediment tested in core tubes. These results from negative controls indicate the suitability of the core tubes as test containers. Intact cores from PPPP, the gradient reference site, showed 29% mortality, while the two Castro Cove stations tested (GD10/20 and GD11/21), with this method, had 50% and 54% mortality respectively.

The range of concentrations tested for Castro Cove sediment (100%, 80%, 60%, 40%, 20% and 0%) was too broad to establish a strong dose response. Over 80% mortality occurred in the first dilution (20% Castro Cove). However, salinity did not have an impact on the survival of Eohaustaurius. Survival was almost identical at salinities of 10 and 25 ppt. Rhepoxinius did not test well and exhibited unsatisfactory survival (56%) in the Carr Inlet control.

Bivalve Larvae Test (elutriate and pore water) - There was a significant difference in toxicity between the pore water and elutriate samples in the deep cores (P=0.0001) and a notable difference in toxicity between the pore water and elutriate samples in the shallow layer samples (Table 13). Pore water samples detected significant toxicity at 4 of the 5 Castro Cove stations.

By comparison, elutriate samples found only one station (GD20) to be significantly more toxic than the reference station (PPP), and this was only in the deep station. These results suggest that pore water tests were more sensitive than elutriates in detecting sediment toxicity, consistent with the fact that elutriates are more dilute fractions of the sediment than pore waters.

Deep cores were more toxic than shallow cores, perhaps indicating that recent deposits are less contaminated with substances toxic to the test organisms. Using the results from deep cores, both elutriate and pore water tests were able to distinguish a statistical difference between stations.

For these tests, variability among field replicates was greater than variability among laboratory replicates. Perhaps more effort should go in to field replication than laboratory replication. For these tests only three laboratory replicates were used.

Oyster pore water toxicity test results were not correlated with pore water ammonia concentrations. In the beginning of the study there was concern about the possible effects of ammonia on pore water toxicity test results, especially in the deep cores. Neither ammonia or hydrogen sulfide seemed to be a problem in the pore water tests.

Oyster pore water toxicity test results were significantly correlated with the results of amphipod solid phase tests, and very significantly correlated with results of sea urchin embryo development in pore waters. They were not correlated with sea urchin fertilization test results.

Toxicity results from elutriate samples, but not pore water samples, were significantly correlated with grain size. There may be a physical effect of fine grain particles in the elutriate.

<u>Sea urchin tests (pore water)</u> - No differences in fertilization success were observed when comparing deep core samples, however, the two shallow layer samples tested (GD10 and GD12-PPP) were both significantly more toxic than the deep samples taken at the same station. The Carr Inlet control was not used in any of the statistical tests because high toxicity was observed in the full core sample. This was also observed in the bivalve larvae test.

The responses observed with the sea urchin development assay contrast with those observed using the fertilization assay. For the development assay, highly significant differences in toxicity of full core samples were observed among stations. When the means of the field replicates for GD20, GD21 and GD23 were compared to the mean of the field replicates for PPP all stations were significantly more toxic than PPP. For this test the shallow layer samples were not significantly more toxic than the deep samples,in fact, one deep sample was more toxic than the shallow.

Additional data were obtained by scoring 25% and 50% dilutions of one laboratory replicate for each field replicate for the deep core samples. Results showed that their order of toxicity from most toxic to least, based on EC50 values and 95% confidence intervals was: 1) GD23, 2) GD20 and GD21 and 3) GD22 - PPP the least toxic. Field variability was also characterized using this method. For the deep core samples, coefficients of variation ranged from 15% for GD20 to 50% for GD22 - PPP. However, the PPP value is especially high because of one anomalous field replicate.

It should be noted that an unusual response was observed in all of the samples in which development was scored: the hatching of gastrula had not occurred normally. For the purposes of this study only, they were considered normal embryos. Still, the sea urchin development data demonstrated excellent concordance with the oyster development data. For both tests, GD20, GD21 and GD23 samples elicited almost 100% abnormal embryos: whereas PPP only elicited moderate toxicity. For all echinoderm studies, as with other pore water studies, water quality parameters were in acceptable ranges, including measurements of ammonia.

Sea urchin cytology and cytogenetic data are still preliminary. However, they indicate that the Castro Cove gradient stations did not exhibit high genotoxic potential but that cytologic aberrations may reflect the potential for cytotoxic effects at the site.

<u>Bacterial Mutagenesis (pore water)</u> - Of the samples tested there were two that elicited mutagenic activity. Both of the samples that tested positive were from the GD23 deep core group of extracts.

<u>Nematode Broodsize and Mutagenesis (pore water)</u> - Results of this test indicate that some pore water samples may be slightly toxic to the nematode but that the substances causing toxicity were not highly mutagenic.

Benthic Community Analysis

All stations were moderately similar in species richness (number of taxa), with the highest diversity at station GD23 (29 taxa) and the lowest at the station closest to the source (16 taxa). Faunal assemblages were similar for all stations, with one or two species dominant in each of the three major taxonomic groups; crustaceans, polycheates, and bivalves. Crustaceans were by far the numerically most important group for all stations. These samples were not collected synoptically with the other samples but were collected two weeks later.

Recommendations For Future Studies

During the performance of the sediment studies and the analysis of data it became apparent that there were several areas that needed further study in order truly identify a toxic hot spot and to develop meaningful sediment quality criteria:

1. In this study and in others conducted by the Regional Board several sites with no or few sources of contamination and low chemical concentrations exhibited high levels of effects in toxicity tests. This occurred in both the amphipod and the bivalve larvae tests. Sites where this occurred were Tomales Bay, Drakes Estero and Bolinas Lagoon. In order to truly identify a toxic hot spot the cause of the effects (mortality or abnormality) in these areas should be ascertained. This could be done with sediment Toxicity Identification Evaluations and positive interference studies.

2. A fine grain reference site needs to be identified in order to have a "clean" sample with the same characteristics (grain size, TOC) as the test sediments for statistical comparison. Investigators in other areas of the country are also finding significant effects at "clean" reference sites. Although finding a reference site that does not produce significant effects is the preferable approach, if this is not possible, a different approach needs to be considered by the Bay Protection Program in defining what actually constitutes a significant effect. This is particularly important for the amphipod test.

   Another approach may be to use the reference sediment for comparison, when there is no significant difference between home sediment and reference sediment. When there is a difference, a 25% decrease in survival between home sediment and test sediment could be used. Fine grain sediment usually does not account for more than 10-15% mortality (personal communication with Ted DeWitt). Unfortunately, this provides an inconsistent evaluation of what constitutes "toxicity". Other possible options may be to use an alternative methods based on quantitatively determining the effect of fine grain sediment on the species of amphipods being used in tests, pooling reference site data or making a decision considering the impact of fine grain sediment and potential environmental impact.

3. Methods for determining the bioavailable fraction of metals in a sample should be evaluated. This issue became particularly apparent in the Peyton Slough sediment sample. In this sample copper exceeded hazardous waste levels and zinc approached those levels and yet there was no toxicity in the bivalve larvae test and 60% survival in the amphipod test. Digestion for total metals was used for these measurements. Since acid volatile sulfides have only been found to be useful for cadmium, other methods such as a weak acid leach or just measuring the fine grain portion of the sediment should be tested. Toxicity tests should be conducted and metal concentrations should be measured by these three methods plus total metals concentrations.

4. Several areas dealing with sampling need to be better addressed. Depth of sample should be better evaluated. The sample depth may be station or area specific. It should be based on the depth that contaminants in sediment may be bioavailable. The artifacts of homogenizing sediment that contain a high sulfide layer should also be considered. Power analyses should also be conducted to determine the optimal amount of grabs in a composite sample. In addition, statistical analyses should be performed to determine if more effort should be going in to field replication and less in to laboratory replication.

BIOACCUMULATION

Study Design

The purposes of the bioaccumulation study were to 1) describe the distribution of trace metals and organics in organisms in the San Francisco Estuary, 2) determine the differences in contaminants in organisms collected in wet and dry seasons, 3) determine the differences between mussels transplanted to shallow and deep water column depths at the same station, 4) determine the effect of depurating sediment from the guts of organisms on the contaminant levels in the whole bodies, 5) determine the optimum length of exposure for transplant organisms and 6) determine the differences in uptake in three species, each with their own salinity tolerances.

Shellfish were deployed at eight stations, two in the Sacramento - San Joaquin River Delta, two in San Pablo Bay, one in Central San Francisco Bay and three in the South Bay (Figure 22). The project was conducted in two phases; once during the dry season (initiated on 4/1/91) and once during the wet season (initiated on 12/16/91). The species tested was mostly Mytilus californianus. Freshwater clams (Corbicula sp.) and oysters (Crassostrea gigas) were also deployed at more freshwater stations because of their tolerance to low salinity waters. However, during one season clams deployed in the Sacramento River were lost and during the other season clams deployed in the San Joaquin River were lost. This limited the amount of data for Corbicula.

At several stations uptake rates were compared between oysters and mussels. Mytilus was transplanted for 30, 60, 90 and 120 days. All other shellfish were transplanted for 90 days. At two sites during the dry season and three sites during the wet season the effect of depuration on mussels was tested by depurating half the organisms. The effect of depth of deployment was tested by deploying mussels at two depths, surface and one meter off the bottom, at three stations. Chemical analysis of tissue samples included analysis for metals, PCBs, DDTs and PAHs.

Methods

Experimental mussels were collected with stainless steel knives at Bodega Head, California, and were handled with polyethylene gloved hands. Phase I (wet weather) oysters were collected at Drakes Bay, California by Johnsons Oyster Company. Phase II (dry weather) oysters were collected by Ted Keiper of the Mad River Oyster Company in Humboldt Bay, California. Control samples were taken at the time of collection to serve as baseline indicators. Control samples were frozen within 12 hours of collection and stored for later analysis. In addition, field blanks were also collected and handled in an identical manner to transplanted specimens but were not deployed. Transplanted bivalves were placed in mesh bags and transported in coolers to transplant sites. After exposures of 30, 60, 90 or 120 days, the samples were collected and frozen at -10 C until dissection. Samples were thawed and dissected in a filtered air positive-pressure room with stainless steel scalpels that had been tested for contamination (Stephenson et al. 1979). Detailed methodologies are found in Phillips (1988). All samples were homogenized with a Brinkman Tissue Homogenizer equipped with a titanium shaft that was cleaned with detergent, methanol and petroleum ether before each homogenization.

Levels of selenium, arsenic, silver, chromium, and lead were determined by GFAAS. Copper, manganese, cadmium, and zinc were determined by FAAS. Dry weights were used in the plots and statistics. Although lipid concentration was measured, data were not normalized to lipid weight since this is usually not done for bivalve bioaccumulation studies (Phillips, 1980). Detection limits are given in the California State Mussel Watch reports (e.g. Phillips, 1988).

The analytical procedure for organics followed that described by MacLeod et al. (1985). The extraction method involved a cleanup step with high pressure liquid chromatography with analysis on Hewlett Packard HP 5890 for pesticides and PCBs and a Finigan Ion Trap #ITD 800 for the PAHs. Detection limits for organics are also provided in Phillips (1988).

Results/Discussion

Since field blanks did not differ significantly from controls, field blank values were used in all statistical comparisons. The results of statistical tests between field blanks and bivalves transplanted in San Francisco Bay are given in Table 14. They indicate that a fairly high percentage of stations were significantly higher in metals than field blanks (35 to 78% in Phase I- dry season and 71-86% in Phase II- wet season). The range is given since tests were performed on 30, 60 90, and 120 day transplants. The percentage of tests that were significantly different increased directly with duration of exposure in Phase I, but no trend was apparent in Phase II (most metals were elevated after 30 days and remained high). Since no field replicate analysis was conducted for organics, no statistical analyses were performed.

Stations within San Francisco Bay were tested for geographic trends. Stations were near channels in different basins of the Estuary. Therefore, trends were for general areas of the Estuary and not for localized areas of contamination. The results of the statistical tests between stations indicate that, in general, stations in the southern end of the Bay (Coyote Cr., Dumbarton Br., Redwood Cr.) were significantly different than the stations in the northern end (Pt. Pinole, Davis Pt.) or central part of the Bay (Treasure Island). In Phase I the longer the transplant duration the greater the number of statistical tests that were significant between stations. In Phase II no such trend existed. Further resolution of differences was not increased by using different species, depurated mussels, or mussels that were deployed near the bottom. An interesting exception was that oysters were better than mussels in resolving differences between stations for zinc.

Table 15 reports the mean values for Phase I and Phase II for the stations furthest south (Coyote Cr. or Dumbarton), Treasure Island which is centrally located and receives the most flushing, and the stations furthest away from the mouth of the Bay in the north (Davis Point or Point Pinole), which should be reflective of contaminants from the Sacramento-San Joaquin River Delta. Silver was much higher in the South and Central Bays than in the North. There were no apparent trends for mercury, lead, cadmium or zinc that could be statistically verified. There was some evidence of a trend of slightly higher levels of selenium, and copper in North and/or Central Bay.

No replicate analyses were done on the organic levels in bivalves, so statistical tests could not be performed. However, levels of most of the organics (PCBs, DDTs and chlordanes) were generally higher in the South Bay. The station at Coyote Creek was exceptionally high in comparison to the control site or the other stations in the Bay. PAHs were highest in the Central Bay but were also fairly high in the South Bay.

In comparing wet and dry seasons, there was no difference between Phase I and Phase II mussels for any metals. In oysters, there were significant differences only in cadmium, mercury and zinc levels at Coyote Creek. Since there was a drought during both transplant periods there was not much difference in runoff between Phase I and Phase II. A more interesting comparison would be between seasons when there is average or above average rainfall.

In comparing samples deployed at different depths, there were no differences between mussels deployed at shallow depths or 1 m off the bottom in either Phase I or Phase II for any metals.

A low percentage of metals were significantly different between depurated and undepurated mussels. Most of the metals tested were not significantly different or were only significantly different in one of the five stations on which this test was performed. The exceptions were lead and selenium which differed in two to three tests of the five performed. Selenium is particularly interesting since it differed significantly between depurated and undepurated only during Phase I, indicating a possible flux of selenium laden sediment during that period.

The ratios of concentrations of metals and organics for mussels and oysters is illustrated in Table 16. The results indicate that there was a near one to one correspondence between the species for chlordane, DDT and PCBs, but not for PAHs. The metals differed greatly between species. Mussels accumulated more of some metals and oysters more of others. This suggests that the two species cannot be used interchangeably for metals and PAHs.

The duration of exposure was studied at 30, 60, 90 and 120 days and indicates that in most cases mussels accumulate more contaminants with longer deployments (Table 17, Figures 23-26). Cadmium is the exception in that the levels in mussel controls and field blanks from Bodega Head were higher than in any of the mussels after transplantation to the Bay. In this study, an equilibrium appeared to be attained during the three and four month transplants for copper, mercury, lead, selenium and possibly DDT. No equilibrium was obtained in mussels for silver and PCBs after 120 days. The sum of the PAHs showed a rapid increase the first month and a decrease or leveling off after 2 months. The patterns exhibited for DDTs, PCBs, and chlordanes were similar indicating a similar source of these compounds. The transplant duration in future studies should be as long as possible since silver, PCBs and possibly DDT did not approach equilibrium over the 4 month interval of this experiment. If these contaminants are excluded then a transplant interval of 3 to 4 months would be adequate. In the Mussel Watch program mussels are deployed from 4 to 5 months. In order to compare stations a consistent time period should be used.

In this study an unsuccessful attempt was made to deploy caged Macoma to measure sediment uptake. An attempt was also made to collect Potamocorbula. Further studies should be made with Potamocorbula to evaluate its utility as a biomonitoring tool since it has a wide salinity tolerance.

WATER COLUMN

Study Design

Bay Monitoring Surveys

The primary objective of the water column portion of the Bay Monitoring Surveys was to assess the current water quality of the San Francisco Bay-Delta and the Sacramento and San Joaquin Rivers in comparison to the chemical specific and toxicity water quality objectives established in the Bays and Estuaries Plan and Inland Surface Water Plan (SWRCB 1991 a,b). Organic chemical analysis and chronic toxicity tests were performed on water samples collected throughout the Estuary to determine if objectives were being met.

Organic contaminants were measured in the water column in order to 1) evaluate concentrations of specific constituents for compliance with the Statewide Plan's water quality objectives, 2) start generating data so that long-term trends can be determined, 3) identify areas of high organic contaminant concentrations or hotspots, 4) accumulate data for application in bay wide pollutant fate and transport models, and 5) provide information for the interpretation of chronic toxicity testing of ambient waters. Water samples were collected using an onboard pumping system separating the particulate and dissolved fractions. Samples were collected at 15 stations goegraphically distributed throughout the Estuary on two separate occasions (June 1991 and April 1992).

The objectives for chronic toxicity testing were similar to those for organic contaminants. Samples were collected from 12 of the 15 stations for toxicity testing. Two different species were used for toxicity testing: Strongylcentrotus sp. (sea urchin) and Menidia beryllina (silverside fish).

Critical Habitat Investigations

Toxicity tests were performed on samples collected from critical habitats (i.e. wetlands) that received the discharge of treated wastewater or stormwater runoff. Stormwater investigations related toxicity in wetlands to storm intensity.

Methods

Organic Chemistry

Organic contaminant sampling was accomplished using an onboard pumping system. Water was pumped by a Teflon impeller pump through a 3/4 inch Teflon tubing to a filter holder with a glass fiber filter with a rated pore size of 0.3 um. Filters were changed whenever the flow rate began to fall off, typically every 20 liters in San Francisco Bay. Water was then passed through four polyurethane plugs mounted in series. Approximately 100 liters were passed through the sampling system at each station. The polyurethane plugs were exhaustively cleaned in the laboratory prior to field sampling by soxhlet-extraction, a minimum of three days with 2:1 hexane:acetone and a minimum of three days with methanol. The plugs were then sealed in teflon bags for transport to the field. The remaining sampling equipment was rinsed with methanol prior to use in the field. The system was transported to the field in a closed state to prevent contamination.

Custom-built soxhlet extraction units were used to extract the organics from both plugs and filters; an acetone extraction is followed by hexane. Water was removed by partitioning into hexane in a separatory funnel; extracts were reduced to 1-2 ml for cleanup with florisil-column chromatography. Florisil was activated at 650 degrees centigrade for 4 hours and deactivated with 0.5% water. The column (18 grams florisil) was eluted with hexane (volume sufficient to elute p,p' - DDT), 30% methylene chloride in hexane (volume sufficient to elute p,p'- DDT but not dieldrin, and 50% methylene chloride in hexane (volume sufficient to elute dieldrin).

Extract volumes were concentrated to approximately 0.1 - 1.0 ml and analyzed by both electron capture gas chromatography and mass spectroscopy (Varian 3400 autosampler). The STAR data system of the GC converts the analogue signals to integrated areas, which are compared with those of authentic standards eluting at the same retention time, and produces a report with compound names and amounts in picograms. The data system of the GC/MS identifies compounds based on a combination of retention times and spectral characteristics and also reports compounds identified, and the amounts in nanogram or picograms of each. Both report files are converted to an ASCII format, in which they can be read into the data management system.

Toxicity Tests

Toxicity tests were generally conducted according to EPA and ASTM protocols. Modification or deviation from protocols are documented in the Quality Assurance Project Plan developed by the contractor and approved by the Regional Board's Quality Assurance Officer.

Different test organisms were used in each survey depending on seasonal availability and salinity of the ambient waters. Each toxicity test had varying endpoints ranging from mortality to inhibition in growth or reproduction. A summary of each survey and test organism is presented below.

Toxicity tests used in the Bay Monitoring Surveys were the larval fish growth and survival test using Menidia beryllina (silverside minnow) and the sea urchin fertilization assay using Strongylocentrotus purpuratus. The silverside minnow test involved exposing 7-9 day old fish to test solutions. Seawater collected from the Bodega Marine Laboratory was used as a seawater control and Arrowhead Spring water with artifical salts was used as a salinity-adjustment control. The test duration for the silverside minnow was 7 days. Statistical comparison are made between the control survival and growth and the test solutions. The sea urchin test involves exposing sperm to the test solution and then adding eggs to examine fertilization success. The test duration was approximately 40 minutes. The same control waters were used in the sea urchin test.

The Critical Habitat Investigations employed a number of different toxicity tests depending on the salinity of the water being tested. In water samples with higher salinities, marine tests using the silverside minnow, sea urchin, mussel development assay (Mytlius sp.), and mysid survival assay (Mysidopsis bahia) were performed. Freshwater tests included the water flea survival and reproduction assay (Ceriodaphnia dubia), the fathead minnow larval growth assay (Pimephales promelas), and algal growth assay (Selenastrum).

Results/Discussion

Bay Monitoring Surveys

The organic chemistry results from the bay surveys are not currently available. It is anticipated that the results will be available in January 1993. Toxicity testing indicated statistically significant toxicity during the June 1991 survey. Menidia survival was statistically different than controls at station BF30 (Port Chicago). Sea urchin fertilization was inhibited at BA40

(Redwood Creek). On other assay or station exhibited significant toxicity. No significant toxicity, using the same tests, was observed in the April 1992 survey.

Critical Habitat Investigations

The results of toxicity screening in the two critical habitat systems indicated that Ceriodaphnia dubia is the preferable test organism for evaluating effects of stormwater discharges. This conclusion is supported by the monitoring results generated by the Santa Clara and Alameda Counties stormwater monitoring programs, in which the incidence of response of Ceriodaphnia was much higher than that of Pinephales promelas or Selenastrum. The most useful measure in the Ceriodaphnia test was mortality as expressed by the median time to lethality (LT_{50}).

The first storm occurring in October 1991 produced nearly 2 inches of rain, effectively flushing the DUST system. Samples collected following the storm event exhibited toxicity to Ceriodaphnia with generally low conductivity values. A second storm in November 1991 produced a horizontal conductivity gradient in the DUST system. Toxicity and conductivity data from these two events is depicted in Figure 27. Toxicity is expressed in time units indicating the duration of exposure which caused mortality in 50% of the test animals (median time to a LT_{50}). Linear regression of the LT50 versus sampling site (dotted line) yielded a slope which was not significantly different from zero ($p=0.778$) for the October storm and a slope difference from zero ($p=0.026$) for the November storm. Toxicity and conductivity correlations were $r=0.75$ and $r=0.97$ for the October and November storms, respectively. The conductivity reflects the degree of dilution and thus provides an indicator of the potential toxicity from stormwater.

Another storm event in March 1992 demonstrated cessation of toxicity (Figure 28). Flow through the DUST system ceased three days after the storm. At this time the water was still toxic and was retained in the creek and the debris basin. Four days later, no toxicity was detected in the debris basin (Station 5) nor was there any detected in the creek (Station 3). This indicates that dissipation of toxicity could be related to toxicity-removal processes which may take place due to retention time.

DATA MANAGEMENT

To manage the data for the entire RMP, EcoAnalysis Inc. developed a common format for all laboratories participating in the program. This allowed data to be more easily interpreted, analyzed and thoroughly checked for quality assurance. All laboratories in the program were provided with consistent formats with QA programs integrated into the data input system to insure accurate data entry. Data were generated at each of the laboratories and sent to EcoAnalysis for review.

EcoAnalysis performed the following operations to combine and review the various datasets: 1) data were extracted from the form received and read to SAS datasets for quality assurance review, 2) data received were compared to master list of data collected, 3) data were reviewed for consistency in station designations (codes), station descriptions, sampling dates, replicate designations and measurement units, 4) ranges of data values were reviewed, 5) apparent outliers and missing data were checked with the respective Principal Investigator and 6) when necessary, laboratory replicates were averaged.

MAJOR ACCOMPLISHMENTS OF PROGRAM

1. The Pilot Regional Monitoring Program evaluated techniques and protocols used to measure chemical contamination, toxicity and bioaccumulation in the Estuary. As a result of this program, a $1.15 million Baseline Monitoring Program will be started in the Estuary this year. Chemical contamination and toxicity in the water column and sediment, and bioaccumulation in the water column will be monitored. This will be a program that will measure longterm temporal and spatial trends and act as the backbone and point of comparison for our Local Effects Monitoring Programs.

2. In the pilot RMP most of the marshes and mudflats in the Estuary were surveyed for chemical contamination and toxicity. Information was generated for vast areas of critical habitats.

3. Toxic hot spots were identified throughout the Bay and also in critical habitat areas.

4. A format was generated for data, and laboratories were trained to use these formats, so that data could be easily checked for quality assurance, and integrated for statistical analysis. Laboratories trained to use this system are those being used for the statewide Bay Protection Program. This provides the first step in setting up the statewide database.

5. Data generated in this program can be combined with other data to generate Apparent Effects Threshold (AET) values for San Francisco Bay. These values will be used to guide in the evaluation of sediment chemistry, for sediment cleanup and for marsh restoration.

6. Techniques were developed and protocols were evaluated that will be used in the statewide Bay Protection Program. Problems that arose are currently being addressed by designing studies to identify fine grain reference sites, determining the cause of toxicity in areas with no sources of contamination, refining toxicity test protocols and determining the best technique to measure the bioavailability of metals. In the long run this will make the program more scientifically rigorous and provide more certainty in the final results of the program.

PART II. WASTELOAD ALLOCATION STUDIES

Introduction

One of the tasks identified in the Bay Protection and Toxic Cleanup Program workplan was the development of a wasteload allocation for South San Francisco Bay based on a predictive water quality model. EPA requires wasteload allocations for water bodies where water quality objectives are exceeded. The goal of a wasteload allocation is first, to determine the maximum loading of pollutants to the water body which will result in attainment of water quality objectives, and second, to allocate the total allowable load among the existing sources, including point sources, nonpoint source, and background.

An important tool in developing wasteload allocations is a predictive water quality model, which is a model of the fate and transport of pollutants. Many processes may affect the fate or transport of pollutants including hydrodynamics, sediment dynamics, chemical speciation, biological uptake, degradation and volatilization. In most aquatic systems these processes are far too complex to simply measure. Predictive water quality models attempt to integrate available data describing the system and use simplifying assumptions where necessary to estimate resulting water quality conditions from different pollutant loading scenarios. Model results can be used to identify possible wasteload allocations and select the most reasonable alternative.

South San Francisco Bay

South San Francisco Bay has long been identified as an area of concern due to the combination of the large volume of wastewater discharged by the cities of San Jose, Sunnyvale and Palo Alto, and the limited amount of flushing flows due to low fresh water inflows. Improved treatment over the past two decades has resolved some of the problems associated with waste discharge such as low oxygen levels and eutrophication. Current concerns are focused on the impacts of toxic pollutants. South San Francisco Bay south of Dumbarton Bridge was listed by both the State of California and the US EPA on the Clean Water Act Section 304(l) list of water bodies impacted by toxic pollutants from point source discharges. The toxic pollutants that were identified were cadmium, copper, lead, mercury, nickel, selenium and silver.

Due to the history of concern, South Bay has been extensively studied and water quality data for this area are more complete than for most other parts of the Bay. However, there are still significant limitations to much of the data including lack of adequate detection limits and low precision. In addition a high percentage of South Bay is shallow or intertidal, so that measurement of basic hydrodynamic variables such as currents or depth is difficult or impossible.

Approach

Model development has two distinct components: modelling of available data and collection of additional data to improve the model. These components are two parts of an iterative process; data collection supports initial modelling efforts which in turn serve to define the most important data gaps. Once those gaps are filled, a more sophisticated model can be developed. Therefore, a phased approach to the wasteload allocation has been undertaken. The first phase was data compilation and model development based on existing data. Although the uncertainty of the initial model results was expected to be great, it was hoped that the results would be useful in supporting Regional Board regulatory actions limiting the discharge of pollutants to South Bay. Generalized models can be useful in making such decisions, as long as the uncertainty associated with their predictions is taken into account.

The second phase includes data collection to address questions related to sediment transport. The lack of understanding of the fate and transport of pollutants associated with sediments has been identified as one of the greatest limitations in developing a predictive water quality model. This phase also includes some hydrodynamic modelling to improve the estimate of residence time for conservative substances in South Bay, and to estimate the residence time of sediment particles.

Phase 1

Scope

The first phase was to perform initial modelling based on available data. The work in this phase was performed by EPA's Center for Exposure and Assessment Modelling. This phase was funded by a grant from the San Francisco Estuary Project and State funds previously earmarked for the wasteload allocation in addition to Bay Protection funds. The purpose of the study was to develop a water quality model to examine the fate and transport of metals in the South Bay, and to recommend possible wasteload allocations based on the model. A secondary goal was to identify the highest priority data needs to improve the ability to model the system.

The study included five major tasks:

1. Review of available data
2. Nontidal (tidally averaged) water quality simulation
3. Tidal water quality simulation
4. Modelling of the partitioning of metals between the dissolved and total phases.
5. Prediction of the results of reducing loading of metals to South Bay.

The water quality model was initially intended to evaluate copper, lead and nickel. Modelling of selenium and mercury is not feasible at this time because concentrations in water that can cause problems are lower than commonly used detection limits. Copper, lead, and nickel were identified as higher priority than cadmium, chromium, or silver based on frequency of exceedance of water quality objectives or effluent limitations. Initial model runs were better able to predict existing concentrations of copper than nickel or lead. In addition, the water quality objective for copper is the most frequently exceeded. For these reasons, most of the study focused on copper.

Methods

Water quality modelling was performed using the US EPA water quality model Water Quality Analysis Program or WASP4. WASP4 is essentially the coding of a series of equations based on the principle of conservation of mass. The water body is divided into a series of segments, and a mass balance of the pollutant in each segment is calculated based on physical transport into and out of the segment, and chemical or biological transformation or accumulation within the segment. WASP4 has the ability to account for sediments as a source or sink of pollutants.

Physical transport of pollutants is driven by hydrodynamics. The nontidal model takes into account advective transport produced by the inflows from the three treatment plans and from local runoff. All other circulation including wind and tidally driven currents is accounted for in a dispersion factor. The purpose of the nontidal analysis is to describe the large scale and long term behavior of the system.

The steps in the modelling process were as follows:

1. Generate a computerized grid system describing South Bay as far north as the Oakland Bay Bridge.
2. Estimate the dispersion coefficient for each segment based on a previous study of South Bay.
3. Input loadings from point sources and stormwater. Parameters included flow, metals concentrations and suspended solids.
4. Simulate suspended solids concentrations and calibrate with historical data.
5. Simulate metals concentrations, and calibrate with recent water quality data.

For the tidal analysis, the two dimensional vertically averaged hydrodynamic and sediment transport model SED2D was used to describe the variation in currents over the tidal cycle. This model was linked to WASP4 to examine variation in water quality over the tidal cycle.

Partitioning of copper was modeled using the geochemical speciation model MINTEQA2. MINTEQA2 was used to predict partitioning of copper between the dissolved and total phase for a variety of conditions. Typical partition coefficients were estimated for each segment of the model. These partition coefficients were used as input parameters to the WASP4 model.

Results

The final report from CEAM is due in December, 1992. This summary of results is based on the draft report.

One of the greatest limitations in modelling the transport of metals was the lack of knowledge concerning sediment transport. For this study, the assumption was made that, on an annual basis, South Bay south of Dumbarton is neither net depositional or net erosional. Under this assumption, sediment resuspension may affect water column concentrations of pollutants, but sediment movement does not serve as a net transport mechanism into or out of the South Bay. Because this assumption only seemed reasonable as an average annual condition, the model predictions were limited to annual average conditions. While ultimately the differences between wet weather and dry weather conditions will be very important to understand, annual average conditions allow us to address some important long term questions.

The model was able to predict existing concentrations of total copper and nickel fairly well. Predictions of lead concentrations were consistently too high and further assessment of lead was not pursued. Comparison of two storm water loading conditions; median of 1977 to 1989, and average of 1988-1990 (drought conditions) showed that reduced stormwater loadings could decrease ambient concentrations by 1 ug/L or more in South Bay.

An assessment of the response time showed that if all loads were removed, the time for copper concentrations to be reduced by 50% ranges from 5 to 16 years depending on the segment.

The contribution from point and non point sources both north and south of Dumbarton to total copper concentrations south of Dumbarton was estimated. Nonpoint sources south of Dumbarton were identified as accounting for the greatest fraction.

Copper concentrations resulting from reducing pollutant loadings from the treatment plants and from storm water were predicted. Results showed that, even in the scenario with greatest reductions, (treatment plants discharging at 2.9 ug/L and storm water loading reduced by 50%) copper concentrations in the furthest south segment would be greater than the water quality objective of 4.9 ug/L. However, this scenario did show significant reductions in copper concentrations, and since the model over-estimates current concentrations in the southernmost part of the Bay, predicted concentrations may be too great as well.

In summary, the quantitative model results have such a high degree of uncertainty that they cannot be used in regulatory decisions. However, the qualitative results are very useful in elucidating the relative importance of various sources of pollutants and the response of the system. This information is currently being incorporated into a Regional Board staff report supporting proposed mass loading reductions of copper to the Lower and South Bay. In addition the model results provide a good overview of our current understanding of pollutant transport in the South Bay and of topics where information is lacking.

Phase 2

Scope

Phase 2 has two components, a data collection element and a hydrodynamic modelling element. The purpose of the data collection is to characterize sediment resuspension by collecting time series of suspended sediment concentrations at various locations in Lower and South Bay. The suspended sediment data will be compared to wind, tide and delta outflow data to identify the major factors influencing sediment movement. This task will add to our understanding of sediment dynamics in South Bay to improve the basis of future water quality modeling efforts.

The purpose of the hydrodynamic modeling is to estimate residence times for dissolved substances under dry weather conditions, and to estimate how sediment residence times are likely to differ from those of dissolved substances. These two estimates should represent maximum and minimum residence times for pollutants. This information will be useful in improving estimates of allowable loading levels of pollutants to South Bay.

The Phase 2 work is being conducted by the US Geological Survey in Sacramento. The work is currently underway and will not be complete until June, 1994.

Methods

1. Data Collection and Analysis

Time series of suspended sediment concentrations are being collected at three deep water sites: San Mateo Bridge, Dumbarton Bridge, and Channel marker 17, south of Dumbarton. Suspended sediment measurements are collected at 15 minute intervals by in situ optical backscatter sensors (OBS) connected to data loggers. OBSs were deployed at two depths, mid-water and near-bottom. In addition, OBS sensors will be deployed for shorter time period (about two weeks) in shallow water areas.

Every two weeks, data is collected, the OBS sensors are cleaned and calibration samples are collected at the location and depths of the OBSs. Calibration samples are analyzed for total suspended sediment concentration and particle size distribution.

Suspended sediment data will be correlated with tide, wind, and fresh water inflow data, to assess the relative importance of these factors in causing resuspension.

2. Hydrodynamic modelling

Hydrodynamic modelling will be conducted using a two dimensional model currently under development by USGS. Estimates of residence times for dissolved substances will include the effects of tidal mixing. The model has the ability to estimate residence times for dissolved particles by tracking the path of a neutrally buoyant particle. To estimate residence time of sediment particles, the computer code will be modified so that the particle becomes stationary below a certain threshold velocity, when particles would be expected to settle out.

Progress to Date

OBSs were deployed at San Mateo Bridge in December 1991 and at Channel Marker 17 in February 1992. Due to difficulties in obtaining permits from CalTrans, the OBSs at Dumbarton Bridge were not deployed until September 1992. All sites have been serviced at two week intervals since their deployment. Calibration curves are being developed.

Initial data evaluation suggests that, during calm wind conditions and energetic tides, sediment concentrations fluctuate with tides, with peaks occurring at low slack water. This result is consistent with the hypothesis that sediment is resuspended in the shallows by tidal currents and advected northward with the ebb tide.

The hydrodynamic modeling has not been completed.

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FIGURES AND TABLES

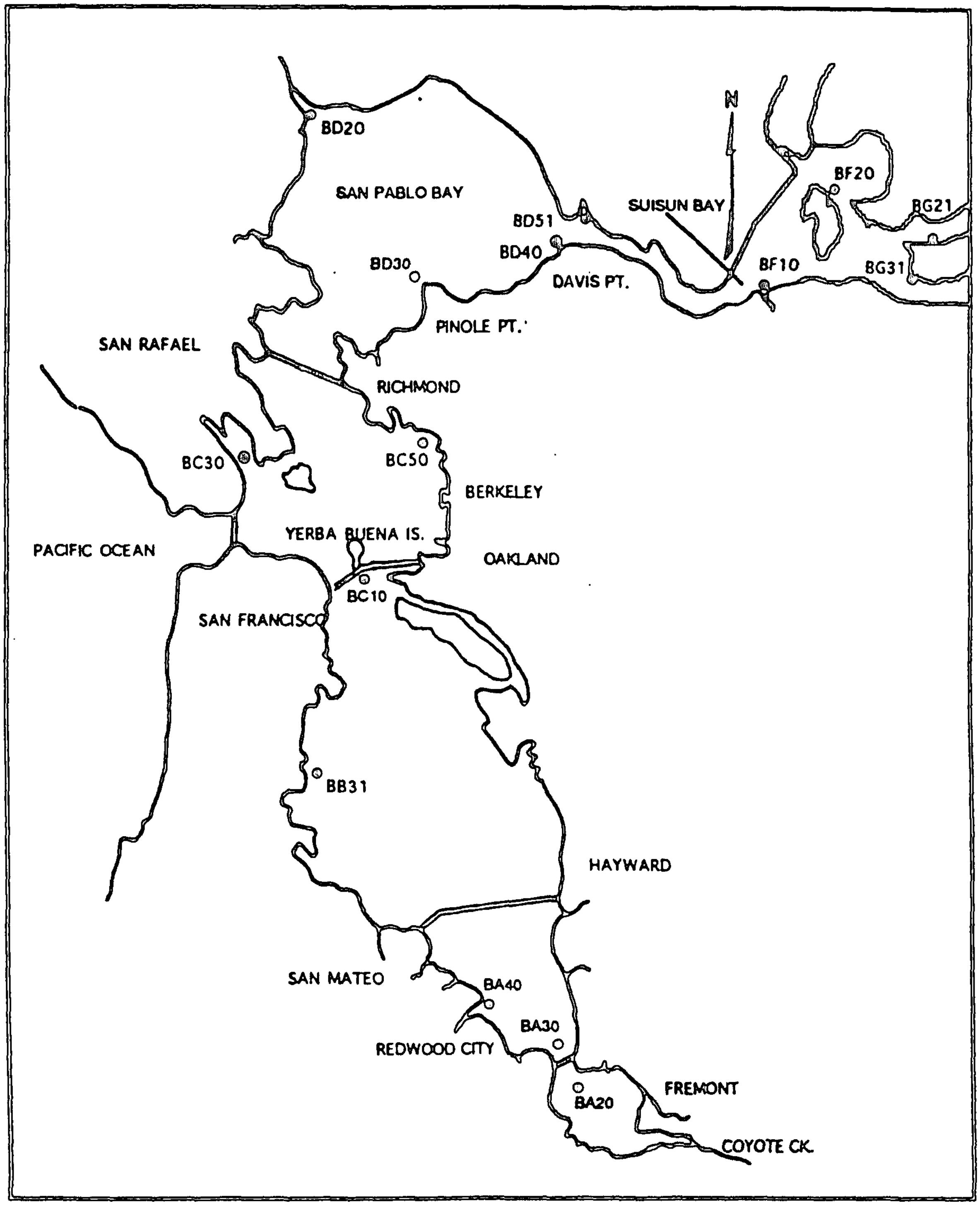


Figure 1. Bay Run #1 station locations collected on August 26-28, 1991 with a modified Gray-Ohare grab.

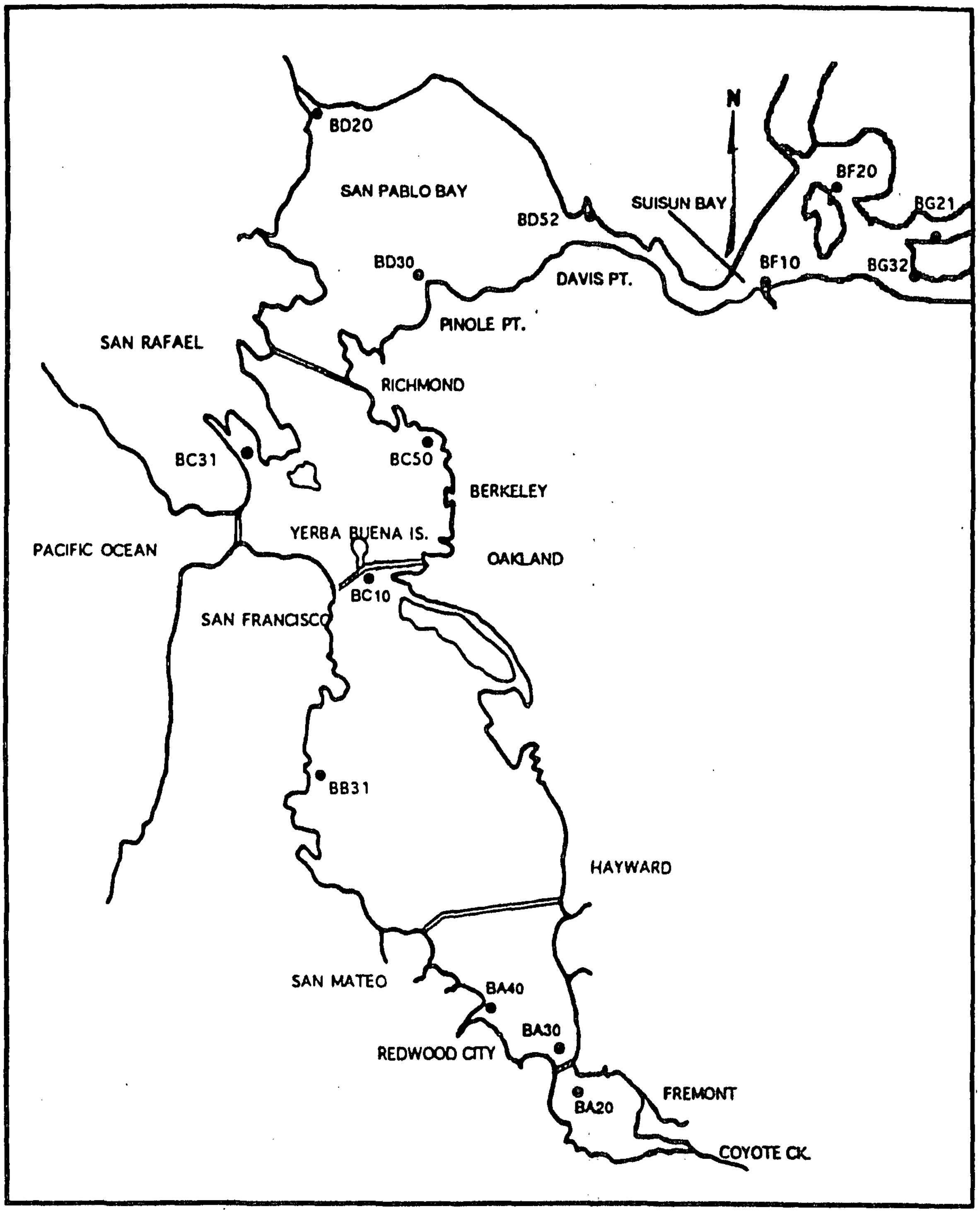


Figure 2. Bay Run #2 station locations collected on March 30-April 1, 1992 with a modified Gray-Ohare grab.

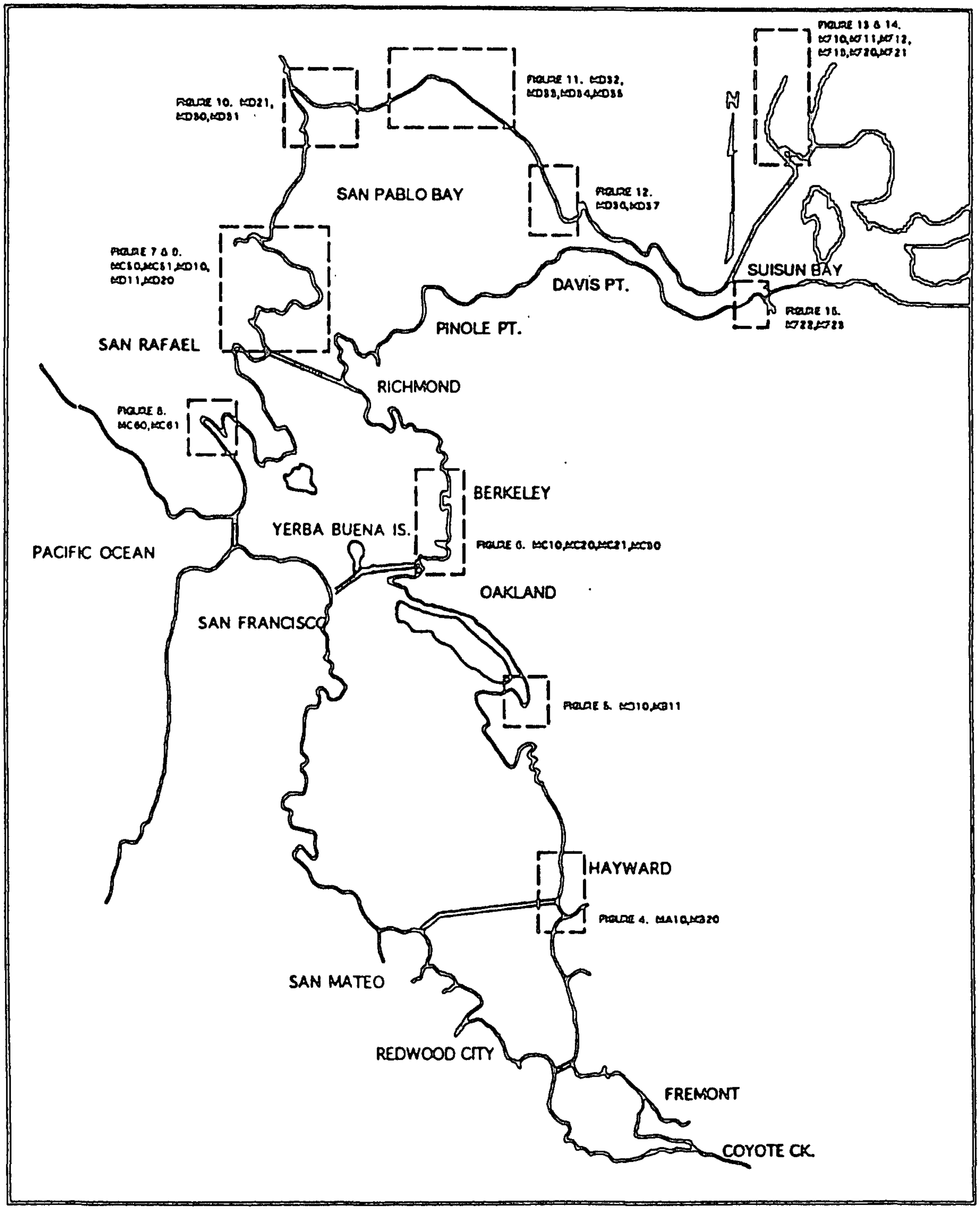


Figure 3. San Francisco Bay areas of marsh sampling.

Figure 4 Gradient stations locations collected on May 25-27, 1991 with diver cores.

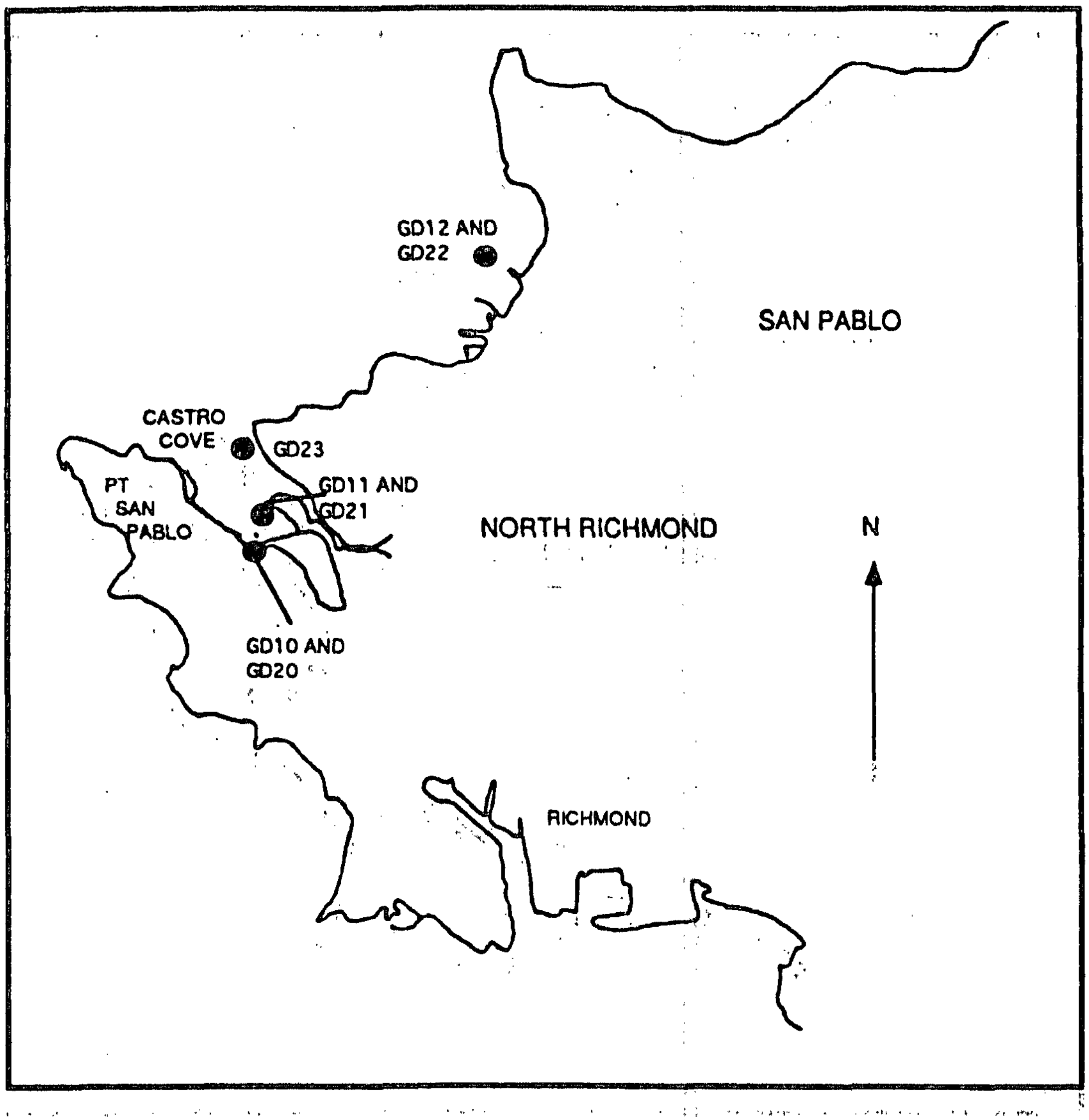
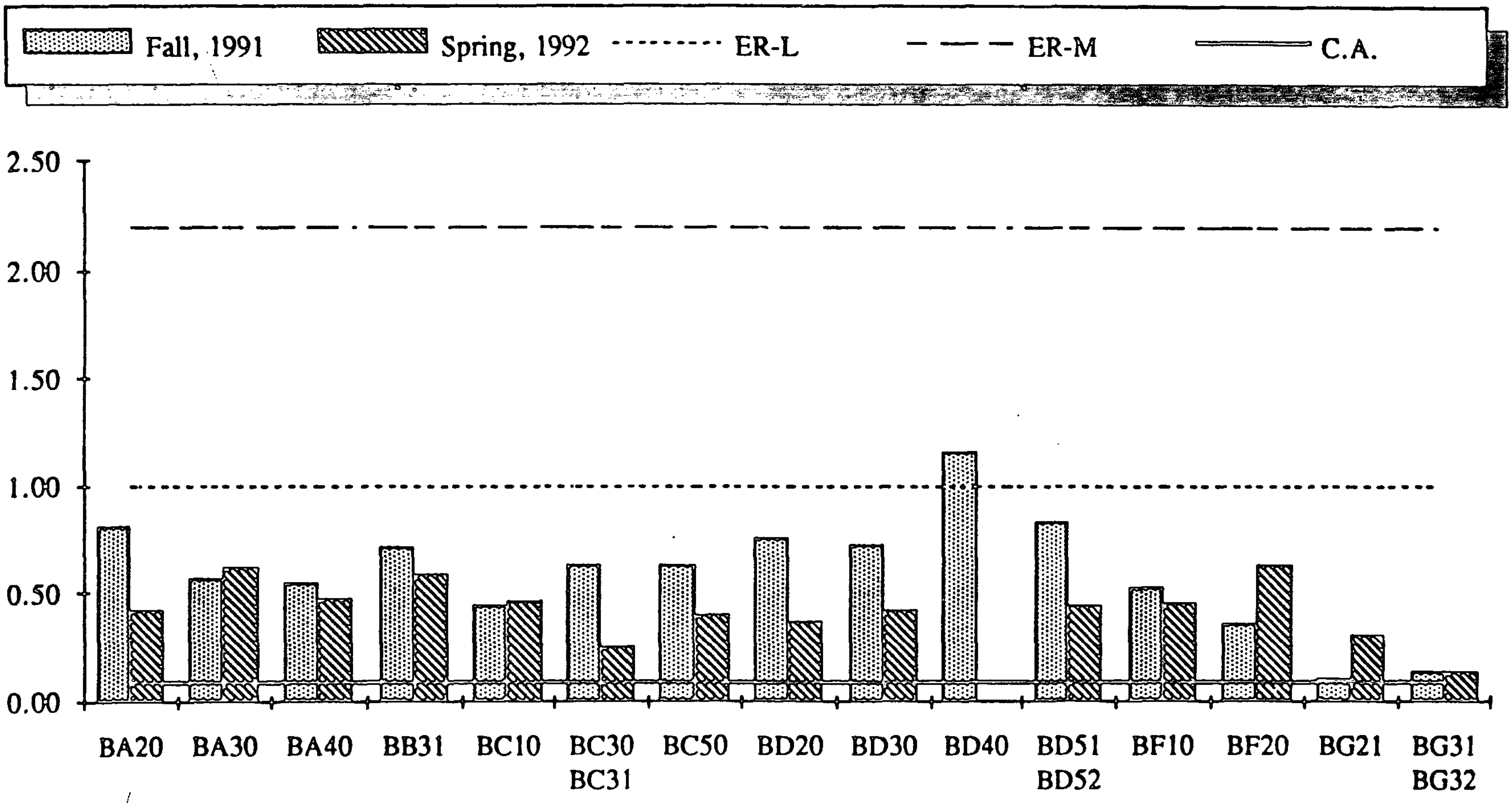
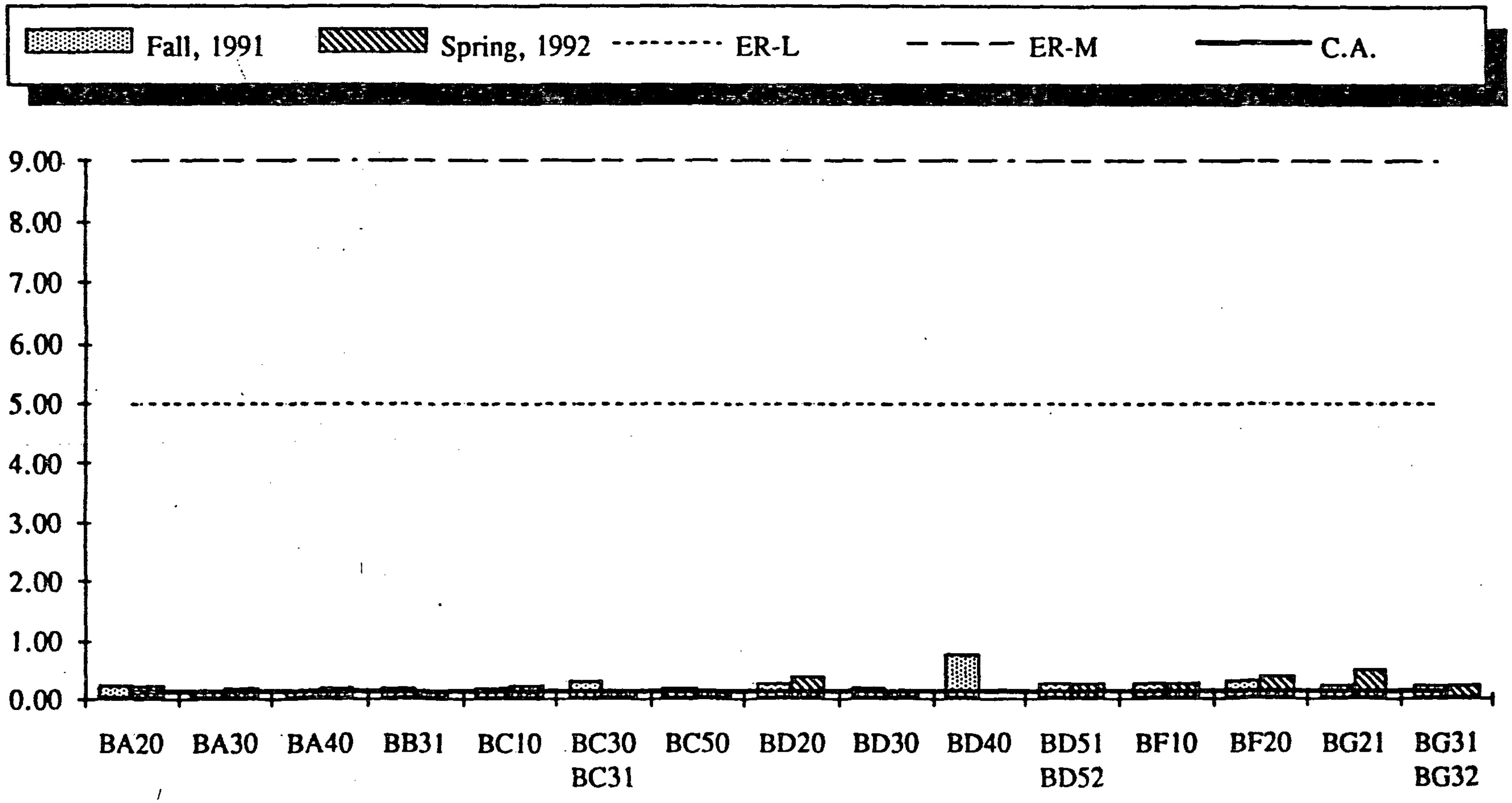


Figure 5 : Ag Concentrations in SF Bay Sediments



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

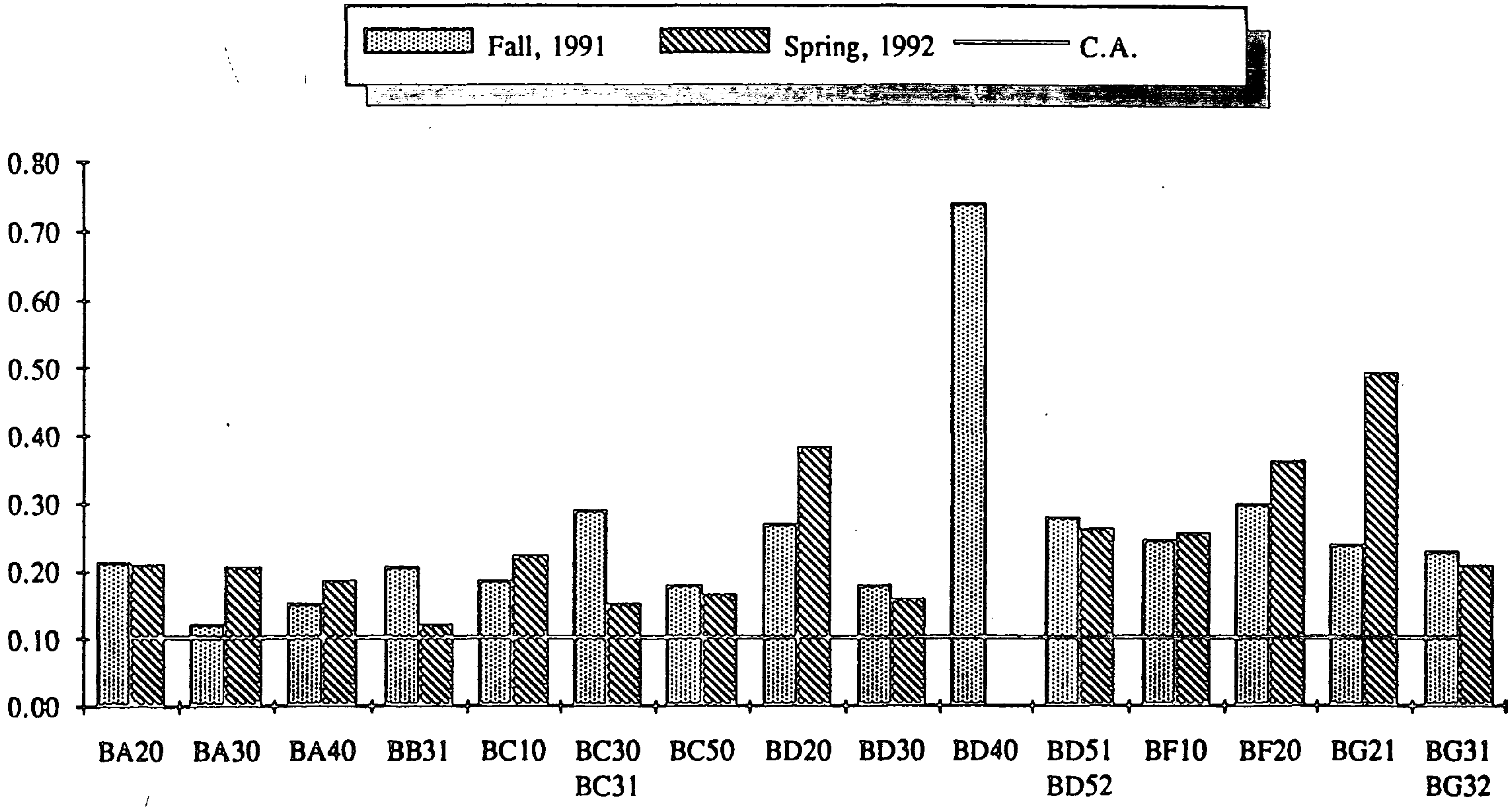
Figure 6 : Cd Concentrations in SF Bay Sediments



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

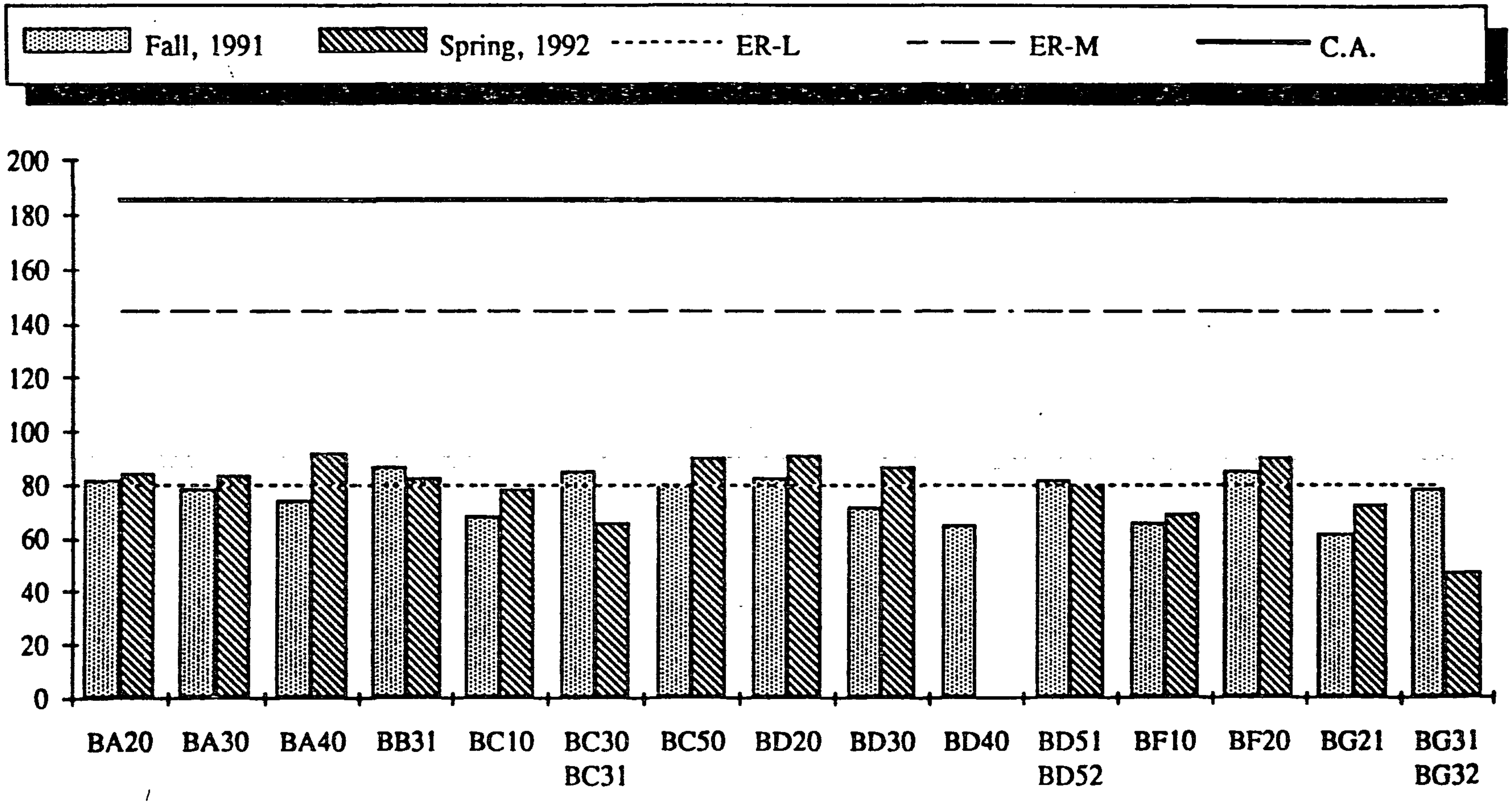
ER-L and ER-M lines removed to adjust scale

Figure 7 : Cd Concentrations in SF Bay Sediments



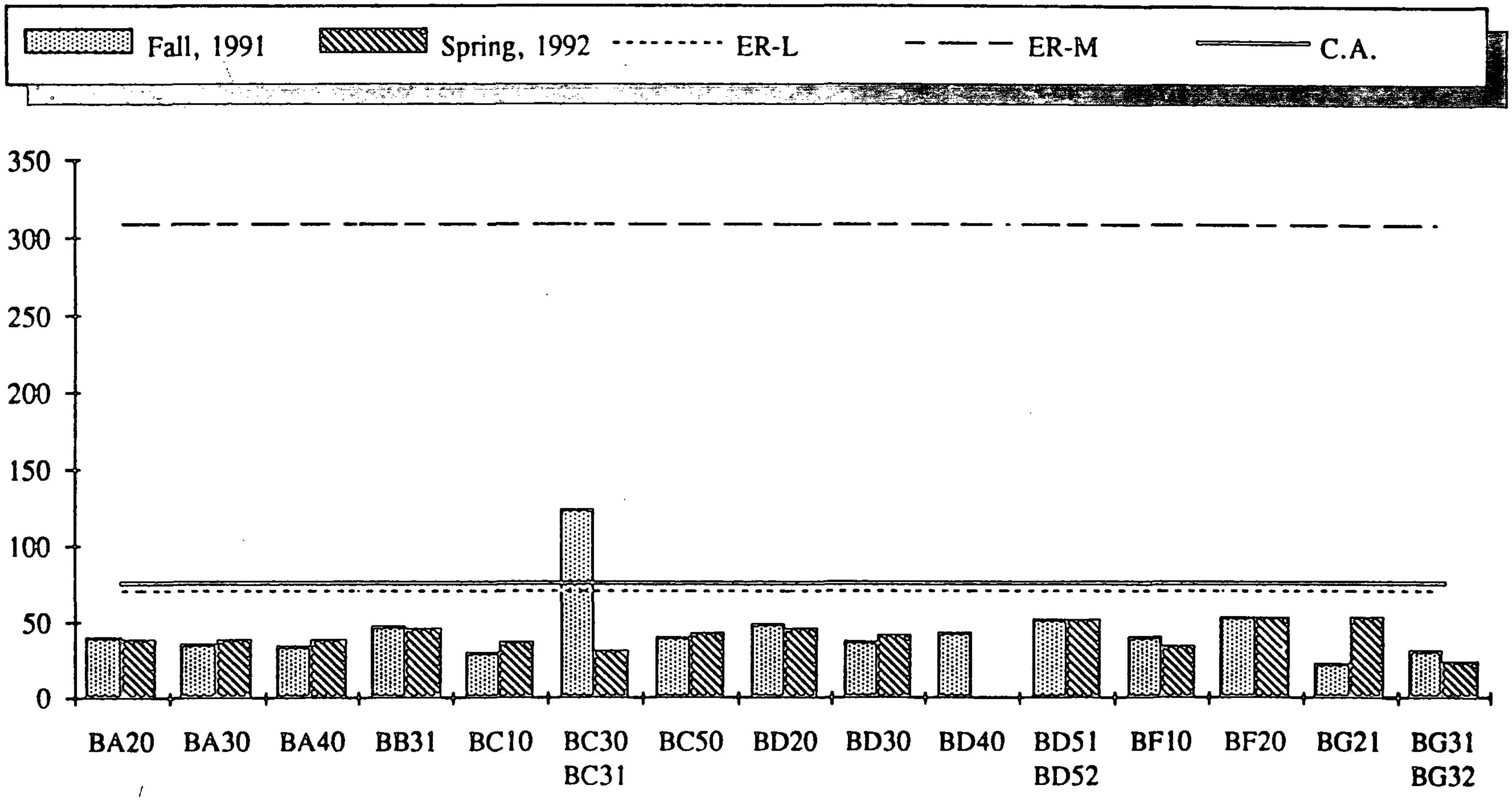
Concentrations given in ppm dry weight. Crustal abundance from Lof (1987).

Figure 8 : Cr Concentrations in SF Bay Sediments



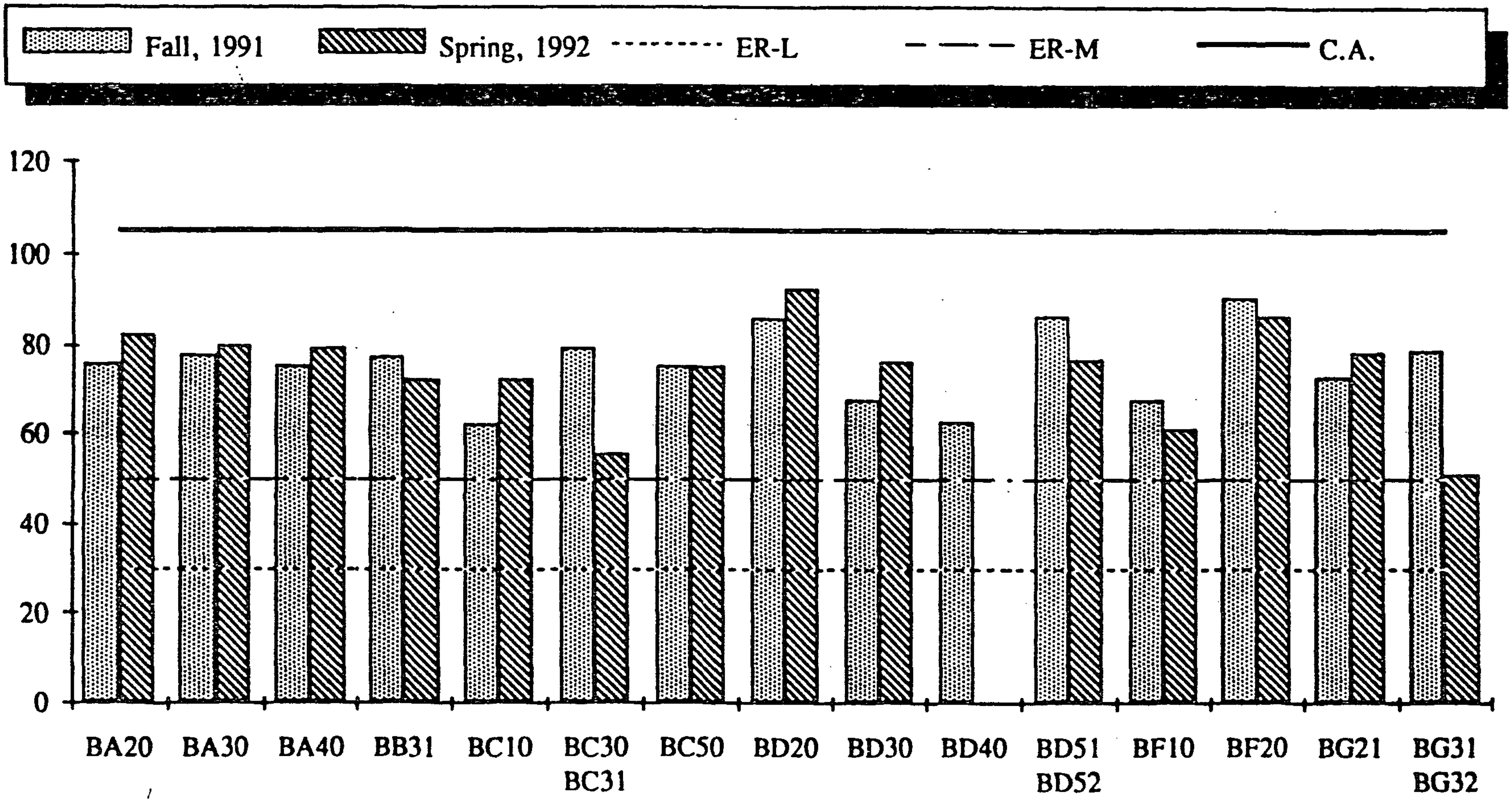
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 9 : Cu Concentrations in SF Bay Sediments



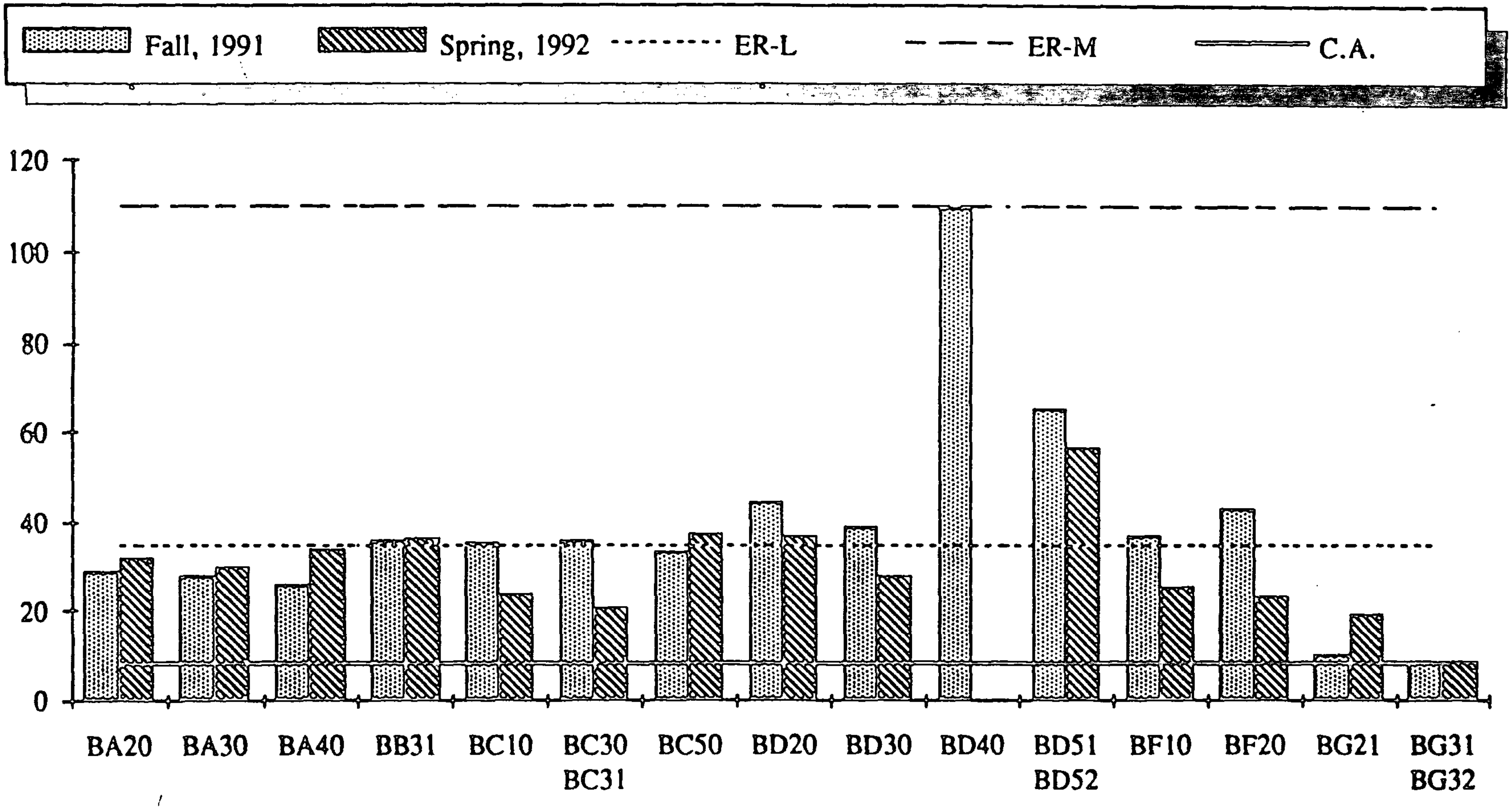
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 10 : Ni Concentrations in SF Bay Sediments



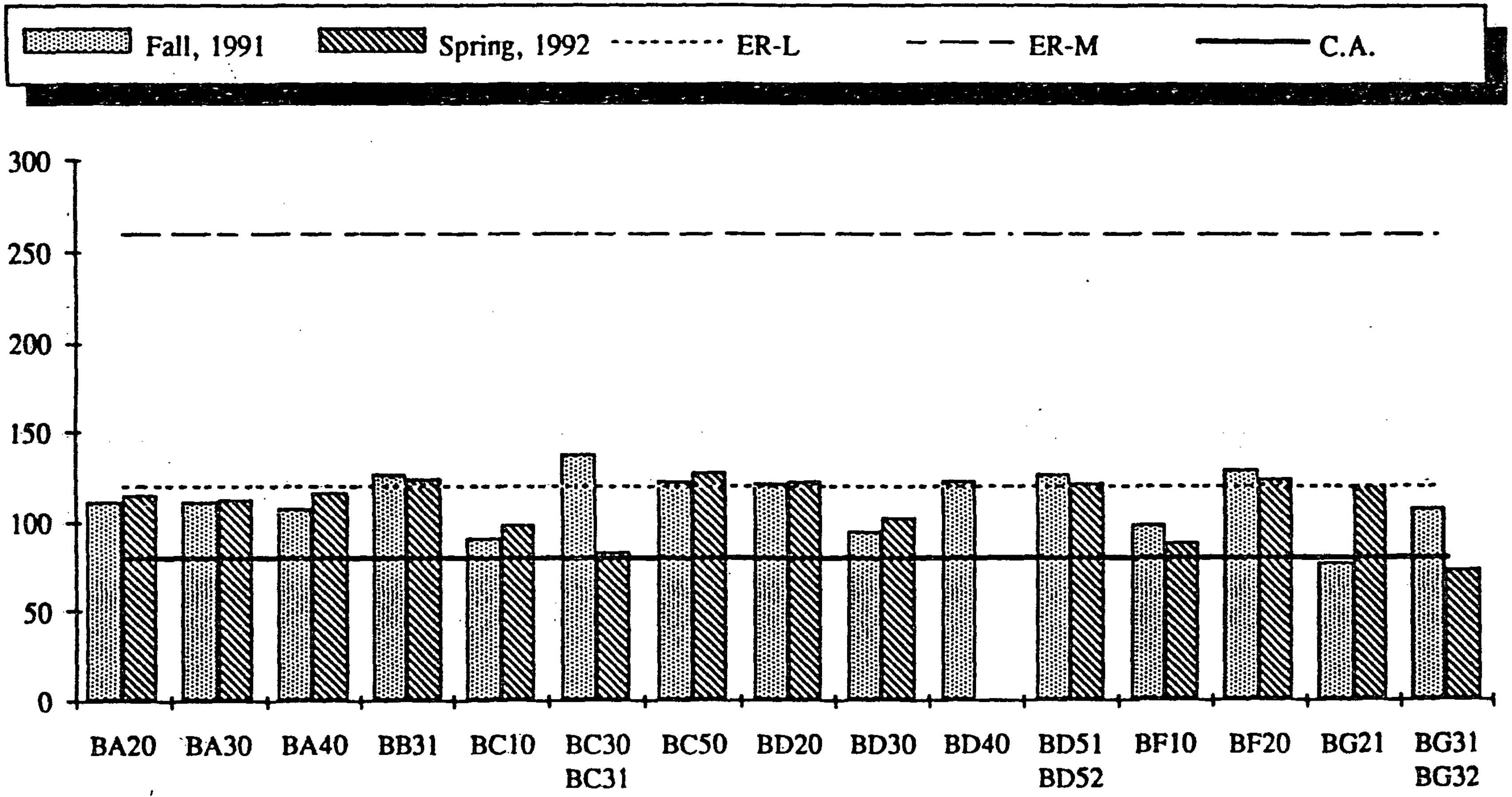
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 11: Pb Concentrations in SF Bay Sediments



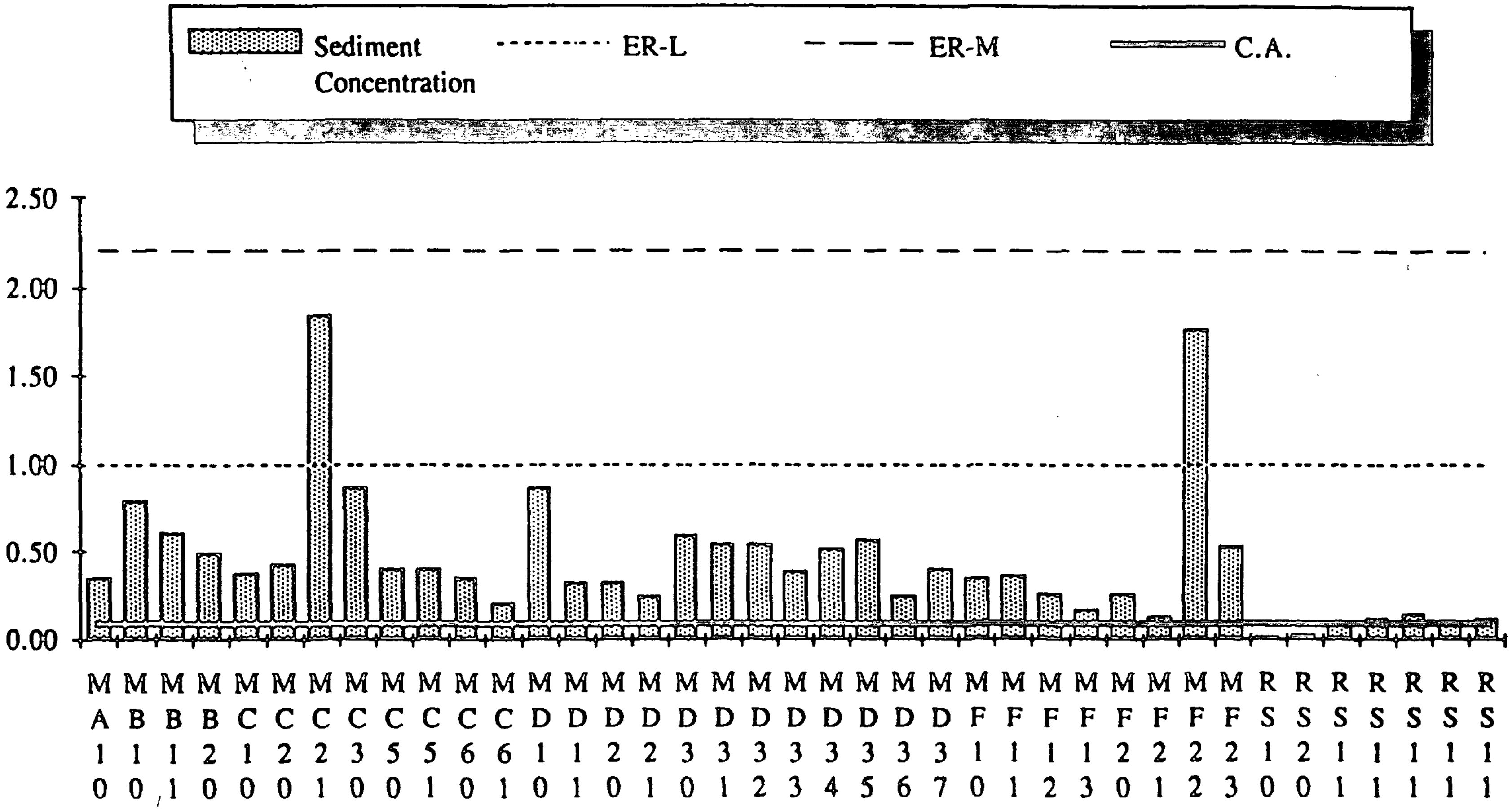
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 12 : Zn Concentrations in SF Bay Sediments



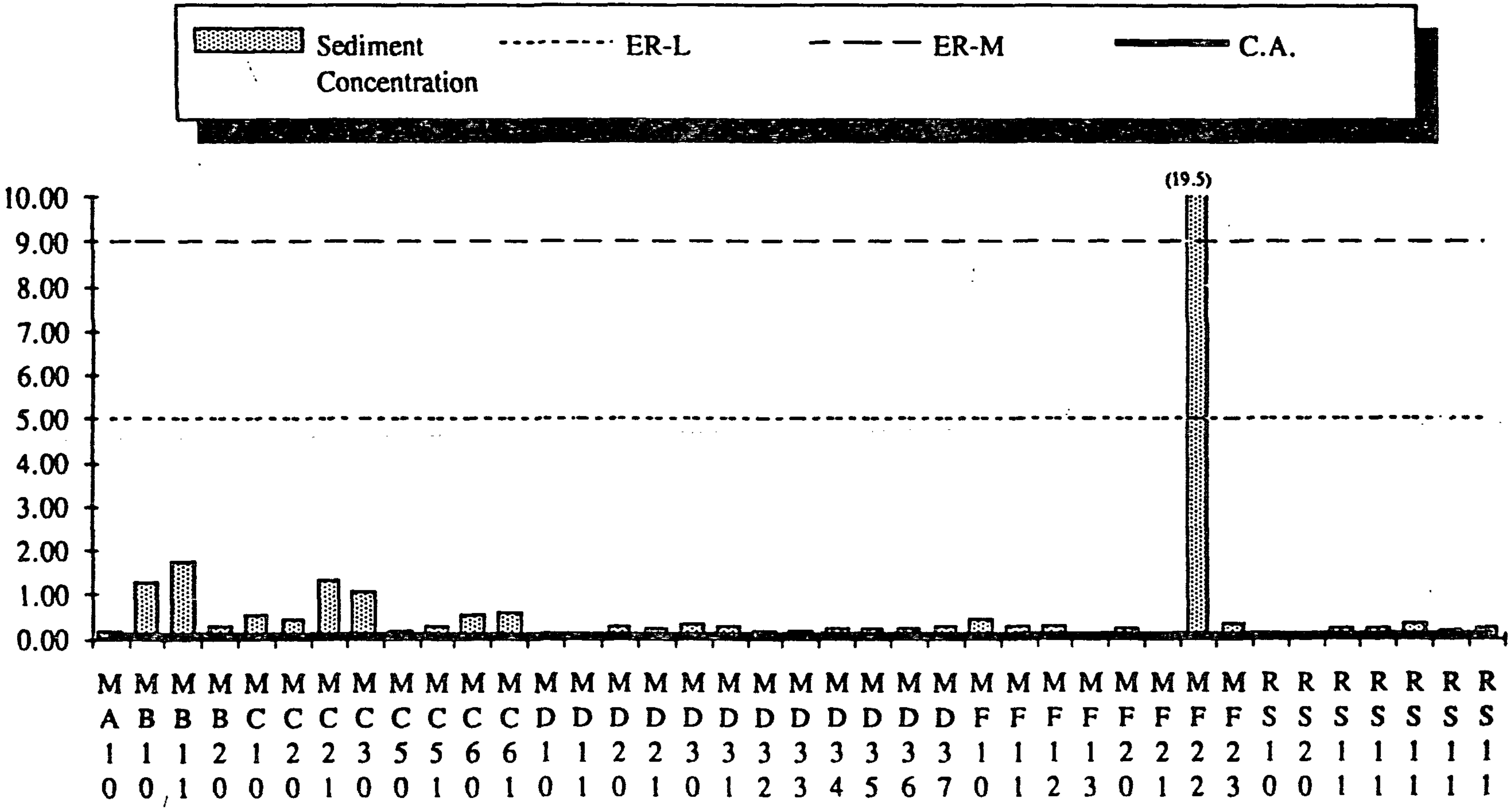
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 13: Ag Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

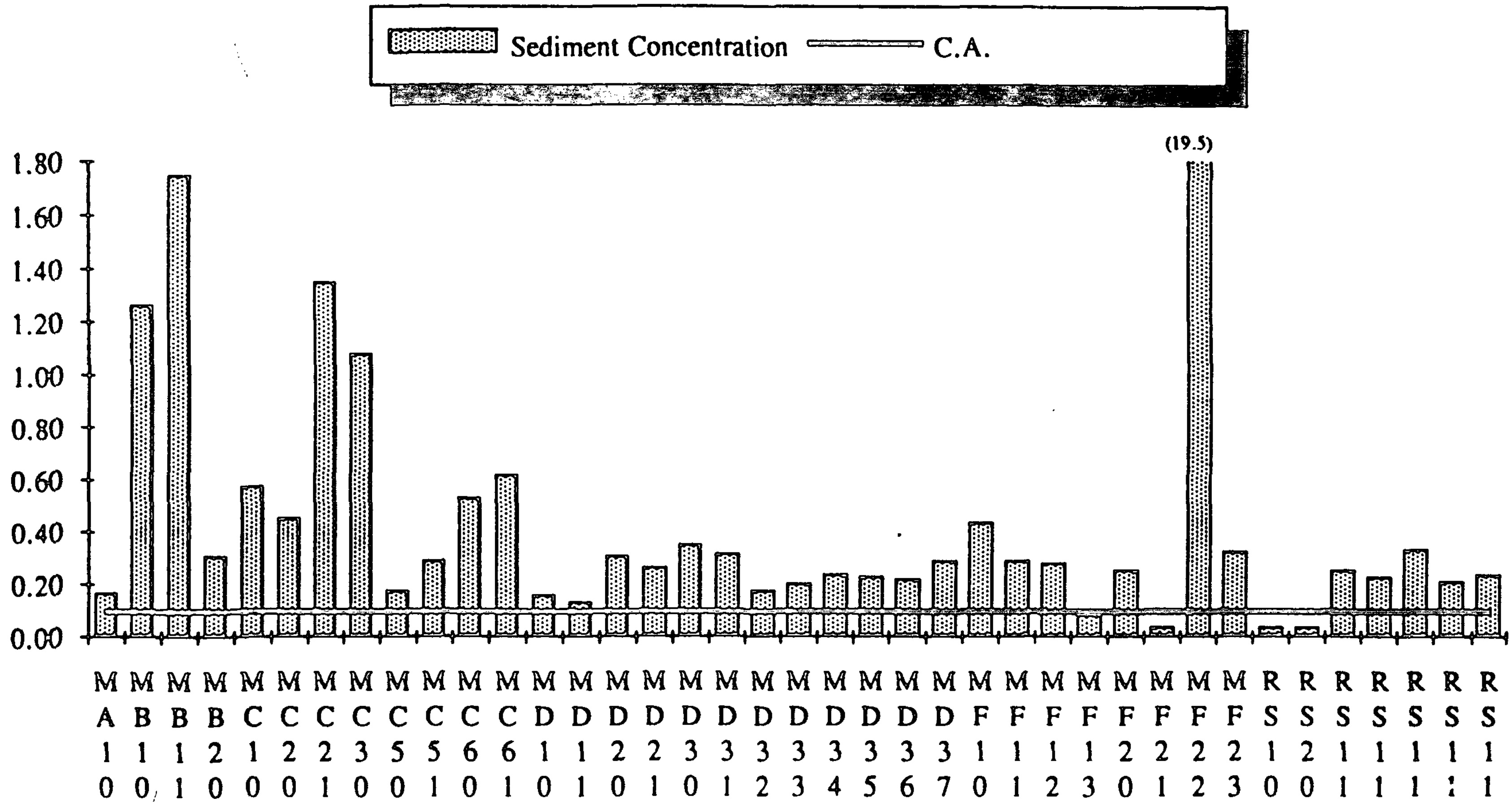
Figure 14: Cd Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

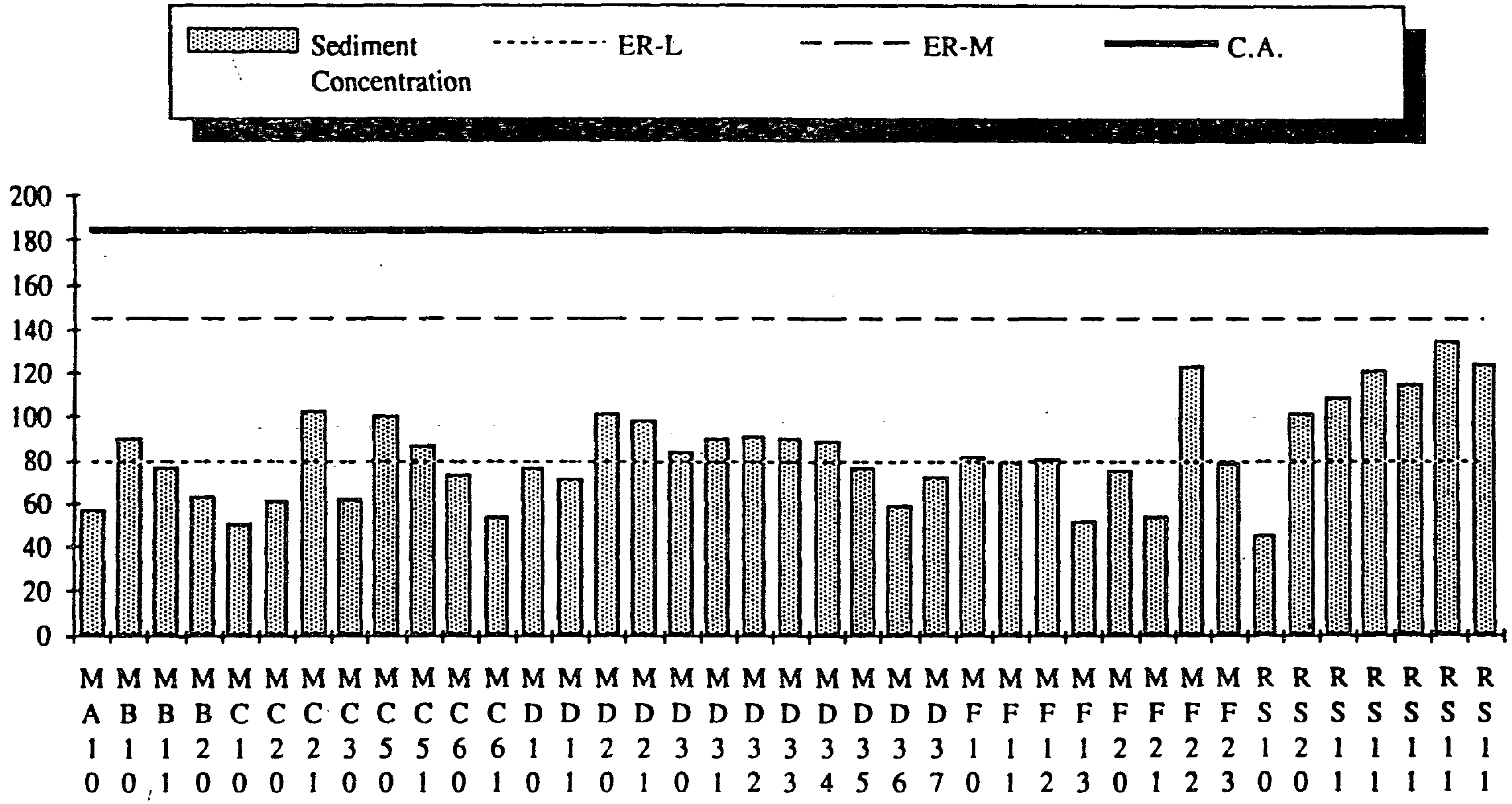
ER-L and ER-M lines removed to adjust scale

Figure 15: Cd Concentrations in Bay Area Creeks and Marshes



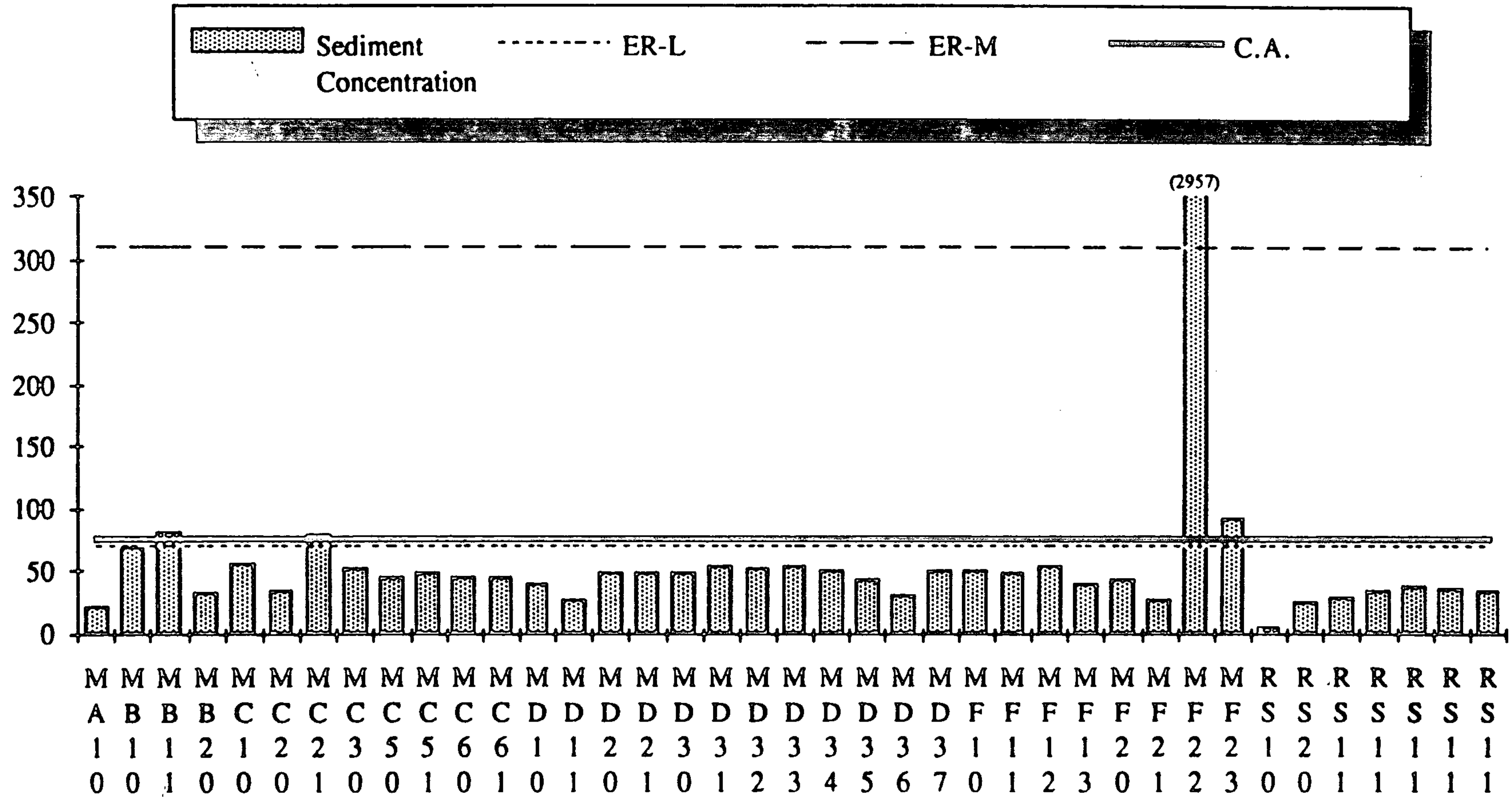
Concentrations given in ppm dry weight. Crustal abundance from Lof (1987).

Figure 16: Cr Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

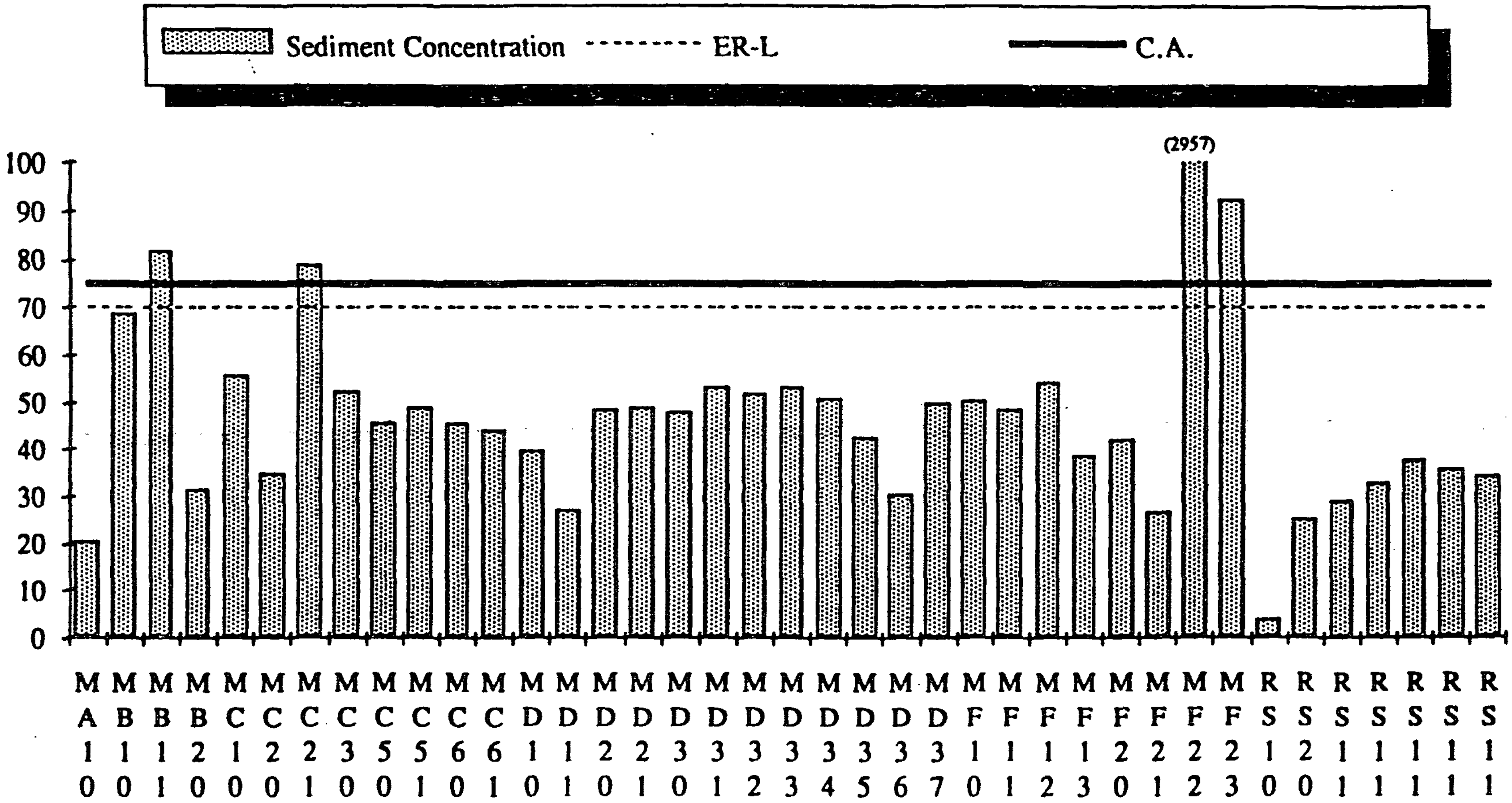
Figure 17: Cu Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

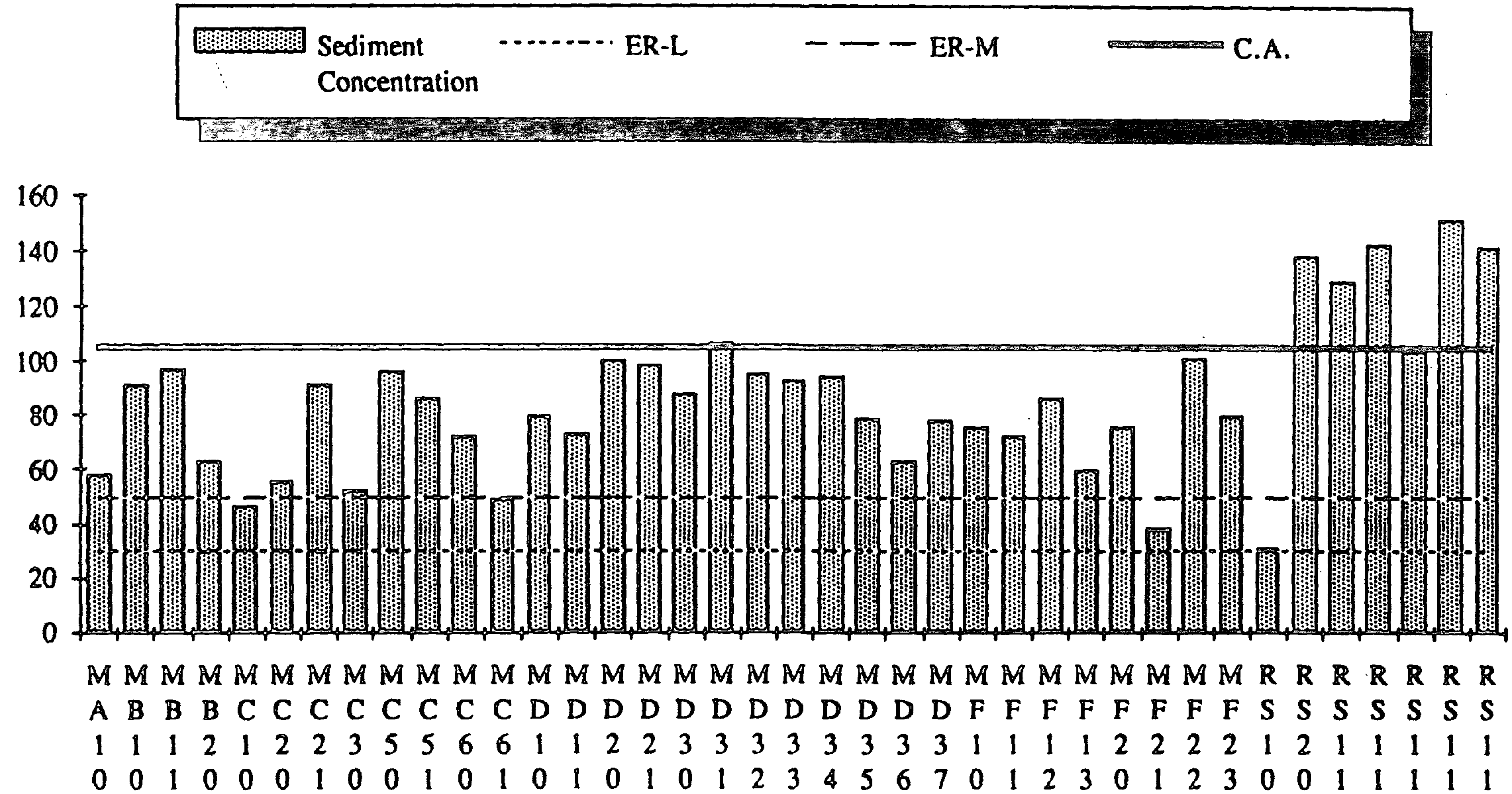
ER-M line removed to adjust scale

Figure 18: Cu Concentrations in Bay Area Creeks and Marshes



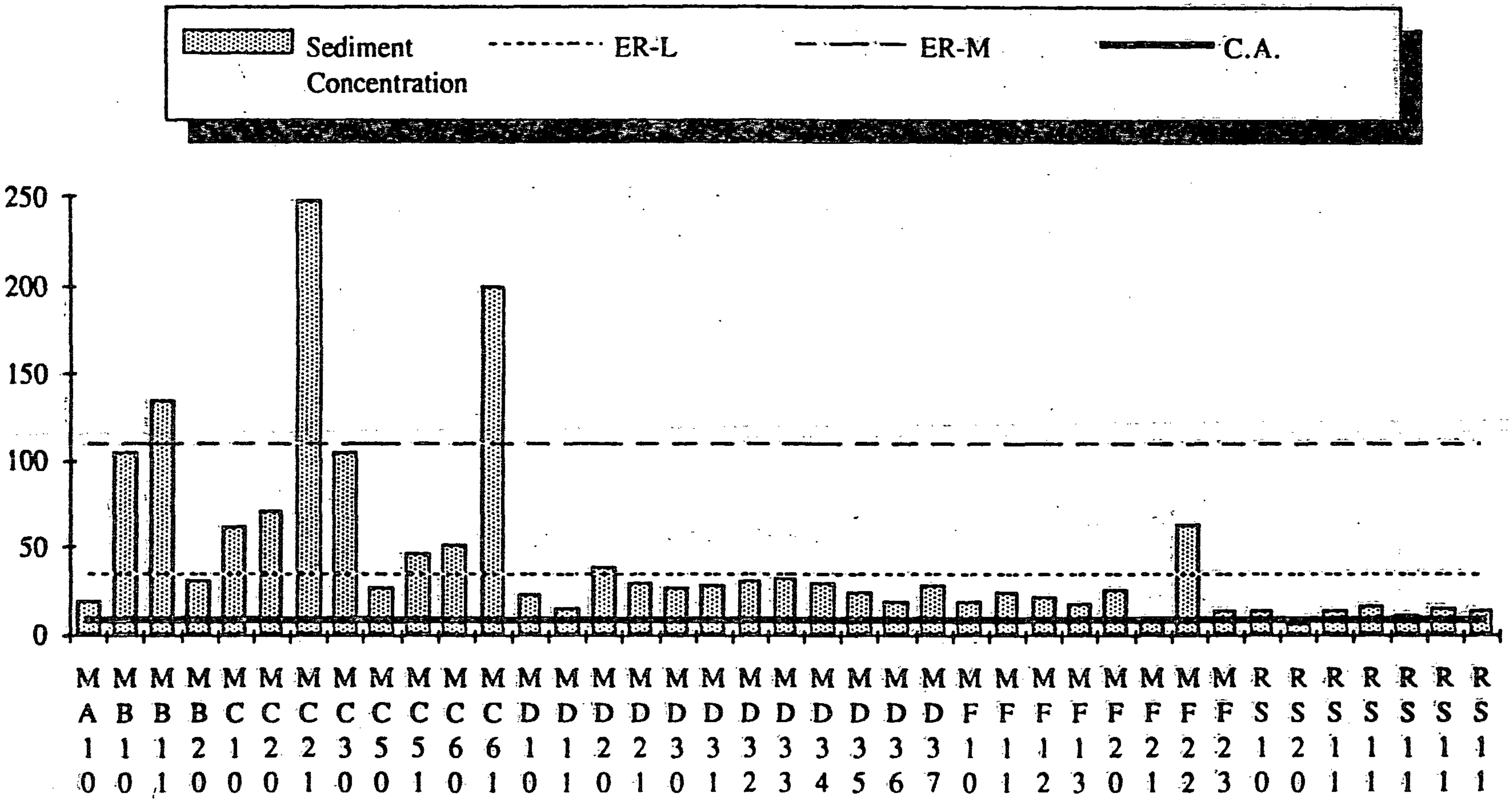
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 19: Ni Concentrations in Bay Area Creeks and Marshes



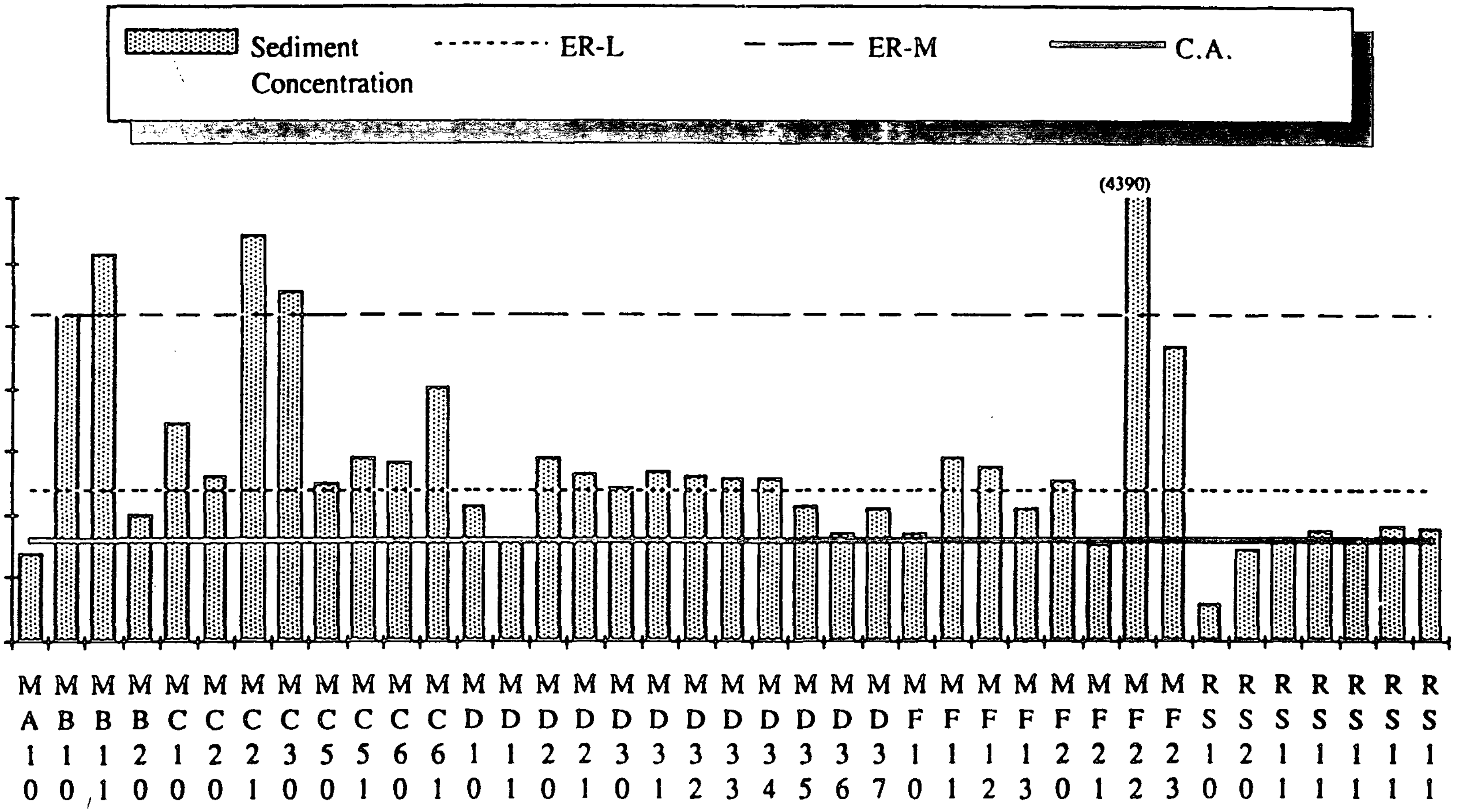
Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 20: Pb Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

Figure 21: Zn Concentrations in Bay Area Creeks and Marshes



Concentrations given in ppm dry weight. ER-L & ER-M values from Long and Morgan (1990). Crustal abundance from Lof (1987).

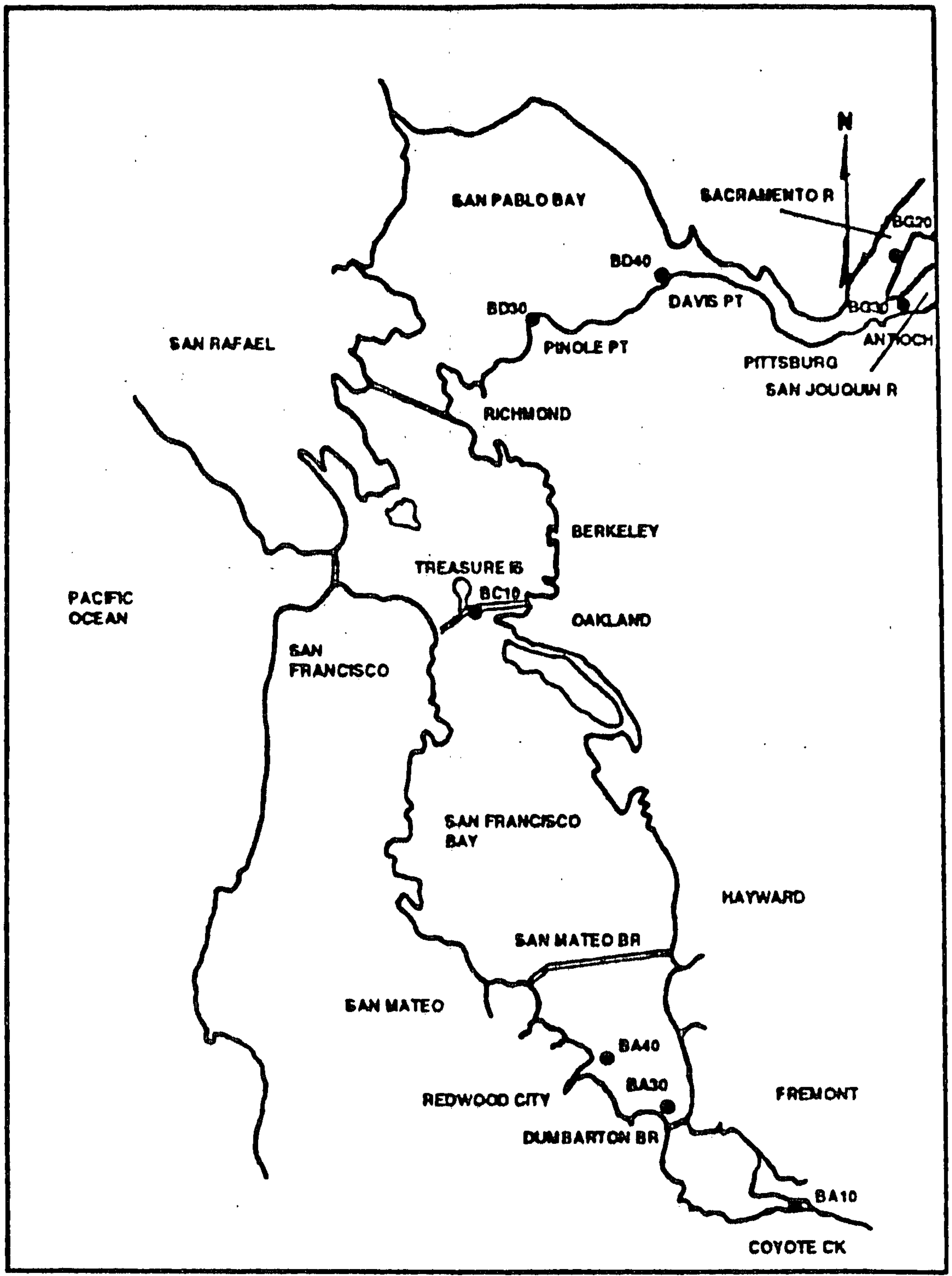


Figure 22 San Francisco Bay bioaccumulation sites.

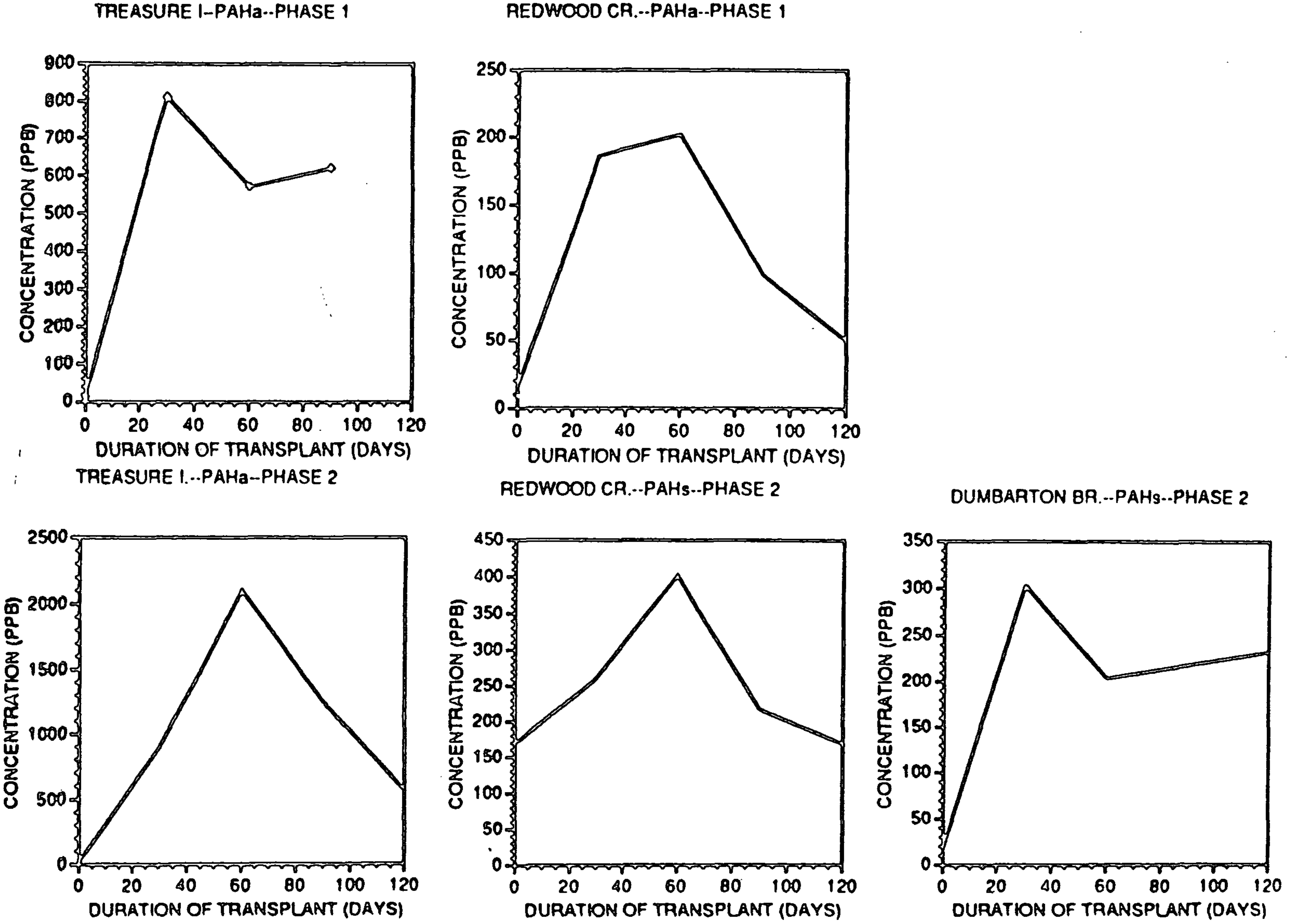
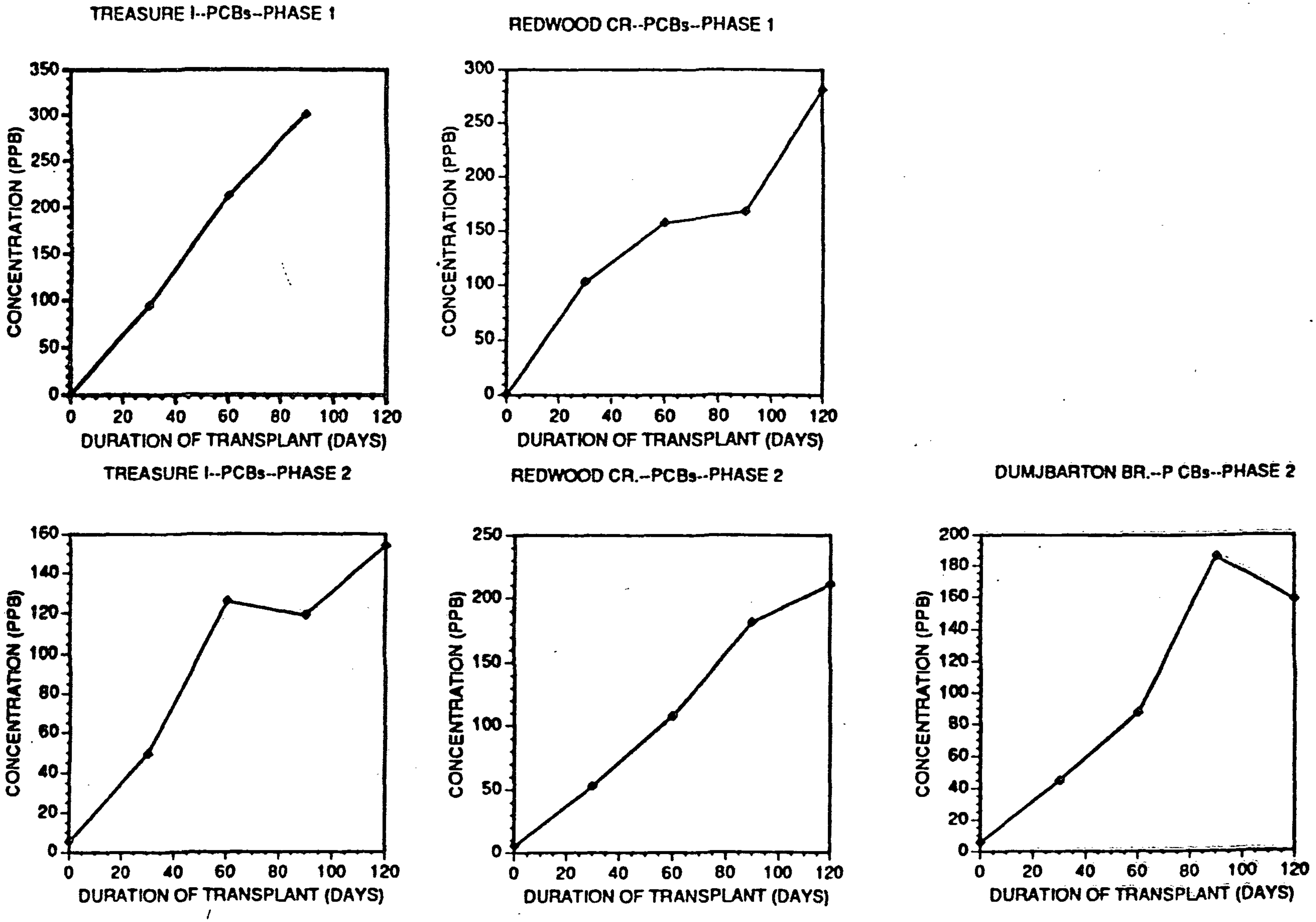

TREASURE I--PAHa--PHASE 1
REDWOOD CR.--PAHa--PHASE 1
TREASURE I.--PAHa--PHASE 2
REDWOOD CR.--PAHs--PHASE 2
DUMBARTON BR.--PAHs--PHASE 2
CONCENTRATION (PPB)
DURATION OF TRANSPLANT (DAYS)
0
20
40
60
80
100
120
900
800
700
600
500
400
300
200
100
250
200
150
100
50
2500
2000
1500
1000
500
450
400
350
300
250
200
150
100
50
350
300
250
200
150
100
50

Figure 23


TREASURE I--PCBs--PHASE 1

REDWOOD CR--PCBs--PHASE 1

TREASURE I--PCBs--PHASE 2

REDWOOD CR.--PCBs--PHASE 2

DUMJBARTON BR.--P CBs--PHASE 2

Figure 24

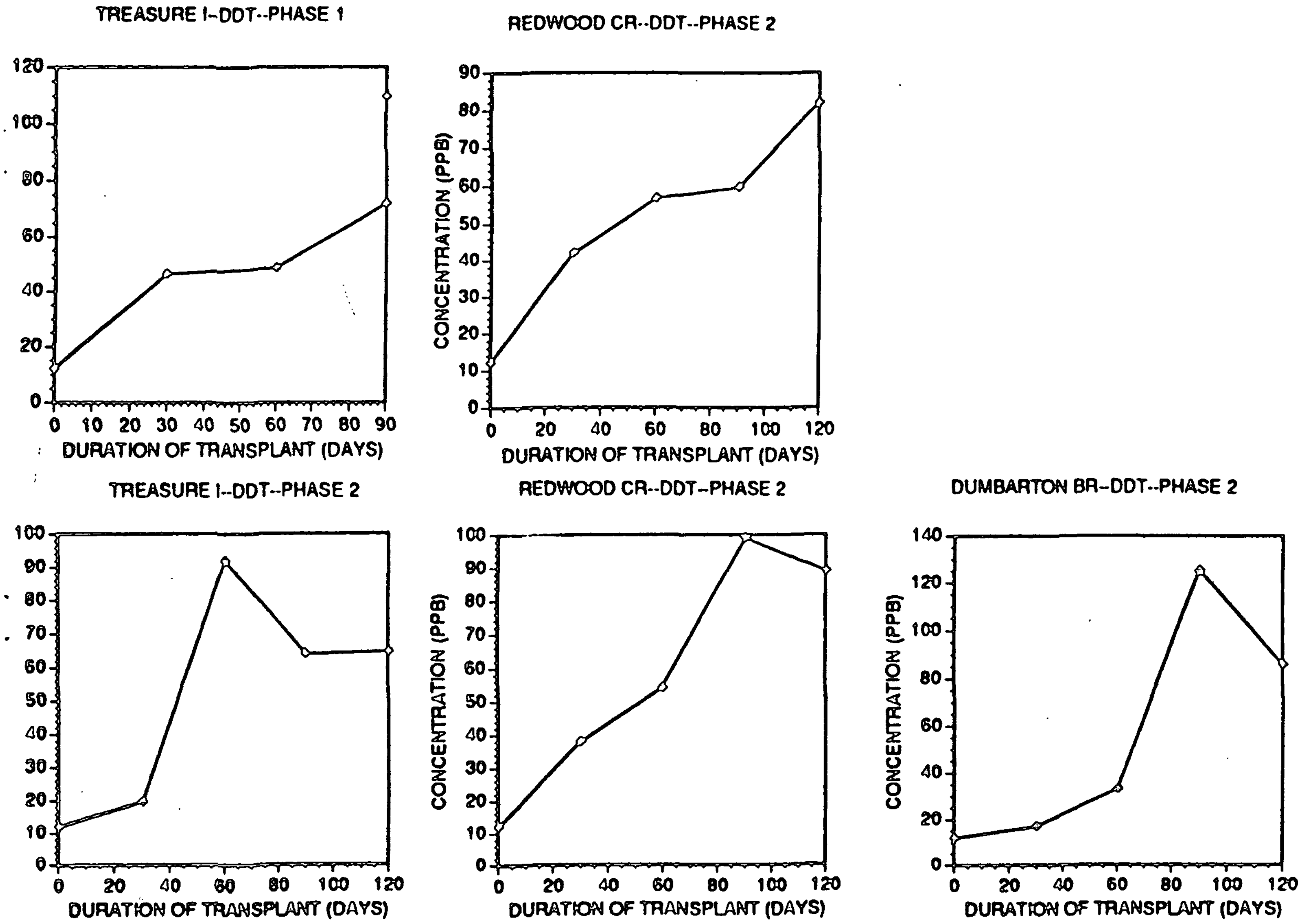

TREASURE I--DDT--PHASE 1
120
100
80
60
40
20
0
0 10 20 30 40 50 60 70 80 90
DURATION OF TRANSPLANT (DAYS)
REDWOOD CR--DDT--PHASE 2
CONCENTRATION (PPB)
90
80
70
60
50
40
30
20
10
0
0 20 40 60 80 100 120
DURATION OF TRANSPLANT (DAYS)
TREASURE I--DDT--PHASE 2
100
90
80
70
60
50
40
30
20
10
0
0 20 40 60 80 100 120
DURATION OF TRANSPLANT (DAYS)
REDWOOD CR--DDT--PHASE 2
CONCENTRATION (PPB)
100
90
80
70
60
50
40
30
20
10
0
0 20 40 60 80 100 120
DURATION OF TRANSPLANT (DAYS)
DUMBARTON BR--DDT--PHASE 2
CONCENTRATION (PPB)
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120
DURATION OF TRANSPLANT (DAYS)

Figure 25

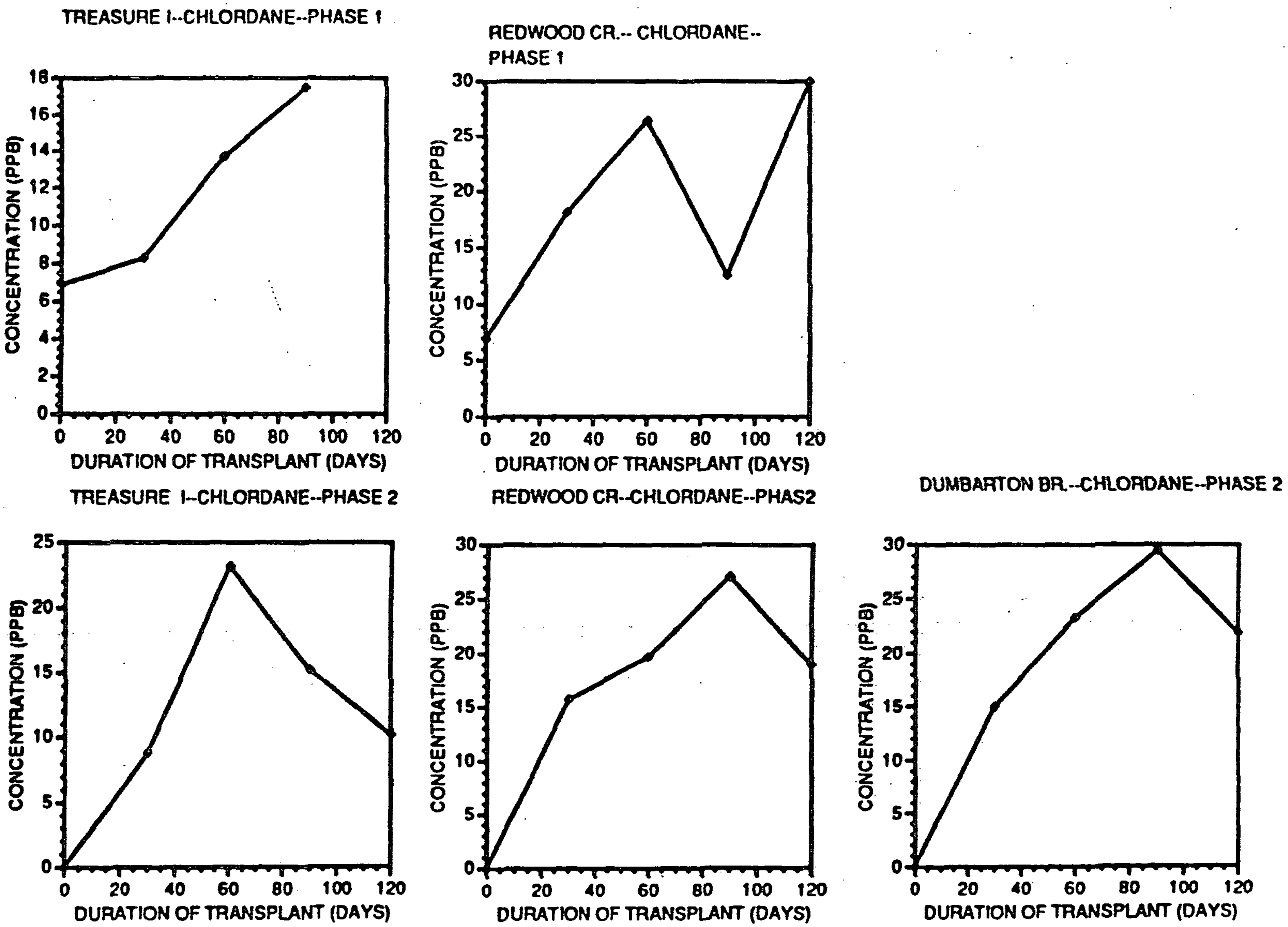

TREASURE I--CHLORDANE--PHASE 1
REDWOOD CR.-- CHLORDANE--
PHASE 1
TREASURE I--CHLORDANE--PHASE 2
REDWOOD CR--CHLORDANE--PHAS2
DUMBARTON BR.--CHLORDANE--PHASE 2
CONCENTRATION (PPB)
DURATION OF TRANSPLANT (DAYS)
0
2
4
6
8
10
12
14
16
18
5
15
20
25
30
40
60
80
100
120

Figure 26

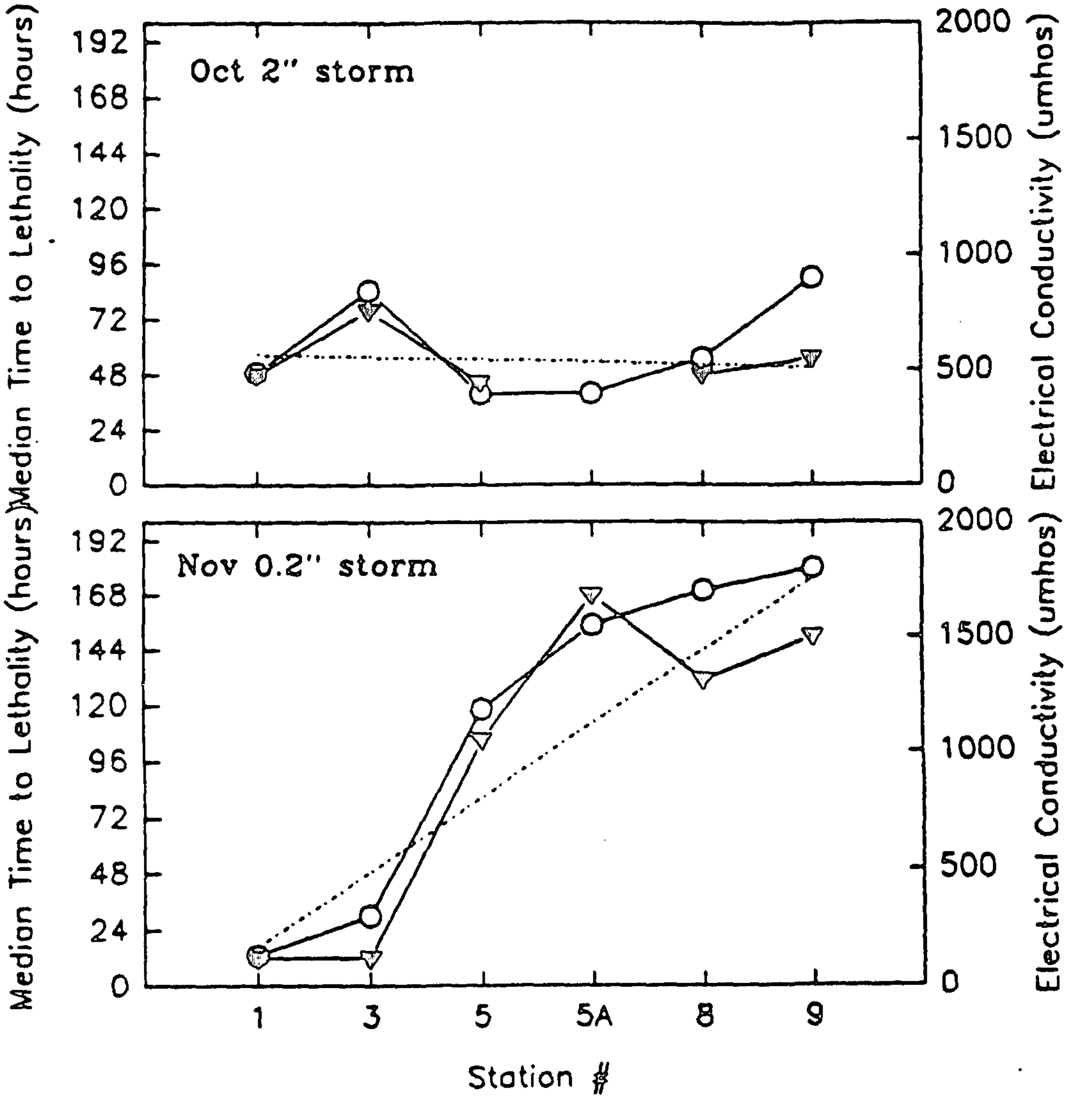


Figure 27 : Spatial Distribution of toxicity and conductivity in the DUST System after a big and a small storm.
Hollow circle, conductivity; full inverted triangle, LT_{50} as calculated by the graphical method; dotted line, linear regression of LT_{50} vs sampling site. Resulting slopes of -1.4 with std. err. of 4.54 for the October 1991 (2") storm, and a slope of 31.7 with std. err. of 9.2 for the November 1991 (0.2") storm.

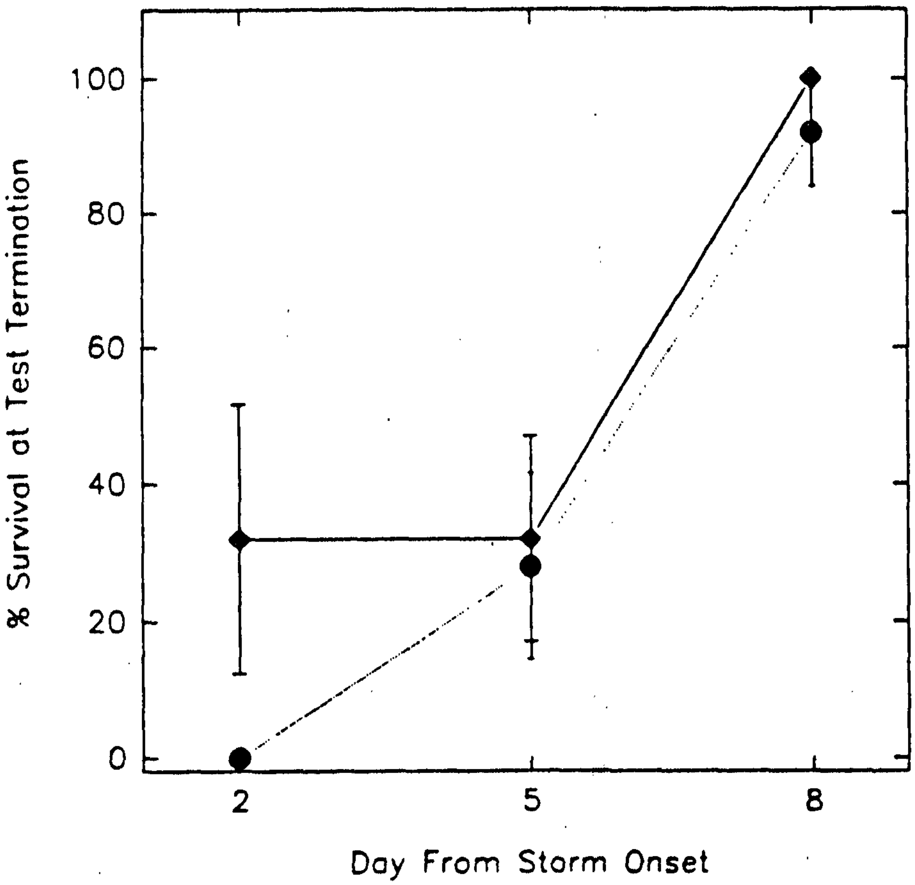


Figure 28: Survival of *Ceriodaphnia* in DUST System samples taken after the storm of March 14, 1992.

Five field-replicates in each station had 5 test animals each, with daily renewal and feeding. Survival in all control chambers was 100% at test termination, which was after 7 days except for the test with March 15 samples. Mean survival after 5-day exposure (Station 5, full diamonds) or 7-day exposure (Station 3, full circles) is presented.

Table 1. Bay Run #1 stations and corresponding data.

STATION CODE	STATIONS*	DATE	LAT	LONG	# GRABS	DEPTH	SAL(ppt)	TEMP
BA20	EXTREME SOUTH BAY	8/29/91	37 28 59	122 05 28	3	9	28	23
BA30	DUMBARTON BRIDGE	8/29/91	37 30 44	122 08 07	2	10	32	22
BA40	REDWOOD CREEK	8/29/91	37 31 42	122 11 51	6	14	28	21
BB31	OYSTER POINT MARINA	8/29/91	37 39 50	122 22 34	20	7	35	21
BC10	YERBA BUENA ISLAND	8/28/91	37 48 46	122 21 31	4	17	35	18
BC30	RICHARDSON BAY	8/28/91	37 52 16	122 29 50	2	10	38	18
BC50	STAUFFER	8/28/91	37 54 10	122 19 59	4	7	35	18
BD20	PETALUMA RIVER	8/28/91	38 06 42	122 29 00	3	7	30	20
BD30	PINOLE POINT	8/27/91	38 00 56	122 21 47	8	9	25	18
BD40	DAVIS POINT	8/27/91	38 03 20	122 15 10	4	12	25	19
BD51	NAPA RIVER (West bank Mare Island)	8/27/91	38 05 17	122 15 15	2	21	21	20
BF10	PACHECO CREEK	8/27/91	38 02 49	122 05 37	10	5	17	19
BF20	GRIZZLY BAY	8/26/91	38 05 42	122 01 54	1	12	12	19
BG21	SACRAMENTO RIVER (at Sherman Lake)	8/26/91	38 03 06	121 47 42	8	9	4	20
BG31	SAN JOAQUIN RIVER (south Kimball Is.)	8/26/91	38 02 01	121 49 42	11	10	4	19

Table 2. Bay Run #2 stations and corresponding data.

STATION CODE	STATIONS*	DATES	LAT	LONG	# GRABS	DEPTH	SAL(ppt)	TEMP
BA20	EXTREME SOUTH BAY	3/30/92	37 29 02	122 05 16	1	16	20	16
BA30	DUMBARTON BRIDGE	3/30/92	37 30 43	122 08 11	1	8	22	16
BA40	REDWOOD CREEK	3/30/92	37 31 41	122 11 50	2	10	24	16
BB31	OYSTER POINT MARINA	3/30/92	37 40 19	122 22 45	2	13	26	16
BC10	YERBA BUENA ISLAND	3/30/92	37 48 46	122 21 30	2	13	27	15.5
BC31	RICHARDSON BAY	3/31/92	37 52 22	122 29 38	7	10	28	16
BC50	STAUFFER	3/31/92	37 54 10	122 19 58	2	8	25	15
BD20	PETALUMA RIVER	3/31/92	38 06 42	122 29 00	5	6	15	17
BD30	PINOLE POINT	3/31/92	38 00 56	122 21 47	8	8	22	16.5
BD52	NAPA RIVER (East bank Vallejo)	4/1/92	38 05 22	122 15 08	5	15	11	17
BF10	PACHECO CREEK	4/1/92	38 02 44	122 05 44	11	10	5	16
BF20	GRIZZLY BAY	4/1/92	38 05 39	122 01 54	7	6	5	17.5
BG21	SACRAMENTO RIVER (at Sherman Lake)	4/1/92	38 03 10	121 47 38	6	9	2	17.5
BG32	SAN JOAQUIN RIVER (southwest Kimball Is.)	4/1/92	38 02 01	121 49 43	13	7	1	17

Table 3. Marsh stations and corresponding data.

STATION CODE	STATIONS	DATE	SALINITY (ppt)	TYPE OF COLLECTION
MA10	COYOTE HILLS SLOUGH	11/25/91	19	TUBES
MB10	SAN LEANDRO BAY/ARROWHEAD MARSH	11/25/91	30	TUBES
MB11	SAN LEANDRO BAY/GARRETSON POINT	11/25/91	30	TUBES
MB20	SAN LORENZO CREEK	11/25/91	34	TUBES
MC10	RICHMOND INNER HARBOR/HOFFMAN MARSH	11/26/91	30	TUBES
MC20	CERRITO CREEK MOUTH	11/26/91	32	TUBES
MC21	CORDORNICES CREEK MOUTH	11/26/91	30	TUBES
MC30	EMERYVILLE MARSH/EBMUD STORMDRAIN	2/21/92	28	NON-DIVER SCRAPE
MC50	CORTE MADERA MARSH S. OF INDUSTRIAL ROAD	2/17/92	28	NON-DIVER SCRAPE
MC51	CORTE MADERA CREEK/LARKSPUR FERRY MARSH	2/17/92	27	NON-DIVER SCRAPE
MC60	SILVA ISLAND MARSH/BEHIND CHEVRON	2/18/92	27	NON-DIVER SCRAPE
MC61	SILVA ISLAND MARSH/SEMINAR DR. STORMDRAIN	2/18/92	28	NON-DIVER SCRAPE
MD10	MILLER CREEK/LAS GALLINAS DISCHARGE	2/19/92	27	NON-DIVER SCRAPE
MD11	MILLER CREEK/UPSTREAM FROM DISCHARGE	2/19/92	28	NON-DIVER SCRAPE
MD20	GALLINAS CREEK/JOHN F. McINNIS COUNTY PARK	2/19/92	28	NON-DIVER SCRAPE
MD21	NOVATO CREEK/AT LOCK	2/19/92	28	NON-DIVER SCRAPE
MD30	PETALUMA RIVER MOUTH/E. BANK MARSH	11/1/91	27	TUBES
MD31	TOLAY CREEK MOUTH	11/1/91	26	TUBES
MD32	NAPA SLOUGH/BRIDGE	11/1/91	26	TUBES
MD33	SONOMA CREEK/TUBBS	11/1/91	26	TUBES
MD34	SONOMA CREEK/BRIDGE	11/1/91	26	TUBES
MD35	INLET EAST OF NAPA SLOUGH	10/31/91	25	TUBES
MD36	MARE ISLAND NORTHERN TIP	10/31/91	23	TUBES
MD37	MARE ISLAND CENTRAL/AT PILES	10/31/91	25	TUBES
MF10	BOYNTON SLOUGH C1	7/23/91	20	DIVER SCRAPE
MF11	BOYNTON SLOUGH C3	7/23/91	20	DIVER SCRAPE
MF12	BOYNTON SLOUGH C4	7/23/91	20	DIVER SCRAPE
MF13	BOYNTON SLOUGH CR2	7/23/91	20	DIVER SCRAPE
MF20	HILL SLOUGH/BELOW BRIDGE	7/24/91	20	DIVER SCRAPE
MF21	HILL SLOUGH/ABOVE BRIDGE	7/24/91	21	DIVER SCRAPE
MF22	PEYTON SLOUGH/BACK END OF SLOUGH	7/24/91	20	DIVER SCRAPE
MF23	PEYTON SLOUGH/MOUTH OF SLOUGH	7/24/91	21	DIVER SCRAPE
RS10	TOMALES BAY/ BRAZIL BEACH	•	29	DIVER SCRAPE
RS11	TOMALES BAY/ MARCONI COVE	••	22	DIVER SCRAPE
RS20	LAKE MENDOCINO	•••	20	DIVER SCRAPE

•	4/8/91,7/16/91
••	9/3/91,10/31/91,11/26/91,2/21/92,4/2/92
•••	4/24/91,6/10/91,7/16/91,9/16/91

Table 4 Statistical Summary of Trace Element Concentrations in San Francisco Bay Sediments

Fall, 1991 (Dry Weather); n=15

	Mean	SD	Median	Max	Min
Cr	76	8	78	87	61
Zn	112	16	111	137	77
Co	16	2	16	19	14
Ni	76	8	76	90	62
V	61	6	63	73	50
Cu	45	24	39	124	22
Cd	0.25	0.14	0.23	0.74	0.12
Pb	39	24	36	110	8
Ag	0.60	0.27	0.63	1.16	0.10

Spring, 1992 (Wet Weather) n=14

	Mean	SD	Median	Max	Min
Cr	79	12	83	92	47
Zn	109	17	115	127	73
Co	16	2	16	20	11
Ni	74	11	77	92	51
V	61	9	62	81	41
Cu	41	8	40	54	24
Cd	0.24	0.10	0.21	0.49	0.12
Pb	29	11	29	56	9
Ag	0.42	0.14	0.43	0.63	0.13

Values Reported in mg analyte per kg dry sediment (ppm)

Table 5 Bay Sediment Toxicity Tests - Eohaustorius
Mean survival ± SD of Eohaustorius estuarius in bay test sediments, "Home" (H) treatments, and reference sediments (RS11). Significant differences between survival in test sediments and "home" and reference tretments is indicated (ANOVA Fisher multiple range test of arcsin(x) transformed % survival values, p,0.01). n= 5 replicates, with 20 or 16 individuals/replicate.

				Significant Difference	
Test Date	Station	Mean	±SD	RS	H
9/20/91	RS 11	17	2		
n=20	H	19	1		
	BA 20	9	2	X	X
	BA 30	10	3	X	X
	BA 40	10	2	X	X
	BB 31	14	2	X	X
	BC 10	19	1		
	BC 30	10	4	X	X
	BC 50	17	1		X
	BD 20	12	3	X	X
	BD 30	15	4		X
	BD 40	18	1		
	BD 51	11	2	X	X
	BF 10	14	2	X	X
	BF 20	13	2	X	X
	BG 21	17	2		
	BG 31	19	0		
4/15/92	RS 11	10	2		
n=16	H	14	1		
	BA 20	7	2		X
	BA 30	8	3		X
	BA 40	10	0		X
	BB 31	10	2		X
	BC 10	11	1		X
	BC 31	9	5		X
	BC 50	8	1		X
	BD 20	9	2		X
	BD 30	14	2	X	
	BD 52	9	3		X
	BF 10	11	1		X
	BF 20	8	3		X
	BG 21	9	3		X
	BG 32	14	2	X	

Table 6 Bay Sediment Toxicity Tests - *Rhepoxinius*
Mean survival ± SD of *Rhepoxinius abronius* in bay test sediments,"Home " (H) treatment, and reference sediment (RS 11). Significant differences between survival in test sediments and "Home" and reference treatments are indicated (ANOVA Fisher multiple range test of arcsin(x) transformed % survival values, $p<0.01$). n= 5 replicates, with 20 individuals/replicate.

				Significant Difference	
Test Date	Station	Mean	±SD	**RS 11**	**H**
9/18/91	RS 11	19	1		
	H	20	1		
	BA 20	13	5	**X**	**X**
	BA 40	17	2		
	BB 30	17	2		
	BC 30	14	2		**X**
	BC 50	17	2		
	BD 40	16	4		

Table 7 Bay Sediment Toxicity Tests - *Daphnia*
Mean survival ± SD and mean number of babies ± SD of *Daphnia magna* in bay test sediments and reference sediment (RS 20). No significant difference between treatments was found (ANOVA Fisher multiple range test of arcsin(x) transformed % survival values and number of babies, $p<0.05$). n= 5replicates, with 10 individuals/replicate.

		Mean±SD			
Test Date	Station	Survival		# of Babies	
9/19/91	RS 20	9	1	56	37
	BG 21	9	1	70	37
	BG 31	9	1	55	41

Table 8 Bay Survey Results.

8a Summary results from larval bivalve and larval fish elutriate toxicity tests from the bay surveys. All data are means ± standard deviations of five laboratory replicates. Date indicates the month samples were collected. "Not tested" indicates samples determined before testing to be outside the salinity range of the test species. "Control" indicates organisms incubated in Granite Canyon seawater adjusted with distilled water to the test salinity.

	Oyster Larvae % Abnormal		*Menidia* Larvae (August 1991)	
Station	August 1991	April 1992	% Mortality	Weight (mg)
Control	23.0 ± 6.9	15.5 ± 8.0	15.0 ± 10.0	
Control*	3.3 ± 0.6*			
RS11	11.6 ± 5.9*	16.5 ± 15.2	15.0 ± 19.1	0.78 ± 0.51
BA20	17.4 ± 7.2	22.1 ± 11.8	15.0 ± 19.1	0.90 ± 0.24
BA30	24.4 ± 7.5	16.3 ± 9.6	20.0 ± 28.3	0.78 ± 0.10
BA40	72.0 ± 11.1	14.1 ± 3.6	30.0 ± 11.5	0.70 ± 17.3
BB31	25.6 ± 7.6	8.8 ± 5.0	30.0 ± 20.0	0.62 ± 0.17
BC10	15.9 ± 6.5	13.2 ± 5.9	0.0 ± 0.0	1.05 ± .079
BC30	31.9 ± 9.9	14.2 ± 5.7	15.0 ± 30.0	0.97 ± 0.21
BC50	18.9 ± 5.6	8.3 ± 2.3	5.0 ± 30.0	0.61 ± 0.23
BD20	28.3 ± 10.8	47.9 ± 18.5	27.5 ± 22.2	0.74 ± 0.25
BD30	29.7 ± 7.5	16.0 ± 5.4	15.0 ± 19.1	0.83 ± 0.15
BD40	17.9 ± 3.5		25.0 ± 30.0	0.91 ± 0.10
BD51	29.6 ± 8.6		15.0 ± 10.0	0.65 ± 0.26
BD52		12.7 ± 6.5		
BF10	45.3 ± 3.7	11.1 ± 7.7	40.0 ± 28.3	0.92 ± 0.22
BF20	3.6 ± 7.3*	6.4 ± 3.9	47.5 ± 25.0	1.08 ± 0.48
BG21	Not Tested	97.5 ± 2.9	45.0 ± 41.2	0.90 ± 0.27
BG31	Not Tested		5.0 ± 10.0	0.77 ± 0.08
BG32		95.4 ± 2.6		

* Samples from these two stations were tested separately at a later date. See text and Table 4.

Table 8b Bay sites exhibiting significant toxicity to test organisms in sediment elutriate tests. Data were analyzed by ANOVA using laboratory replicates to define the error term.

Test Series & Date	Species	Sites Significantly More Toxic Than Seawater Controls	Sites Significantly More Toxic Than Reference Sites
Bay #1	Bivalve	BA40, BF10	NA
August 91	*Menidia*	None Significantly Different	None Significantly Different
Bay #2	Bivalve	BD20, BG21, BG32	BD20, BG21, BG32

Table 9 Marsh Toxicity Tests - *Eohaustorius*
Mean survival ± SD of *Eohaustorius estuarius* in marsh test sediments, "Home" (H) treatments, and reference sediment (RS 10 or RS 11). Significant differences between survival in test sediments and "Home" and reference treatments are indicated for significance levels listed (ANOVA Fisher multiple range test of arcsin(x) transformed % survival values). n=5 replicates, with 20 individuals/replicate in all tests except 7/26/91, in which there were 12 individuals/replicate.

				Significant Difference	
Test Date	Station	Mean	±SD	**RS**	**H**
7/26/91	RS 10	2	2		
p=0.01	H	10	1		
	MF 10	4	1		X
	MF 11	5	2		X
	MF 12	5	2		X
	MF 13	8	3	X	
	MF 20	6	2		X
	MF 21	5	3		X
	MF 22	6	3		X
	MF 23	8	1	X	
11/9/91	RS 11	17	2		
p=0.05	H	19	1		
	MD 30	16	3		X
	MD 31	13	3	X	X
	MD 32	12	2	X	X
	MD 33	10	2	X	X
	MD 34	10	2	X	X
	MD 35	15	2		X
	MD 36	18	3		
	MD 37	19	1	X	
12/19/91	RS 11	18	0		
p=0.01	H	19	2		
	MA 10	17	3		
	MB 10	15	2		X
	MB 11	17	2		
	MB 20	17	2		
	MC 10	18	2		
	MC 20	19	2		
	MC 21	16	1		
2/26/92	RS 11	10	2		
p=0.05	H	18	1		
	MC 30	11	5		X
	MC 50	12	3		X
	MC 51	14	3	X	X
	MC 60	17	2	X	
	MC 61	16	2	X	X
	MD 10	15	4	X	X
	MD 11	15	3	X	X
	MD 20	8	3		X
	MD 21	10	2		X

Table 10 Marsh Survey Results.

10a Summary results from larval bivalve and larval fish elutriate toxicity tests from the marsh surveys. All data are means ± standard deviations of five laboratory replicates. Date indicates the month samples were collected. "Not tested" indicates samples determined before testing to be outside the salinity range of the test species. "Control" indicates organisms incubated in Granite Canyon seawater adjusted with distilled water to the test salinity.

		Oyster Larvae	*Menidia* Larvae		*Atherinops* Larvae	
Date	Station	% Abnormal	% Mortality	Weight (mg)	% Mortality	Weight (mg)
July 91	Control	15.7 ± 10.0	7.5 ± 6.8	0.70 ± 0.08	0.0 ± 0.0	0.98 ± 0.12
	RS10	74.8 ± 6.9	7.5 ± 11.2	0.75 ± 0.10	4.0 ± 8.9	1.15 ± 0.15
	LM	100.0 ± 0.0	24.7 ± 12.9	0.72 ± 0.13	28.0 ± 30.3	0.98 ± 0.31
	MF10	94.6 ± 2.6	10.0 ± 10.5	0.80 ± 0.09	0.0 ± 0.0	1.16 ± 0.12
	MF11	61.0 ± 6.9	5.0 ± 6.8	0.73 ± 0.08	0.0 ± 0.0	1.11 ± 0.08
	MF12	63.3 ± 13.9	10.4 ± 10.6	0.72 ± 0.07	4.0 ± 8.9	1.11 ± 0.10
	MF13	73.4 ± 7.3	12.5 ± 12.5	0.82 ± 0.08	8.0 ± 17.9	1.09 ± 0.02
	MF20	Not Tested	5.0 ± 6.8	0.76 ± 0.08	4.0 ± 8.9	0.97 ± 0.16
	MF21	Not Tested	10.4 ± 10.6	0.68 ± 0.06	48.0 ± 26.8	1.14 ± 0.21
	MF22	12.3 ± 6.6	5.0 ± 6.8	0.79 ± 0.07	0.0 ± 0.0	1.21 ± 0.12
	MF23	39.9 ± 10.1	2.5 ± 5.6	0.69 ± 0.05	0.0 ± 0.0	1.14 ± 0.10
Oct. 91	Control	1.9 ± 1.7	8.0 ± 11.0	1.03 ± 0.19		
	RE11	1.2 ± 1.1	4.0 ± 8.9	1.11 ± 1.24		
	MD30	2.6 ± 2.0	0.0 ± 0.0	1.25 ± 0.17		
	MD31	1.4 ± 0.6	0.0 ± 0.0	1.28 ± 0.24		
	MD32	1.8 ± 1.2	4.0 ± 8.9	1.15 ± .26		
	MD33	1.5 ± 1.4	8.0 ± 11.0	1.18 ± .28		
	MD34	0.4 ± 0.6	4.0 ± 8.9	1.69 ± .741		
	MD35	0.7 ± 0.6	0.0 ± 0.0	1.46 ± 0.13		
	MD36	1.1 ± 0.7	0.0 ± 0.0	1.16 ± 0.29		
	MD37	1.2 ± 1.1	0.0 ± 0.0	1.15 ± 0.23		

Oct. 91 Oyster Larvae in Pore Water[†]

Control	4.7 ± 1.3
RE11	10.7 ± 5.9 (n = 2)
MD36	6.5 ± 4.2
MD37	4.5 ± 2.1

[†] Pore water = supernatant water remaining above settled sediment in original sample jars.

Table 10 (Continued).

Date	Station	Mussel Larvae % Abnormal	*Menidia* Larvae % Mortality	 Weight (mg)
Nov. 91	Control	0.8 ± 0.4	4.0 ± 8.9	0.76 ± 0.15
	RS11	2.4 ± 2.5	8.0 ± 17.9	0.60 ± 0.17
	MA10	1.7 ± 1.1	17.0 ± 9.7	0.87 ± 0.07
	MB10	1.2 ± 1.9	0.0 ± 0.0	0.70 ± 0.10
	MB11	1.0 ± 0.7	20.0 ± 20.0	0.94 ± 0.16
	MB20	0.8 ± 0.5	16.0 ± 16.7	0.79 ± 0.13
	MC10	1.5 ± 0.8	8.0 ± 11.0	0.75 ± 0.09
	MC20	2.1 ± 1.9	12.0 ± 11.0	0.86 ± 0.07
	MC21	1.4 ± 0.8	8.0 ± 11.0	0.88 ± 0.05

Date	Station	Oyster Larvae % Abnormal	*Menidia* Larvae % Mortality	 Weight (mg)
Feb. 92	Control	14.9 ± 4.6	8.0 ± 11	0.74 ± 0.09
	RS11	51.1 ± 7.0	0.0 ± 0.0	0.84 ± 0.15
	MC30	19.5 ± 7.5	8.0 ± 11.0	0.89 ± 0.14
	MC50	27.1 ± 8.0	0.0 ± 0.0	0.76 ± 0.15
	MC51	20.2 ± 8.6	12.0 ± 11.0	0.77 ± 0.15
	MC60	26.4 ± 15.9	0.0 ± 0.0	0.94 ± 0.12
	MC61	99.1 ± 1.6	24.0 ± 26.1	0.89 ± 0.48
	MD10	29.2 ± 14.0	4.0 ± 8.9	0.80 ± 0.14
	MD11	98.6 ± 1.4	4.0 ± 8.9	0.84 ± 0.09
	MD20	25.7 ± 10.3	8.0 ± 11	0.87 ± 0.08
	MD21	26.0 ± 5.6	4.0 ± 8.9	0.84 ± 0.09

Table 10b Sites exhibiting significant toxicity to test organisms in sediment elutriate tests from the marsh survey. Data were analyzed by ANOVA.

Test Series & Date	Species	Sites Significantly More Toxic Than Seawater Controls	Sites Significantly More Toxic Than Reference Sites
Marsh #1	Bivalve	All except MF22 (incl. Ref Sites)	LM, MF10
July 91	*Menidia*	LM	LM
	Atherinops	LM, MF21	LM, MF21
Marsh #2	All Tests	None Significantly Different	None Significantly Different
October 91			
Marsh #3	All Tests	None Significantly Different	None Significantly Different
November 91			
Marsh #4	Bivalve	RS11, MD10, MD11, MC61	MD11, MC61
February 92	*Menidia*	MC61	MC61

Table 11 : Porewater concentrations of trace elements for gradient study

		Pb	Pb	Ag	Ag	Zn	Zn	Cu	Cu	Cd	Cd	Ni	Ni	Mn	Mn
CODE	Station	avg ppb	SD	avg ppb	SD	avg ppm	SD	avg ppb	SD	avg ppb	SD	avg ppb	SD	avg ppm	SD
GD10	EVSO4 shallow	142	108	6.7	7.9	31	13	509	200	85	30	6377	773	1940	616
GD20	EVSO4 deep	77	22	6.3	4.6	10	3	379	187	20	17	2948	1037	467	46
GD12	Pt.Pinole piling shallo	148	70	12.9	13.0	242	414	3034	3131	329	162	6377	1736	4646	1163
GD22	Pt.Pinole piling deep	80	83	27.2	44.4	34	9	284	122	182	185	3324	766	2137	81
GD21	CC2 deep	16	9	24.6	20.2	17	8	396	137	10	7	2364	477	969	146
GD23	CC4 deep	2	5	5.4	10.8	10	3	242	46	13	19	2474	315	1463	222
CI10	Carr Inlet shallow	340	n=1	39.9	n=1	13	n=1	1651	n=1	139	n=1	2101	n=1	81	n=1
CI20	Carr Inlet deep	79	n=1	0.0	n=1	13	n=1	248	n=1	8	n=1	1174	n=1	494	n=1

Five field replicates for each station, except for Carr Inlet

Table 12 : Sediment concentrations of trace elements for gradient study

Code	Location	Cr	Cr	Zn	Zn	Cu	Cu	Ni	Ni	Pb	Pb	Cd	Cd	Ag	Ag
		avg ppm	SD	avg ppm	SD	avg ppm	SD	avg ppm	SD	avg ppm	SD	avg ppm	SD	avg ppm	SD
GD10	EVSO4 shallow	86	6	135	6	74	18	86	4	33	2	0.37	0.06	0.30	0.03
GD20	EVSO4 deep	100	4	191	15	154	48	100	2	58	5	1.05	0.14	0.42	0.02
GD12	Pt.Pinole piling shallow	91	8	130	4	47	2	82	2	30	2	0.20	0.00	0.28	0.02
GD22	Pt.Pinole piling deep	63	3	84	4	25	1	48	1	21	3	0.30	0.03	0.17	0.02
GD21	CC2 deep	61	9	90	12	37	7	49	7	25	4	0.41	0.06	0.16	0.02
GD23	CC4 deep	86	11	148	22	53	10	82	11	49	17	0.70	0.27	0.32	0.08
CI10	Carr Inlet shallow	41	n=1	55	n=1	25	n=1	30	n=1	13	n=1	0.59	n=1	0.17	n=1
CI20	Carr Inlet deep	27	n=1	57	n=1	40	n=1	31	n=1	12	n=1	0.57	n=1	0.16	n=1

Five field replicates for each station, except for Carr Inlet

Table 13a Comparisons of various factors affecting larval oyster toxicity test results from the Castro Cove gradient study. ANOVA tests were conducted using means for each field replicate (n=5). Comparisons between field replicates were made using laboratory replicates to define the ANOVA error term.

* Indicates significant differences.

b Individual comparisons among sites are given below in Table 3c.

Comparison	Samples Used in Comparison	Probability
Between Sites	shallow layer, pore water	0.58
Between Sites	deep core, pore water	0.0001*b
Between Sites	shallow layer, elutriates	0.24
Between Sites	deep core, elutriates	0.03*b
Shallow layer (.38) vs Deep Core (.58)	pore water, PP and EVS 04	0.35
Shallow layer (.10) vs Deep Core (.15)	elutriate, PP, EVS 04, and CC2	0.44
Pore water (.38) vs Elutriate (.11)	shallow layer, PP and EVS 04	0.06
Pore water (.79) vs Elutriate (.13)	deep core, PP, EVS 04, CC2 & CC4	0.0001*
Between Field Reps	shallow layer, pore water, PP	0.0001*
Between Field Reps	shallow layer, pore water, EVS 04	0.0001*
Between Field Reps	deep core, elutriate, CC2	0.03*
Between Field Reps	all others	> 0.05

Table 13b Individual comparisons of sites within the gradient study indicate the following sites had significantly greater toxicity than reference sites at $p < 0.05$ using Dunnett's multiple comparison test. The proportion abnormal for each site is given in parentheses.

Type of Sample	Reference Site	Sites with Significant Toxicity
Deep Core, Pore Water	GD22 (0.17)	GD20 (0.99) GD23 (1.00) GD21 (0.98) (CI20 (1.00))
Deep Core, Elutriate	GD22 (0.09)	GD20 (0.29)

Table 14

Differences between sites and control levels of trace metals in mussels and oysters
at 30, 60, 90, and 120 days during Phase I and II. *=significant difference for metal indicated

Phase 1	Duration	Site Names	No. of metals Sign. Diff.	Ag	Cd	Cu	Hg	Pb	Se	Zn
Mussels										
	30 days	Redwood Creek	2			*				*
	30 days	Treasure Island	3			*	*		*	
	60 days	Redwood Creek	4	*				*	*	*
	60 days	Treasure Island	4	*		*		*		*
	90 days	Redwood Creek	3				*	*		*
	90 days	Treasure Island	6	*		*	*	*	*	*
	90 days	Dumbarton Bridge	5	*	*	*		*		*
	90 days	Pt Pinole	5			*	*	*	*	*
	120 days	Redwood Creek	4	*			*	*		*
	120 days	Treasure Island	7	*	*	*	*	*	*	*
Oysters	90 days	Redwood Creek	5	*		*		*	*	*
	90 days	Treasure Island	4	*		*		*	*	
	90 days	Dumbarton Bridge	4	*		*		*	*	
	90 days	Pt Pinole	4	*		*		*		*
Phase II				**Ag**	**Cd**	**Cu**	**Hg**	**Pb**	**Se**	**Zn**
Mussels	30 days	Redwood Creek	7	*	*	*	*	*	*	*
	30 days	Treasure Island	4			*	*	*	*	
	30 days	Dumbarton Bridge	4	*		*	*	*		
	60 days	Redwood Creek	7	*	*	*	*	*	*	*
	60 days	Treasure Island	6	*		*	*	*	*	*
	60 days	Dumbarton Bridge	4			*	*	*		*
	90 days	Redwood Creek	5	*		*	*	*	*	
	90 days	Treasure Island	6	*		*	*	*	*	*
	90 days	Dumbarton Bridge	6	*		*	*	*	*	*
	90 days	Davis Point	4			*		*	*	*
	90 days	Coyote Creek	5		*	*		*	*	*
	90 days	Pt Pinole	5		*	*		*	*	*
	120 days	Redwood Creek	6	*		*	*	*	*	*
	120 days	Treasure Island	6	*		*	*	*	*	*
	120 days	Dumbarton Bridge	6	*		*	*	*	*	*
	90 days	Redwood-depurated	6	*		*	*	*	*	*
	90 days	Treasure I-depurated	6	*		*	*	*	*	*
	90 days	Dumbarton-depurated	6	*		*	*	*	*	*
	90 days	Redwood-deep	6	*		*	*	*	*	*
	90 days	Dumbarton-deep	6	*		*	*	*	*	*
Oysters	90 days	Coyote Creek	5		*		*	*	*	*
	90 days	Davis Point	5		*	*		*	*	*

Table 15

CONTAMINANTS IN SOUTH, CENTRAL AND NORTH BAY MUSSELS

CONTAMINANT	MEAN SOUTH	MEAN TREASURE I	MEAN NORTH	PREDOMINANT TREND
SILVER	0.305	0.345	0.15	NORTH LOW
CADMIUM	7.25	8.3	9.5	NORTH SLIGHTLY HIGH
COPPER	10	12.5	12.1	CENTRAL, NORTH SLIGHTLY HIGH
MERCURY	0.25	0.295	0.235	NONE
LEAD	2.355	2.5	3.05	NORTH SLIGHTLY HIGH
SELENIUM	1.75	3.1	2.55	NORTH, CENTRAL SLIGHTLY HIGH
ZINC	230	230	230	NONE
SUM DDT	226.5	68	92	SOUTH HIGH
SUM CHLORDANE	60.05	20.35	17	SOUTH HIGH
SUM PAH	429.5	936	246.5	CENTRAL AND SOUTH HIGH
SUM PCB	391.5	213	86.5	SOUTH AND CENTRAL HIGH

MEANS ARE FROM TWO VALUES (PHASE 1 AND PHASE II)

Table 16

RATIOS BETWEEN MUSSELS AND OYSTERS				MEAN					MEAN
	MUSSELS	OYSTERS	RATIO	RATIO		MUSSELS	OYSTERS	RATIO	RATIO
DDT	117	132	0.89		COPPER	13	240	0.05	
	72	110	0.65			13	200	0.07	
	58	97	0.60			7.5	253	0.03	
	73	124	0.59			9	180	0.05	
	267	228	1.17	0.78		10	417	0.02	0.04
CHLORDANE	18	18	1.00		MERCURY	0.27	0.12	2.25	
	17	31	0.55			0.3	0.13	2.31	
	19	20	0.95			0.2	0.13	1.54	
	25	25	1.00			0.22	0.12	1.83	
	92	70	1.31	0.96		0.2	0.2	1.00	1.79
SUM PAHS	104	807	0.13		MANGANESE	26	49	0.53	
	621	1905	0.33			26	76	0.34	
	99	773	0.13			23.6	95	0.25	
	116	978	0.12			32	88	0.36	
	859	1423	0.60	0.26		22.9	56	0.41	0.38
SUM PCBS	129	169	0.76		LEAD	2.2	0.52	4.23	
	300	318	0.94			2.5	0.51	4.90	
	187	263	0.71			1.8	0.59	3.05	
	252	299	0.84			1.9	0.54	3.52	
	647	368	1.76	1.00		3.9	1.6	2.44	3.63
SILVER	0.2	5.9	0.03		SELENIUM	2.6	2.7	0.96	
	0.92	6.1	0.15			3	3.5	0.86	
	0.3	8.3	0.04			2.3	3.5	0.66	
	0.41	5.9	0.07			1.2	3.3	0.36	
	0.1	8	0.01	0.06		2.5	4.3	0.58	0.68
CADMIUM	8.9	6.1	1.46		ZINC	260	1100	0.24	
	7.6	6.6	1.15			260	1100	0.24	
	9.8	8	1.23			240	1400	0.17	
	7	7.8	0.90			250	900	0.28	
	10.1	8.1	1.25	1.20		200	1133	0.18	0.22
CHROMIUM	15	6	2.50		ALUMINUM	1433	410	3.50	
	8	2.8	2.86			1233	770	1.60	
	6.1	5	1.22			1400	640	2.19	
	9.7	1.8	5.39			1633	953	1.71	
	4.8	4.1	1.17	2.63		1800	750	2.40	2.28

Table 17

Relative rankings of heavy metal concentrations at times of 0, 1, 2, 3, and 4 months in mussels in Phase I and II
Intervals joined by lines are not significantly different.

	AG	CD	CU	HG	PB	SE	ZN
Phase I							
Redwood Creek	0 1 2 3 4	3 1 0 4 2	0 3 4 2 1	0 2 3 1 4	0 2 1 4 3	0 4 1 3 2	0 3 4 1 2
Treasure Island	0 1 2 3 4	4 2 1 3 0	0 2 4 3 1	0 2 1 4 3	0 1 2 4 3	0 2 1 3 4	0 1 2 4 3
Phase II							
Redwood Creek	0 3 1 2 4	4 3 0 2 1	0 1 3 4 2	0 4 1 3 2	0 1 3 4 2	0 1 3 2 4	0 3 4 2 1
Treasure Island	0 1 2 3 4	4 3 2 0 1	0 1 2 3 4	0 1 4 3 2	0 2 1 3 4	0 1 2 4 3	0 1 2 3 4
Dumbarton Br	0 1 2 3 4	4 3 0 2 1	0 1 2 3 4	0 4 1 2 3	0 2 1 4 3	0 1 2 4 3	0 1 2 4 3
Average Ranks: (lowest to highest months)							
Phase I	0.0 1.0 2.0 3.0 4.0	3.5 1.5 0.5 3.5 1.0	0.0 2.5 4.0 2.5 1.0	0.0 2.0 2.0 2.5 3.5	0.0 1.5 1.5 4.0 3.0	0.0 3.0 1.0 3.0 3.0	0.0 2.0 3.0 2.5 2.5
Phase II	0.0 1.7 1.7 2.7 4.0	4.0 3.0 0.7 1.3 1.0	0.0 1.0 2.3 3.3 3.3	0.0 3.0 2.0 2.7 2.3	0.0 1.7 1.7 3.7 3.0	0.0 1.0 2.3 3.3 3.3	0.0 1.7 2.7 3.0 2.7
Overall	0.0 1.4 1.8 2.8 4.0	3.8 2.4 0.6 2.2 1.0	0.0 1.6 3.0 3.0 2.4	0.0 2.6 2.0 2.6 2.8	0.0 1.6 1.6 3.8 3.0	0.0 1.8 1.8 3.2 3.2	0.0 1.8 2.8 2.8 2.6

APPENDIX D

Strategy for Establishing Sediment Quality Objectives based on Human Health Risk Assessment

This report is the product of a contract between the State Water Board and the CalEPA Office of Environmental Health Hazard Assessment. In the future, the State Water Board will consider funding this strategy.

STRATEGY FOR
ESTABLISHING SEDIMENT QUALITY OBJECTIVES
BASED ON
HUMAN HEALTH RISK ASSESSMENT

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PREFACE

The California Legislature and Governor added Chapter 5.6, Bay Protection and Toxic Cleanup (BPTC), to the state Water Code in an effort to protect the valuable resources within the estuarine waters and bays of the state. The BPTC section directs the State Water Resources Control Board (SWRCB) to formulate and adopt a plan to accomplish this goal (SWRCB, 1991). This plan is designated the Enclosed Bays and Estuaries Plan (EBEP).

One of the goals of the EBEP is to develop sediment quality objectives (SQO). These objectives will supplement existing water quality criteria. Sediment quality objectives are being developed to protect aquatic life and human health from chemical contaminants accumulating in sediments. The Office of Environmental Health Hazard Assessment (OEHHA) in cooperation with the SWRCB is responsible for developing recommendations for SQO for California bays and estuaries. This document describes the scientific background and a proposed technical strategy for establishing SQO based on human health concerns.

ACKNOWLEDGEMENTS

The strategy presented in this document reflects an ongoing collaboration between the Office of Environmental Health Hazard Assessment (OEHHA) and the State Water Resources Control Board (SWRCB). Staff of the SWRCB and OEHHA have contributed to the present document by gathering and reviewing information related to chemical contamination of fish and sediments. OEHHA acknowledges the contributions of these scientists in formulating the present strategy.

We also thank the following for their diligence in preparing this document: Ms. Patricia Henry for preparing and organizing the text; Ms. Mercedes Danao for preparing the figure; and Ms. Shirley Brouillette for the tables.

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EXECUTIVE SUMMARY

This report describes the scientific background and a proposed technical strategy for setting Sediment Quality Objectives for environmental chemicals in California based on human health effects in California. This strategy was developed by the Office of Environmental Health Hazard Assessment (OEHHA) in cooperation with the State Water Resources Control Board (SWRCB). The state Water Code requires that Sediment Quality Objectives (SQO) be developed in conjunction with the Bay Protection and Toxic Cleanup program.

Sediment quality objectives are levels of a contaminant in sediment which will not result in potentially unhealthy or hazardous levels of the contaminant in seafood (fish or shellfish) when consumed by humans, or which do not result in excessive environmental contamination (Water Code Section 13391.5). SQO are based on and are intended to be predictive of biological effects or tissue levels. SQO extend the process of protecting water quality by regulating sediment as a reservoir for contaminants and recognize fish or shellfish ingestion as an important route of exposure.

The following seven tasks comprise the strategy proposed by OEHHA to develop recommendations for SQO for human health effects in California.

1) Select contaminants of concern based on EPA lists. Prioritize contaminants of concern in California based on in-state use, toxicology profile, and California monitoring data.

2) Identify appropriate cancer potency (q_1*) or reference dose (RfD) for the prioritized contaminants of concern identified above.

3) Develop human exposure scenarios considering potentially different patterns of seafood consumption in California. Include alternative scenarios such as consumption of finfish and/or shellfish; and consumption by sensitive subpopulations (e.g., fishers, children, ethnic groups).

4) Determine a maximum tissue level of chemical contaminant allowable in fish and/or shellfish tissue using the appropriate seafood consumption scenario(s) and potency values identified above.

5) Use all appropriate bioaccumulation models to predict the accumulation of chemical contaminant from sediment to finfish and/or shellfish tissue.

6) Evaluate the bioaccumulation predictions by comparison to laboratory and field data. Based on the appropriate bioaccumulation value(s) calculate sediment levels that could lead to the maximum tissue level identified above. Sediment levels calculated in this way are proposed SQO based on human health effects.

7) Recommend the proposed SQO to the SWRCB for adoption. Include a discussion of the scientific basis and limits of certainty of this recommendation.

The Office of Environmental Health Hazard Assessment recommends adoption of this human health-based strategy to develop SQO.

1.0 INTRODUCTION

Chemical contaminants in the environment are a problem because they may reduce our quality of life and may threaten human health. Contaminants may be merely noxious or have serious toxic effects. Government agencies have addressed the problem of chemical contaminants in the environment by setting standards and guidelines for important air and water borne contaminants with the goal of protecting environmental quality and human health.

Sediments are a significant reservoir of environmental contaminants in aquatic environments (Dickson et al., 1987). At this time, regulatory controls for sediment-bound contaminants have not been completely incorporated into existing water quality standards. Consequently, recent legislation has focused on developing guidelines for chemical contaminants in sediments. These levels have been referred to as "sediment quality objectives" (SQO) in California (Water Code Section 13391.5), and "sediment quality criteria" (SQC) by the U.S. Environmental Protection Agency (EPA, 1991).

Human exposure to chemical contaminants in contaminated sediments is indirect via the consumption of seafood. Seafood species may directly assimilate the chemical contaminant from sediment or indirectly via consumption of contaminated organisms from lower levels of aquatic food-webs. This is the primary route through which humans can be exposed to chemicals present in the sediments, potentially leading to adverse health effects.

The purpose of developing SQO is to protect the broad scope of beneficial uses of California's coastal waters. The accumulation of chemical contaminants in sediments in California's bays and estuaries presents a potential hazard to both aquatic life and human health. Separate SQO will be developed for the protection of human health and aquatic life. Although both processes are related and equally important, the derived values may be very different. For a given chemical and site, the lower SQO will protect both endpoints.

Contaminated sediments have already resulted in the contamination of seafood in several locations in the United States. As an example, estimates of potential human carcinogenic risks from consumption of highly contaminated fish and shellfish range from 10^{-4} to 10^{-2} (see Appendix 1). Health advisories regarding consumption of fish or shellfish in contaminated locations have been issued throughout the United States including southern California (Pollock et al., 1991), Quincy Bay, Massachusetts (Reimold et al., 1988) and Puget Sound, Washington (Tetra Tech, 1988). These evaluations have been based on site-specific seafood tissue levels detected after extensive contamination had already occurred. There is a pressing need for the establishment of regulatory standards for a wide range of chemicals and locations that can be applied to prevent future contamination.

The objective of this report is to describe a strategy for developing such standards (SQO) for the protection of human health. While it is clear that sediment-bound contaminants have led to undesirable levels in seafood (see Pollock et al., 1991), a formal process for regulating contaminants in sediments has not been developed (Shea, 1988). Therefore, a strategy needs to be developed for establishing these levels.

2.0 REGULATORY FOUNDATION FOR SETTING SEDIMENT QUALITY OBJECTIVES

The regulation of chemical contaminants has focused on setting standards and criteria which protect humans from excessive exposure to the contaminants. Risk assessment methodology is currently used in this process (EPA, 1991). Using this methodology, acceptable exposure levels can be established for likely environmental exposure routes (typically air and water), and measures can be identified to mitigate excessive exposure.

The regulation of chemical contaminants in the air, soil and water serves to protect not only humans, but also other organisms from the toxic effects of these contaminants. Chemical contaminants in an environment can have far ranging adverse effects on organisms occupying that environment. Contaminants can have direct toxic effects on single organisms in the environment, either increasing or decreasing reproduction or survival. These direct individual effects may cause changes in the ecosystem by changing population size, species composition and etc. These changes may affect humans and wildlife that showed no direct toxic response or had no direct exposure to the source of contaminant.

In aquatic environments, chemical contaminants can directly impact organisms in or on the sediments (Giesy et al., 1990) or those in the water column (Malueg et al., 1983). These environments may have four or five trophic levels in complex food-webs (Dickson et al., 1987). A variety of invertebrate and vertebrate benthic or pelagic organisms can be exposed by consumption of lower trophic level organisms and/or direct ingestion or absorption of contaminant. Humans or wildlife consuming these organisms as food can be indirectly exposed to the contaminant and consequently may be put at risk of adverse health effects. Figure 1 shows an aquatic food-web tracing human exposure to a chemical contaminant introduced into the aquatic environment.

Federal regulations to protect aquatic environments are promulgated by the EPA and are based on the premise that the beneficial uses of aquatic environments should be protected (EPA, 1991). Protection includes aquatic organisms in these environments, and is extended to include the terrestrial organisms (e.g., humans) that use these environments. These aquatic organisms must not be adversely effected by exposures to a waterway. General water quality standards have been adopted by EPA which protect aquatic life and human health. National water quality criteria are the established means to translate narrative standards into numeric values. These numeric criteria are used for the control of toxic pollutants in water.

Individual states in turn adopt the general standards and objectives or customize them to meet their specific needs. State procedures generally follow the basic principles used by the EPA when adopting objectives to protect aquatic life and human health. Again, risk assessment methodology is presently the established foundation for deriving water quality criteria based on human health effects.

California has adopted regulatory standards and objectives for water quality (California Water Code) and will extend them to include SQO (Water Code Section 13392.6 and 13393). The State Water Resources Control Board (SWRCB) is responsible for the general development and implementation of these objectives and related programs (Water Code Sections 13390 - 13396) such as the California Enclosed Bays and Estuaries Plan (EBEP). Related programs will utilize SQO to identify and prioritize toxic hot spots in California bays and estuaries.

The Office of Environmental Health Hazard Assessment is charged with formulating SQO recommendations based on human health risk assessment (Water Code Sections 13393 and 13395.5). In developing a SQO strategy, OEHHA has built upon the established process for setting water quality criteria and incorporated relevant scientific information specific to sediments.

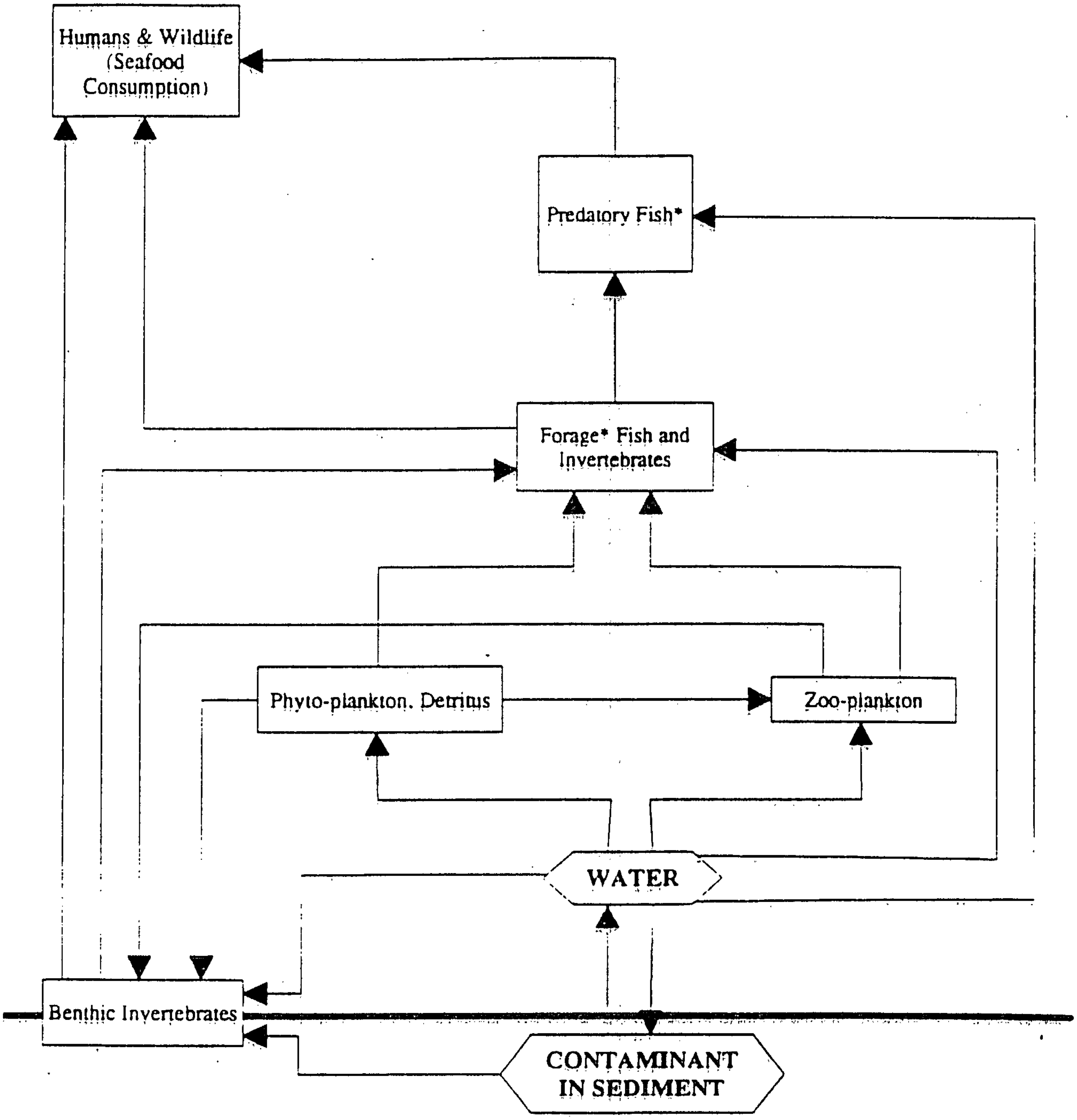

Figure 1: Pathways of Human and Wildlife Exposure through a Simplified Aquatic Food-web Due to Chemical Contamination of Sediments

→ Arrows show movement of contaminant.

* There may be more than one trophic level here.

3.0 APPROACH TO SETTING SEDIMENT QUALITY OBJECTIVES

The Office of Environmental Health Hazard Assessment proposes a technical strategy for developing SQO recommendations for human health in California. The strategy has been organized as a series of tasks for deriving SQO based on the methodologies of human health risk assessment and environmental fate modeling. These tasks include selecting and prioritizing contaminants of concern in California, setting maximum tissue levels for seafood tissue, predicting bioaccumulation, estimating sediment contaminant levels (proposed SQO) leading to the protective tissue levels, and evaluating the accuracy of each proposed SQO. The end product of application of this strategy will be a recommendation to the SWRCB for adoption of proposed SQO for selected chemical contaminants in sediments in California.

The scientific background for the strategy is presented below. This is followed by presentation of the seven basic tasks of the strategy.

4.0 SCIENTIFIC BACKGROUND FOR THE SEDIMENT QUALITY STRATEGY

4.1. Sediment Quality Objectives For Aquatic Life

Washington State has established standards for regulating the quality of marine sediments by using the apparent effects threshold (AET) approach (Washington State, Department of Ecology 1991). These AET values for chemical contaminants in sediment were developed based on the level of contaminant which caused an acute or chronic toxic effect to sensitive aquatic life forms in laboratory tests. Since toxicological effects in the AET approach depend on the environmental surroundings of a specific site, the sediment quality standards of Washington State are applicable only to the site for which they were developed, in this case Puget Sound.

EPA recognizes the AET approach as a credible step towards development of sediment quality criteria (EPA 1989b). EPA is evaluating this approach and the equilibrium partitioning (EqP) approach (EPA, 1989b, and 1990) for use in setting sediment quality criteria. The EqP is also being used to set contaminant levels in dredged materials (US Army Corps of Engineers and EPA, 1991). Thus far, these approaches have been applied to aquatic life. The SWRCB is also evaluating the AET approach for setting aquatic life objectives.

4.2. Sediment Quality Objectives For Human Health

A standardized procedure for setting SQO based on human health effects has not been established within the regulatory community (Shea, 1988). Any procedure to set SQO must recognize the indirect nature of human exposure to sediment contamination and the complex relationship(s) between contaminant levels in the sediment and in aquatic organisms at different trophic levels. The elements for a procedure can be developed by combining the risk assessment process and models estimating the movement and bioaccumulation of chemical contaminants in aquatic ecosystems. These models are necessary to predict the sediment concentration of a contaminant that would lead to a given concentration in edible seafood.

Risk assessment and bioaccumulation modeling are based on different underlying assumptions that incorporate available biological data and facilitate prediction of specified endpoints. Both are flexible and may incorporate options or methods that are more appropriate in different situations. This section reviews the scientific background for risk assessment and bioaccumulation modeling with emphasis on applications for deriving SQO. In addition, some of the underlying uncertainties in risk assessment and bioaccumulation modeling are discussed. Some of the uncertainties in bioaccumulation modeling may be reduced with the collection of monitoring data that can be used to calibrate and validate models.

4.2.1. Human Risk Assessment

Human risk assessment can be used to establish acceptable levels of contaminants under specified exposure conditions (e.g., consumption of contaminated seafood)(EPA, 1989a; NRC, 1983; Pastorok, 1988). Risk assessment is the process for evaluating the toxicity of a contaminant and quantifying the potential harm (risk), if any, caused by exposure to the contaminant. Risk assessment is usually divided into four discrete steps: hazard identification, dose-response assessment, exposure assessment and risk characterization (NAS, 1975; NRC, 1983).

Hazard Identification (HI) is the determination of whether a particular chemical is or is not causally linked to a particular adverse health effect. Cancer and non-cancer (e.g., birth defects, nerve damage or organ dysfunction) endpoints are considered germane health effects for risk assessment. Hazard identification involves a qualitative determination of the toxicity of the contaminant. Pertinent health effects are observed in humans and/or experimental animals.

Dose-Response Assessment (DRA) is the determination of the relation between the magnitude of exposure and the extent of biological response or the probability of occurrence of the health effects in question. DRA is the quantitative determination of the potency of a contaminant and may vary with the route of exposure to the contaminant.

HI and DRA, combined, involve a complete review of the toxicology database, a determination of the quality of the toxicology studies, and mathematical modeling of the dose-response data. The result of a DRA for a carcinogenic compound is the determination of a carcinogenic potency value (q_1*) for the compound. The q_1* can be used to estimate excess cancer risk due to exposure to a specified dose of the carcinogenic contaminant.
A reference dose (RfD), previously referred to as an acceptable daily intake (ADI), is usually determined for non-carcinogenic toxicological endpoints (e.g., effects believed to have a

threshold for response). The RfD is defined as a daily level of exposure which can be tolerated over a lifetime without anticipated adverse effects. The RfD is usually determined by identifying the No Observed Effect Level (NOEL) in animal studies and dividing this level by an uncertainty factor. The uncertainty factor is determined based on the quality, nature, and completeness of the database and usually ranges from 10 to 10,000. In some cases, the NOEL may be estimated using a newer approach for evaluating non-carcinogenic data, referred to as the benchmark dose procedure.

Hazard identification and dose-response assessments of many common contaminants have already been completed by various organizations such as OEHHA, EPA, and the World Health Organization. OEHHA maintains a current listing of q_1* values determined by California agencies for many contaminants (OEHHA, 1992). The EPA Integrated Risk Information System (IRIS) database also contains q_1* and RfD information.

Exposure Assessment (EA) is the determination of the extent of exposure before or after application of regulatory controls. The route (e.g., oral, dermal or inhalation), the magnitude, frequency, and duration of exposure are considered in the EA. EA also requires identifying the population of health concern (usually a subpopulation with high exposure).

For SQO, the relevant exposure route is consumption of contaminated fish or shellfish. Thus, EA involves estimating human rates of seafood consumption and tissue concentrations of chemical contaminants in the consumed seafood species. The relevant time-frame for exposure may vary from a single meal to a lifetime depending on the identified health hazard. A comprehensive EA would include other sources of exposure (e.g., air or water).

Risk Characterization (RC) is the description of the nature and often the magnitude of human risk, including attendant uncertainty. RC brings together the toxicity information from HI and DRA and the exposure information from EA to estimate the potential risks in a specified exposure situation.

4.2.1.1. Maximum Tissue Levels in Seafood

Risk assessment, therefore, can be used to calculate acceptable levels of a contaminant in seafood based on a given level of risk (e.g., 1×10^{-6} cancer risk). This major step in setting sediment quality objectives is similar to the EPA's method for calculation of Reference Tissue Concentrations (RTC) for seafood in their Technical Support Document for Water Quality-based Toxics Control (EPA, 1991). The SWRCB adapted EPA's RTC approach in calculating Maximum Tissue Residue Limits (MTRL) for fish in the Pollutant Policy Document (1988). The difference between the derivation of RTC and MTRL is that MTRL focus on water as the exposure source. The MTRL equation for carcinogens is:

$$\text{MTRL (mg/kg)} = \frac{RL \times WT}{q_1{}^* \times FC} \qquad (1)$$

The corresponding MTRL equation for non-carcinogens is:

$$\text{MTRL (mg/kg)} = \frac{RfD \times WT}{FC} \qquad (2)$$

where:

RL = risk level (e.g., 10^{-6}),
WT = standard weight of average human adult (70 kg),
$q_1{}^*$ = cancer potency factor $(\text{mg/kg/day})^{-1}$,
FC = daily fish or shellfish consumption (kg/day), Different values can be used to reflect the eating habits of different target populations and,
RfD = reference dose (mg/kg/day).

These equations will be adapted to develop maximum tissue levels for SQO for bays and estuaries.

4.2.2. Predicting Bioaccumulation

Deriving SQO requires determination of the concentration of contaminant in the sediment that would yield the maximum tissue levels. This involves following and predicting the movement and accumulation of a chemical within bay and estuarine food-webs.

The movement and concentration of contaminants from the physical environment to the biota is termed bioaccumulation. In some cases, lower concentrations of contaminants accumulate in organisms, but in many cases the observed concentrations in biota are higher than found in the physical environment (Dickson et al., 1987; Young, 1988). Quantitative models for describing the bioaccumulation of a chemical contaminant have been developed. Generally, these models have described the property of bioaccumulation as a function of bioconcentration and other related factors. Bioaccumulation estimates from these models can be used in reverse to calculate sediment levels corresponding to tissue concentrations. These calculated sediment levels are derived SQO.

Aquatic organisms can bioaccumulate chemical contaminants from either the water phase or the solid (particulate and/or sediment) phase (Dickson et al., 1987). Sediments are composed of a particle phase and an interstitial water phase (pore water). Chemical contaminants tend to either associate more with water or be bound more closely with particles. Ionic and water soluble compounds tend to be dissolved in the water. Nonionic or neutral organic compounds tend to be more tightly bound to the particles.

Compounds which are associated with particles or are themselves particles may settle out of the water into the sediment. Over time, the accumulated total mass of a contaminant in sediment can become much greater than the amount dissolved in the overlying water column. Thus, sediments act as an important reservoir for particle-bound chemical contaminants in aquatic environments (Morel and Schiff, 1983).

Bioaccumulation specifically due to exposure to the water column is designated bioconcentration and is expressed as a bioconcentration factor (BCF). This form of accumulation is defined as the concentration of the chemical in tissue divided by the concentration in the water column (EPA, 1980; 1991). BCF can be determined in relatively simple laboratory tests.

In sediments, benthic organisms are exposed to contaminants within the pore water and by ingestion of sediment particles. These organisms can bioaccumulate concentrations of the chemical above the level predicted based on the BCF because they also ingest sediment-bound contaminants (Dexter and Field, 1989). Similarly, organisms higher in the food-web which consume (ingest) contaminated benthic organisms can bioaccumulate levels of contaminant above that estimated by BCF (Thomann and Connolly, 1984). The total bioaccumulation via all routes is called the Bioaccumulation Factor (BAF). (See Figure 1 for a diagram of a simplified aquatic food-web.)

4.2.2.1. Methods for Estimating Bioaccumulation

A number of mathematical equations and models using field or laboratory data have been developed to predict the bioaccumulation potential or tissue concentration of contaminants associated with sediments or water. These models follow two general approaches: equilibrium-based models and kinetic models. Equilibrium models assume that a chemically based equilibrium will be reached for any contaminant within components of the system being sampled and modeled. The equilibrium approach focuses on the partitioning of chemicals between sediment and benthic organisms assuming that thermodynamic equilibrium exists between the sediment and the organisms in the sediment (Lake et al., 1987; McFarland, 1984). This approach simplifies data requirements for these models. Theoretically, equilibrium based models can predict the concentration of non-polar organic chemicals in an organism (bioaccumulation) given a known concentration of chemical in the sediment (Lee, 1992; Tetra Tech, 1985). These models may prove especially useful as screening tools or for organisms at specific levels in the food-web. The first five models presented below are equilibrium-based models.

Kinetic models are needed to predict contaminant movement in complex and variable environments in greater detail. These models do not assume equilibrium conditions within the system. Simple kinetic models do assume that steady-state conditions exist, while more complex forms can model non-steady-state conditions such as those associated with varying exposures. Kinetic models are based on rates of flux between physical (e.g. organism:water) or physiological compartments (e.g. blood:liver). Most of the fate models used to express bioaccumulation are undergoing further development and validation (Lee, 1992; Tetra Tech, 1985).

4.2.2.1.1. Bioaccumulation Estimation from Bioconcentration and Food-Chain Multiplier

EPA (EPA 1991) has used the bioconcentration factor (BCF) of a chemical contaminant coupled with an estimated food-chain multiplier (FM) to predict the accumulation of persistent organic compounds in fish tissue. BAF is then equal to a food-chain multiplier times the bioconcentration factor as shown by the equation:

$$BAF = FM \times BCF \quad (3)$$

FM values for this equation have been derived by Thomann (1989) based on a four level food-chain model. An expanded table of these food-chain multiplier values estimated from n-octanol/water partition coefficient is given by EPA (U.S. EPA. 1991).

4.2.2.1.2. Bioaccumulation Estimated from Field Data

The BAF for an organism measured in its environment is expressed as the ratio of the concentration of chemical contaminant in the organism's body to the concentration of the chemical in the exposure source. The general form of this equation has been proposed by Thomann et al. (1992) as the Biota Sediment Factor (BSF). This is an expression of bioaccumulation specifically from a sediment source, and includes accumulation via ingestion. The BSF is not specific to benthic organisms.

$$BSF = C_{b,L} / C_{s,oc} \quad (4)$$

where:

$C_{b,L}$ = the lipid-normalized chemical concentration in the organism $_{(b)}$, and

$C_{s,oc}$ = total organic carbon-normalized chemical concentration in sediment $_{(s)}$.

This relationship can be used to generate BSF values from fish, shellfish and sediment monitoring data. In some cases, sufficient California monitoring data may be available for a chemical to calculate this bioaccumulation factor. In such cases, the modeling discussed below may be unnecessary for specific chemicals or organisms. Monitoring information can also provide data points for evaluation of the accuracy of modeling.

Equations 5 and 6 below are specific modifications of this general equation.

4.2.2.1.3. Accumulation Factor Model of Bioaccumulation

The Accumulation Factor (AF) model is essentially a laboratory based formulation of the BSF model. It is also referred to as the equilibrium partitioning approach (EqP). Like the BSF model, it assumes that chemical contaminants exchange freely between the organic carbon in different sediments and the lipids in different organisms. The AF model includes normalizing sediment for its total organic content and normalizing benthic organisms for total lipid content (Bierman, 1990; Ferraro et al., 1990). Partitioning based on this approach was found to yield a theoretical accumulation factor that was similar to those calculated from laboratory and field data (Rubenstein et al., 1987). This Accumulation Factor (AF) is expressed as follows:

$$AF = (Ct/L)/(Cs/TOC) \qquad (5)$$

where:

Ct = tissue concentration at equilibrium (ug/g dry wt),

L = lipid concentration of organism (g/g dry wt),

Cs = sediment concentration (ug/g dry wt), and

TOC = total organic carbon in sediment (g/g dry wt).

Calculating an equilibrium-based AF is very promising for setting sediment quality criteria for nonionic organic chemicals in benthic organisms (Di Toro et al., 1992), and EPA is considering using this approach. This approach yielded conservative estimates of tissue concentrations (Ferraro, 1990; and Bierman, 1990) when applied to selected neutral organic chemicals. Its applicability to other groups of contaminants (e.g., metals, ionic compounds, etc.) and to non-benthic organisms is not as well established and should be further tested.

4.2.2.1.4. Army Corps Dredging Model of Bioaccumulation

A modified EqP approach has been used by the US Army Corps of Engineers and EPA (1991) as a screening tool to estimate the Theoretical Bioaccumulation Potential (TBP) of contaminants in dredged material. TBP in this model is the tissue concentration, and a theoretically-based constant [4] is equivalent to the AF in equation 5. TBP is expressed as:

$$TBP = 4\ (Cs/TOC)\ /\ L \qquad (6)$$

where:

TBP = tissue concentration based on whole-body wet-weight,

Cs = sediment concentration,

TOC = total organic carbon content of sediment, and

L = species lipid content as a decimal fraction of whole-body wet-weight.

Again, this model is expected to work best for nonionic organic chemicals and benthic organisms.

4.2.2.1.5. Food-Web Equilibrium Model

Thomann (1989) used an equilibrium-based model to calculate the concentrations of organic chemicals in different compartments of a simple aquatic food-web. However, this model did not include benthic organisms. Thomann et al. (1992) and Connolly (1991) have extended similar models to successfully predict tissue concentrations in organisms in complex food-webs that include benthic and non-benthic organisms. These models solve for a series of accumulation factors (from water or sediment), one for each trophic level. Each accumulation factor is dependent on an uptake rate divided by the sum of an elimination rate and a growth rate. Rates are assumed to be at steady-state. Additional equations are presented to estimate rates based on physiochemical properties (e.g., n-octanol/water partition coefficient [K_{ow}]).

4.2.2.1.6. Kinetic Models of Bioaccumulation

The kinetic approach views bioaccumulation as resulting from the dynamic uptake and elimination of a contaminant between different parts (compartments) of the system. Kinetic models therefore are based on the rate of movement of the contaminant between compartments. These models can be simple so-called first-order one-compartment models (cf. Davies and Dobbs, 1984) or very complex multi-compartment models; so-called bioenergetically-based toxicokinetic models (cf. Landrum, 1989). These models may assume a linear relationship for the rates (which means that threshold processes may be misrepresented), or more complex non-linear relationships can be used.

In the first-order one-compartment model, bioaccumulation is essentially the ratio between the rate of uptake of a chemical and its elimination rate (elimination includes metabolism and excretion) over infinite time. These rates are assumed to be constant and not a function of sediment concentration, tissue concentration, or exposure route. The rates are, however, dependent on factors which alter uptake or elimination such as differences in bioavailability, physiology, or feeding patterns of different organisms. Essentially this model views the organism as a compartment with one input and one elimination rate (Lee, 1992; Tetra Tech, 1985).

The bioenergetically-based toxicokinetic models incorporate more compartments and rates for processes within the system than the one-compartment models. As an example, the bioavailability or absorption of a contaminant in a specific sediment can be a variable in this model (Lee, 1992; Tetra Tech, 1985). Rates used in these models can be estimated, and complex models have successfully estimated observed BAF within an order of magnitude.

4.2.2.1.7. Bioaccumulation Model for SQO Estimation

Ultimately, the choice of which model should be used when setting sediment quality objectives will depend on which model more accurately predicts bioaccumulation given available data. The EqP approach requires less data but may not be applicable to all contaminants or organisms. The kinetic approach may be more useful for certain contaminant groups such as metals whose chemical characteristics are difficult to generalize. Despite differences, Clark et al. (1990) showed that the equilibrium and kinetic models are just different ways of expressing the same phenomenon. They also show the importance in any model of accounting for differences in bioacccumulation between uptake from food and uptake from water. Variations on both models need to be investigated to determine situations where they work best in California.

A number of general factors will affect the accuracy of bioaccumulation modeling regardless of model choice. These factors include: physical and chemical properties of the contaminants (e.g., octanol/water partition coefficient); environmental characteristics (e.g., sediment organic carbon, pH and temperature); and differences between species composition of the food-web in an environment (Tetra Tech, 1985). Physical and chemical properties determine the bioavailability of a particular contaminant. Chemical contaminants with log octanol/water partition coefficients (log K_{ow}s) below two are highly soluble in water or are rapidly metabolized and generally do not accumulate in fish. Contaminants with log K_{ow}s above seven are so tightly bound to sediments that they do not accumulate in the food-web (Connell and Miller, 1984). Environmental characteristics such as pH can alter the bioavailability of some chemicals by affecting the ionic state of metals and their movement and toxicity. And high organic carbon content in the sediment will increase the sediment's holding capacity for non-polar organic chemicals. Identical or similar organisms may bioaccumulate different concentrations of contaminant due to differences in the species composition and complexity of the food-web (Lake et al., 1990).

4.2.3. Analysis Of Uncertainties For The Sediment Quality Objective Strategy

Although risk assessment and bioaccumulation modeling are based on sound scientific principles, it is recognized that uncertainties are introduced by the underlying assumptions and extrapolations involved in these processes. Additional uncertainty and errors may be introduced by poor quality or inappropriate data. The discussion below identifies some of the ways in which uncertainty may be introduced into the process of setting SQO. Recognition of these areas of uncertainty is constructive for identifying weaknesses in the process and areas in which the process can be improved, and is an integral part of the SQO strategy.

4.2.3.1. Human Health Risk Assessment

The risk assessment process involves making assumptions and extrapolations which create uncertainties in the estimation of acceptable tissue levels (NAS, 1975; NRC, 1983). One of the more general assumptions is that the effects caused by a chemical in experimental animals can predict the possible effects caused in humans. This affects both hazard identification and dose-response assessment. Another more controversial assumption is that the carcinogenic effects caused by a chemical at high doses will also occur at much lower doses and that the probability of this occurrence can be extrapolated based on the magnitude of exposure. These assumptions affect the dose-response assessment step in risk assessment. The assumptions in this step of risk assessment are based on toxicological data and hypotheses. They are subject to evolving interpretations of scientific knowledge which in some cases may result in changing existing q_1* or RfD values.

The most significant source of uncertainty in the exposure assessment step of risk assessment is the estimation of fish consumption rate (EPA, 1989a, and 1991). Exposure assessment involves determining the dose of chemical contaminant that an individual is exposed to by consuming contaminated fish. This assessment is primarily based on two factors: (1) the concentration of chemical contaminant in specified fish tissues and (2) the amount of specified fish tissues consumed. In determining SQO the chemical contaminant concentration in fish tissues is determined by setting the risk and therefore the amount of fish tissue consumed is the only variable.

The amount of fish consumption is difficult to estimate because adequate relevant data are not available. It is clear that for some people fish may be a large part of their diet, while others may rarely eat any seafood. In reality, a number of subpopulations with different consumption behaviors exist, but for convenience and consistency a single average exposure has often been used. Estimates most pertinent to setting SQO for California bays and estuaries would be specific to fish consumption in the state and include different ethnic or other sensitive or vulnerable subpopulations (i.e., pregnant women, children). At least one study would directly apply to California (Puffer et al., 1982). Unfortunately, this study may be outdated, and it only determined fish consumption for pier anglers.

Overall, the existing data allow some reasonable best estimates of fish consumption to be made. However, developing alternative scenarios specifically for finfish or shellfish or for sensitive subpopulations (e.g. fishers or children) should be pursued.

The Office of Environmental Health Hazard Assessment presently uses an exposure scenario that assumes an individual consumes 23 grams per day of seafood (DHS, 1989). A consumption rate of 23 grams per day is equivalent to 18.7 pounds per year, 1.6 pounds per month, or roughly one meal (about 6 ounces) per week. This consumption rate is considered to be a minimum for active anglers and higher consumption rates may be more representative of anglers (DHS, 1989; Puffer et al., 1982). It should be noted, however, that estimates of average consumption ranging from 23 to 40 grams per day do not change the calculation of tissue levels by a significant amount. Such calculated levels would vary by less than a factor of two.

4.2.3.2. Predicting Bioaccumulation

Uncertainties can be introduced in the bioaccumulation modeling step due to inappropriate or unmet assumptions (Lee, 1992; Tetra Tech, 1985). Each model is most sensitive to variations in its own set of assumptions. For example, the EqP model will not be accurate when the equilibrium assumption is not met while collecting laboratory data (i.e., data are used from experiments which are conducted for less time than necessary for equilibrium to be reached). Poor quality data used to model bioaccumulation can also introduce uncertainty. Laboratory and field collected data can add different types of uncertainty. Laboratory tests cannot simulate the complexity of real field situations. This will introduce uncertainty when estimating bioaccumulation in a real food-web. One source of uncertainty in field generated data is the assumption that all tissue contamination is due to a constant exposure level at a single site. When contamination is unevenly distributed or when fish move within large geographical areas this assumption will be violated.

The magnitude of the uncertainty will be established as these models are tested for specific situations.

5.0 STRATEGY FOR DETERMINATION OF SEDIMENT QUALITY OBJECTIVES

The OEHHA has divided the elements of the strategy for setting SQO into a series of tasks necessary for implementation. These tasks are discussed below.

5.1. Contaminant Selection And Prioritization (Task 1)

The selection of contaminants is guided by federal requirements under the Clean Water Act which directs the states to set criteria for Section 307(a) priority pollutants for which EPA has published Section 304(a) criteria. A listing of some priority pollutants and 301(h) pesticides is included in Appendix 2.

> **Task 1:** The OEHHA will establish a listing of contaminants for developing California SQO based on human health. Criteria for listing include comparing the EPA priority pollutants with California usage and monitoring data on chemical contaminants in bay and estuarine sediments in order to identify the chemicals most frequently discharged and detected in California sediments. Additional factors to be considered in the process of identifying and prioritizing the chemicals of concern-will be the potential for bioaccumulation (e.g., K_{OW}), toxicological concern (e.g., potency), and the concentrations in sediments.

It is anticipated that this prioritized list of chemical contaminants of concern will be similar to the list included in the Pollutant Policy Document (1988) for which MTRL have been derived.

5.2. Human Health Risk Assessment (Tasks 2-4)

Human health risk assessment will be used in the SQO strategy to calculate maximum tissue levels of contaminants. The steps in human risk assessment are relatively straight-forward as described earlier, but interpretation of the data requires professional judgement. Tissue levels will be calculated that correspond to some specified level of health risk. The OEHHA will choose appropriate risk levels based on the toxicological properties of each contaminant and health policy considerations.

5.2.1. Hazard Identification And Dose-response Assessment

> **TASK 2:** Appropriate q_1* and/or RfD values will be added to the prioritized listing of chemicals developed in Task 1.

5.2.2. Exposure Assessment

Appropriate fish consumption rates must be developed in order to calculate numeric SQO because consumption rate is a major determinant in the equation for calculating maximum tissue levels.

> TASK 3: Consumption scenarios for finfish and shellfish and for sensitive subpopulations (e.g., fishers or children) will be developed as appropriate.

5.2.3. Calculation of Maximum Tissue Levels

> **TASK 4:** Maximum tissue levels will be determined for the prioritized list of chemicals using the cancer potency (q_1*) or reference dose (RfD) values and consumption scenarios identified above.

5.3. Predicting Bioaccumulation (Task 5)

A critical step in the process of developing SQO is the determination of BAF using one of the models discussed above. Presently, there is limited consensus regarding the best model for estimation of bioaccumulation.

BAF for the prioritized list of chemicals will be calculated using selected models and the resulting values evaluated. There are differences between these models that may make one more applicable under specific conditions (e.g., for metals vs. organics). These conditions will be examined and described and only applicable models will be used for a given chemical.

5.3.1. Predicting Bioaccumulation using FM

> **TASK 5a:** BAF will be determined using equation 3 described in section 4.2.2.1.1. which is based on food-chain multipliers.

5.3.2. Predicting Bioaccumulation based on the EqP Approach

> **TASK 5b:** BAF will be determined based on the equilibrium models expressed in equations 4, 5, and 6. The BSF, AF, and TBP variations on this model are described in section 4.2.2.1.2, 4.2.2.1.3, and 4.2.2.1.4. The appropriate equation will be selected based on the available input data.

5.3.3. Predicting Bioaccumulation based on Food-Web Compartments

TASK 5c: BAF will be determined using the food-web model equations of Thomann et al. (1992) described in section 4.2.2.1.5.

5.3.4. Predicting Bioaccumulation based on a Kinetic Model

TASK 5d: BAF will be determined using kinetic model equations like those of Clark et al. (1990) described in section 4.2.2.1.6.

5.4. Critique of Predicted Bioaccumulation Factors and Calculation of Sediment Quality Objectives *(Task 6)*

The results of the above calculations of BAF (Task 5) will be evaluated to determine the most appropriate methods for application in California. Models will be evaluated based on concordance of their predictions with known laboratory or field measurements of bioaccumulation. This critique will include identification of the main sources and estimated magnitude of uncertainty in the human risk assessment and the estimation of BAF. The most appropriate BAF will be used to calculate a sediment level corresponding to the maximum tissue concentration.

TASK 6: The results of this evaluation will be the identification of the most appropriate BAF based on available data. The evaluation will also include recommendations for further development and refinements in the process. The selected BAF will be used to calculated a proposed SQO.

5.5. Recommendation of Sediment Quality Objectives to the State Water Resources Control Board

TASK 7: OEHHA will recommend to the SWRCB adoption of the proposed SQO derived as described above. The recommendation will include a summary of the scientific basis for selection of the BAF and corresponding SQO and discussion of related uncertainty.

6.0 SUMMARY

The Office of Environmental Health Hazard Assessment has developed a strategy for development of sediment quality criteria in cooperation with the State Water Resources Control Board. The OEHHA recommends that the SWRCB adopt this strategy for development of SQO to protect human health. The strategy combines elements of human health risk assessment with methods for assessing bioaccumulation of contaminants in sediments. It includes an evaluation of methods and uncertainties that should be addressed before the adoption of California numeric SQO.

Once developed these SQO can be applied to the regulation of chemical contaminants in aquatic sediments, to the identification of toxic hot spots, and to protect the overall beneficial uses of the bays and estuaries of California.

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8.0 GLOSSARY OF TERMS

Accumulation factor (AF) is the calculated bioaccumulation factor in one of the equilibrium models of bioaccumulation (Rubenstein et al., 1987).

Apparent effects threshold (AET) is a method of generating sediment criteria that focuses on identifying chemical concentrations in sediments above which adverse effects will always be found in aquatic species. This method has been used in Washington to set sediment quality criteria for aquatic life.

Aquatic community is an association of interacting populations of aquatic organisms in a given waterbody or habitat.

Benthic organisms are those organisms associated with the substrata of a body of water. This includes all organisms living on or moving in or on the sediments.

Bioaccumulation is the phenomenon whereby the concentration of a chemical in a living organism accumulates to a concentration greater than that in the media (e.g., water or sediment) that is the source of the chemical exposure.

Bioaccumulation factor (BAF) is the expression of the total bioaccumulation between an organism and chemical contaminants in its environment. For aquatic organisms it includes chemical accumulated via absorption (from water) and ingestion (from the food-web).

Bioavailability is a measure of the physiochemical access that a toxicant has to the biological processes of an organism. In general, the lower the bioavailability of a toxicant, the lower its toxic effect on an organism.

Bioconcentration is the process by which a compound is absorbed from water through gills or epithelial tissues and is concentrated in the body. This is a restricted form of bioaccumulation which does not include accumulation from ingestion.

Bioconcentration factor (BCF) is the ratio of a substance's concentration in tissue versus its concentration in water in situations where the food chain contamination and exposure is disregarded, assumed to be minimal, or expressed in some other way. This is a restricted measure of bioaccumulation. For nonmetabolized substances, it represents equilibrium partitioning between water and organisms.

Biomagnification is the process by which the concentration of a compound increases in species occupying successive trophic levels.

Biota sediment factor (BSF) is the ratio of the concentration of a chemical in tissue versus its concentration in sediment in nature. BSF is similar to, but not equal to BAF. For aquatic organisms it includes chemical accumulated via absorption (from water) and ingestion (from the food-web). This is a closely defined expression of bioaccumulation.

Cancer potency slope factor (q_1*) is an indication of a chemical's potential to cause human cancer. It is derived using animal studies or epidemiological data on human exposure. This factor is the slope of the dose-response curve. It is based on extrapolating high-dose levels over short periods of time to low-dose levels and a lifetime exposure period. A linear model is used to perform this extrapolation.

Chemical contaminants are undesirable or toxic chemicals present in excessive levels in an environment. Many of these are of anthropogenic origin.

Demersal fishes are those that live and feed mainly near the ocean bottom (especially the sediment).

Dose-response assessment is the determination of the relationship between the magnitude of exposure and the extent of biological response.

Ecosystem is a functional system of living organisms and their environment, in which there exists a complementary relationship in the transfer and circulation of energy and matter.

Equilibrium partitioning (EqP) is a method for generating sediment criteria that focuses on the chemical interaction between sediment and contaminants under presumed equilibrium conditions.

Estuary is the place where fresh water from rivers and streams meet the salt water of the ocean. Estuaries are bordered by or partially isolated from the ocean by continental land masses. Estuaries may be associated with the mouth of a river, bays, and tidal marshes or flats.

Exposure assessment is the determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure to a chemical or physical agent.

Food-chain describes a series of transfers of material and energy from one organism to another organism in a community as one eats or decomposes the other. These transfers are linear and one directional.

Food-web is the interconnection of food chains to show how resources are shared and linked in a habitat.

Fugacity or chemical potential is the measure of the tendency of a chemical to move from one phase to another. Hypothetically a chemicals fugacity controls its biological activity. This concept is a fundamental assumption in all bioaccumulation modeling.

Hazard identification is the determination of whether a particular chemical is or is not causally linked to a particular adverse health effect.

Infauna are animals living in a substrate, especially in sediments.

Integrated Risk Information System (IRIS) is an EPA database containing verified RfDs and slope factors, and up-to-date health risk and EPA regulatory information for numerous chemicals.

Interstitial water (the same as pore water) is the water between sediment particles which is tightly associated with sediment.

K_{ow} (n-octanol/water partition coefficient) is the ratio, in a two-phase system consisting of n-octanol and water at equilibrium, of the concentration of a chemical in the n-octanol phase to that in the water phase.

No Observed Effect Level (NOEL) is an exposure level at which there are no statistically or biologically significant increases in the frequency or severity of any effect between the exposed population and its appropriate control.

Non-polar organic chemicals are organic chemicals whose molecules are not polarized by electrical charges. They typically have high affinity for lipids and a low solubility in water.

Pelagic organisms are those organisms that mainly live and move in the ocean water column as opposed to in or on the ocean-bottom.

Persistent pollutant is not subject to decay, degradation, transformation, volatilization, hydrolysis, or photolysis.

Pore water (the same as interstitial water) is the water between sediment particles which is tightly associated with sediment.

Priority pollutants are those pollutants listed by the EPA Administrator under Clean Water Act Section 307(a).

Reference dose (RfD) is an estimate of the level of daily exposure to a human population that is likely to be without an appreciable risk of deleterious effect during a lifetime; derived from no observed adverse effect level or lowest observed adverse effect level.

Reference tissue concentration (RTC) is an estimate of the daily exposure from a specific tissue to a human population that is likely to be without an appreciable risk of deleterious effect during a lifetime; derived from No Observed Adverse Effect Level or Lowest Observed Adverse Level.

Risk assessment is a process to estimate the likelihood that a given chemical exposure may damage the health of exposed individuals.

Risk characterization is the description of the nature and magnitude of human health risk due to the exposure to a particular chemical or physical agent.

Theoretical bioaccumulation potential (TBP) is a tissue concentration of chemical predicted from a specific formulation of an equilibrium model for bioaccumulation. This is the equilibrium model recommended by the U.S. Army Corps of Engineers (1991) for application to dredged sediments. In calculating TBP a theoretically-based constant is used.

Trophic level is a limited producer or consumer feeding group. Several levels in a community are arranged in a hierarchical arrangement in food-chains.

Water quality criteria are comprised of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal.

Water quality standard is a law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.

Note: Definitions in the glossary have been adapted from various sources including EPA (1989c, 1989d and 1991).

9.0 LIST OF ABBREVIATIONS AND ACRONYMS

ADI	Acceptable Daily Intake
AF	Accumulation Factor
AET	Apparent Effects Threshold
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BPTC	Bay Protection and Toxic Cleanup
BSF	Biota Sediment Factor
DHS	Department of Health Services
DRA	Dose-Response Assessment
EA	Exposure Assessment
EBEP	Enclosed Bays and Estuaries Plan
EPA	U.S. Environmental Protection Agency
EqP	Equilibrium Partitioning
FM	Food-Chain Multiplier
HI	Hazard Identification
K_{ow}	n-Octanol/Water Partition Coefficient
MTRL	Maximum Tissue Residue Limit
NAS	National Academy of Sciences
NOEL	No Observed Effect Level
NRC	National Research Council
OEHHA	Office of Environmental Health Hazard Assessment
q_1^*	Cancer potency slope factor
RC	Risk Characterization
RfD	Reference Dose
RTC	Reference Tissue Concentration
SDCDHS	San Diego County Department of Health Services
SQC	Sediment Quality Criteria
SQO	Sediment Quality Objectives
SWRCB	State Water Resources Control Board
TBP	Theoretical Bioaccumulation Potential

10.0 APPENDICIES

APPENDIX I

Examples of Estimated Human Health Risks from Contaminated Seafood (plausible upper limits)

Eating Activities	Estimated Lifetime Risks
Typical exposure:	
1. 23 g/day white croaker from the Palos Verdes Shelf in southern California[+]	1.0×10^{-3} to 1.6×10^{-3}
2. 15 g/day mixed diet of Quincy Bay seafood, including lobster tomalley[*]	2.7×10^{-3}
3. 23 g/day trout fillet from the Sacramento River at Anderson[**]	5.1×10^{-3}
4. 31 g/day mixed diet of San Diego Bay fish[++]	1.1×10^{-4} to 2.9×10^{-4}
Maximal exposure:	
5. 225[+++] g/day white croaker from the Palos Verdes Shelf in southern California[+]	1.0×10^{-2} to 1.5×10^{-2}
6. 165 g/day mixed diet of Quincy Bay seafood[*]	1.5×10^{-2} to 2.3×10^{-2}
7. 225 g/day trout fillet from the Sacramento River at Anderson[**]	5.0×10^{-2}
8. 165 g/day mixed diet of San Diego Bay fish[++]	5.6×10^{-4} to 1×10^{-3}

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[*] Calculated from "Analysis of risks from consumption of Quincy Bay fish and shellfish," prepared by the U. S. EPA, 1988; tomalley is lobster hepatopancreas, which is considered a delicacy.

[**] Pollock et al., 1989.

[+] DHS, 1991.

[++] SDCDHS, 1990.

[+++] Puffer, et al., 1982.

Adapted from Pollock et al., 1992.

APPENDIX 2: List of Priority Pollutants and 301(h) Pesticides Listed According to Structural Compound Class and Octanol/Water Partition Coefficients

Structural Compound Class	PP[a]	Pollutant	LogKow
Phenols	65	phenol	1.46
	34	2,4-dimethylphenol	2.42
Substituted Phenols	21	2,4,6-trichlorophenol	3.69
	22	para-chloro-meta-cresol	3.10
	24	2-chlorophenol	2.16
	31	2,4-dichlorophenol	3.08
	57	2-nitrophenol	1.77
	58	4-nitrophenol	2.91
	59	2,4-dinitrophenol	1.53
	60	4,6-dinitro-*o*-cresol	2.85
	64	pentachlorophenol	5.00
Organonitrogen Compounds	5	benzidine	1.81
	28	3,3'-dichlorobenzidine	3.02
	35	2,4-dinitrotoluene	2.00
	36	2,6-dinitrotoluene	2.00
	37	1,2-diphenylhydrazine	2.94
	56	nitrobenzene	1.83
	61	*N*-nitrosodimethylamine	-.58
	62	*N*-nitrosodiphenylamine	3.13
	63	*N*-nitrosodipropylamine	1.31
Low Molecular Weight Polynuclear Aromatic Hydrocarbons (PAH)	1	acenaphthene	3.92
	55	naphthalene	3.59
	77	acenaphthlene	4.08
	78	anthracene	4.34
	81	phenanthrene	4.46
	80	fluorene	4.38

Structural Compound Class	PP[a]	Pollutant	LogKow
High Molecular Weight Polynuclear Aromatic Hydrocarbons (PAH)	39	fluoranthene	5.53
	72	benzo(*a*)anthracene	5.61
	73	benzo(*a*)pyrene	6.00
	74	benzo(*b*)fluoranthene	6.60
	75	benzo(*k*)fluoranthene	6.85
	76	chrysene	5.60
	79	benzo(*ghi*)perylene	7.00
	82	dibenzo(*a,h*)anthracene	6.00
	83	indeno (1,2,3-*cd*)pyrene	7.70
	84	pyrene	4.88
Chlorinated Aromatic Hydrocarbons	8	1,2,4-trichlorobenzene	4.23
	9	hexachlorobenzene	5.23
	20	2-chloronaphthalene	4.72
	25	1,2-dichlorobenzene	3.40
	26	1,3-dichlorobenzene	3.44
	27	1,4-dichlorobenzene	3.53
Chlorinated Aliphatic Hydrocarbons	52	hexachlorobutadiene	4.28
	12	hexachloroethane	3.93
	53	hexachlorocyclopentadiene	5.51
Halogenated Ethers	18	bis(2-chloroethyl)ether	1.12
	40	4-chlorophenyl ether	4.92
	41	4-bromophenyl ether	5.08
	42	bis(2-chloroisopropyl)ether	2.58
	43	bis(2-chloroethoxy)methane	1.26

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[a] PP: Priority Pollutant designation number

[b] Chlorinated 301 (h) pesticides that are not on the Priority Pollutant list.

[c] Organophosphorus 301(h) pesticides that are not on the Priority Pollutant list.

[d] NA = Not Applicable

Adapted from Tetra Tech, 1985.

(continued)

Structural Compound Class	PP[a]	Pollutant	LogKow
Phthalates	66	bis(2-ethylhexyl)phthalate	4.20
	67	butyl benzyl phthalate	4.05
	68	di-*n*-butyl phthalate	5.15
	69	di-*n*-octyl phthalate	9.20
	70	diethyl phthalate	1.40
	71	dimethyl phthalate	1.61
Polychlorinated Biphenyls (PCB) as Aroclors	106	PCB-1242	6.00
	107	PCB-1254	6.48
	108	PCB-1221	4.00
	109	PCB-1232	4.48
	110	PCB-1248	6.11
	111	PCB-1260	6.91
	112	PCB-1016	5.88
Miscellaneous Oxgenated Compounds	129	TCDD (dioxin)	6.10
	54	isophorone	1.67
Pesticides	89	aldrin	3.00
	90	dieldrin	5.48
	91	chlordane	6.00
	92	DDT	5.75
	93	DDE	5.69
	94	DDD	6.00
	95	*a*-endosulfan	3.60
	96	*b*-endosulfan	3.60
	97	endosulfan sulfate	3.60
	98	endrin	4.56
	99	endrin aldehyde	5.60
	100	heptachlor	5.45
	101	heptachlor epoxide	5.40
Pesticides (cont'd)	102	α-hexachlorocyclohexane	3.85
	103	β-hexachlorocyclohexane	3.85
	104	δ-hexachlorocyclohexane	3.85
	105	γ-hexachlorocyclohexane	3.85
	113	toxaphene	3.30
	__	mirex[b]	6.89
	__	methoxychlor[b]	4.30
	__	parathion[c]	3.81
	__	malathion[c]	2.89
	__	guthion[c]	2.18
	__	demeton[c]	1.93
Volatile Halogenated Alkanes	6	tetrachloromethane	2.64
	10	1,2-dichloroethane	1.45
	11	1,1,1-trichloroethane	2.47
	13	1,1-dichloroethane	1.78
	14	1,1,2-trichloroethane	2.18
	15	1,1,2,2-tetrachloroethane	2.39
	16	chloroethane	1.54
	23	chloroform	1.90
	32	1,2-dichloropropane	2.28
	44	dichloromethane	1.30
	45	chloromethane	0.90
	46	bromomethane	1.00
	47	bromoform	2.30
	48	dichlorobromoethane	1.88
	49	fluorotrichloromethane	3.53
	50	dichlorodifluromethane	2.16
	51	chlorodibromomethane	-2.08

[a] PP: Priority Pollutant designation number
[b] Chlorinated 301 (h) pesticides that are not on the Priority Pollutant list.
[c] Organophosphorus 301(h) pesticides that are not on the Priority Pollutant list.
[d] NA = Not Applicable

Adapted from Tetra Tech, 1985.

(continued)

Structural Compound Class	PP[a]	Pollutant	LogKow
Volatile Halogenated Alkenes	29	1,1-dichloroethylene	1.48
	30	1,2-*trans*-dichloroethylene	1.97
	33	*trans*-1,3-dichloropropene	1.98
	33	*cis*-1,3-dichloropropene	1.98
	85	tetrachloroethene	2.88
	87	trichloroethene	2.42
	88	vinyl chloride	0.60
Volatile Aromatic Hydrocarbons	4	benzene	2.11
	38	ethylbenzene	3.15
	86	toluene	2.21
Volatile Chlorinated Aromatic Hydrocarbons	7	chlorobenzene	3.79
Volatile Unsaturated Carbonyl Compounds	2	acrolein	0.90
	3	acrylonitrile	1.20
Volatile Ethers	19	2-chlorethylvinylether	1.28
		bis(chloromethyl)ether	
Metals	114	antimony	NA[d]
	115	arsenic	NA[d]
	117	beryllium	NA[d]
	118	cadmium	NA[d]
	119	chromium III	NA[d]
	119	chromium VI	NA[d]
	120	copper	NA[d]
	122	lead	NA[d]
	123	mercury	NA[d]
	123	methylmercury	NA[d]
	123	phenylmercury	NA[d]
Metals (cont'd)	123	mercuric acetate	NA[d]
	124	nickel	NA[d]
	125	selenium	NA[d]
	126	silver	NA[d]
	127	thallium	NA[d]
	128	zinc	NA[d]
Miscellaneous	121	cyanide	NA[d]
	116	asbestos	NA[d]

[a] PP: Priority Pollutant designation number
[b] Chlorinated 301 (h) pesticides that are not on the Priority Pollutant list.
[c] Organophosphorus 301(h) pesticides that are not on the Priority Pollutant list.
[d] NA = Not Applicable

Adapted from Tetra Tech, 1985.

APPENDIX E

Staff Report by the Division of Water Quality
Criteria to Rank Toxic Hot Spots in Enclosed Bays and Estuaries of California

This report is provided for information only. This staff report will be revised and the various issues discussed in the staff report will be included in a draft Functional Equivalent Document for amendments to the California Enclosed Bays and Estuaries Plan.

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD
DIVISION OF WATER QUALITY

Staff Report:

CRITERIA TO RANK TOXIC HOT SPOTS IN ENCLOSED BAYS AND ESTUARIES OF CALIFORNIA

March 1993

DRAFT

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EXECUTIVE SUMMARY

California Water Code Section 13393.5 requires the State Water Board to adopt criteria for the priority ranking of toxic hot spots in bays and estuaries. The criteria are to take into consideration factors relating to public health, environmental quality, toxic hazards to fish, shellfish, and wildlife, and the extent to which deferral of remedial action is likely to result in increases in human health risks, environmental damage or cleanup costs. The priority ranking of toxic hot spots for each region is to be included in a Toxic Hot Spot Cleanup Plan which describes a number of factors including identification of likely sources of the pollutants that are creating the toxic characteristics at the site and actions to be taken to remediate each site. Waste discharge requirements for each source identified as contributing to a toxic hot spot are to be reviewed and revised (with certain exceptions) to prevent further pollution of existing toxic hot spots or the creation of new hot spots. The reevaluation of permits is to be conducted in the order established by the priority ranking of known toxic hot spots.

Staff has reviewed two ranking systems potentially suitable for satisfying the Water Code Section 13393.5 requirements: the State Water Board's Clean Water Strategy and the U.S. Environmental Protection Agency's Hazard Ranking System. Since these systems were developed for purposes other than ranking of toxic hot spots for Bay Protection and Toxic Cleanup Program (BPTCP), they cannot be directly applied to the program. Staff has developed two alternative systems for State Water Board consideration.

The principal characteristics of the alternatives are that they are based on the definition of a toxic hot spot and rely only on existing information to develop the rankings. The principal difference between the two alternatives is the degree of detail provided in the rankings. The recommended alternative (which is a modification of Clean Water Strategy) utilizes all available, relevant information whereas the other alternative uses only some pertinent information. The ranking system is designed to be integrated with monitoring being conducted under the BPTCP. The monitoring data and other pertinent information will be used in establishing site rankings.

This report contains an overview of the statutory and programmatic considerations relevant to the development of ranking criteria. A brief description of the Clean Water Strategy and the Hazard Ranking System is provided, followed by the two alternative systems developed by staff. The recommended alternative and an illustration of its application are also presented. Further details on each of the ranking systems are provided in the appendices.

CRITERIA TO RANK TOXIC HOT SPOTS IN ENCLOSED BAYS AND ESTUARIES OF CALIFORNIA

INTRODUCTION

The development of criteria for the priority ranking of toxic hot spots in enclosed bays and estuaries is required by statute. This report reviews the statutory requirements, programmatic considerations, various ranking systems, and presents a recommended system for use in the Bay Protection and Toxic Cleanup Program (BPTCP). Appendices are included which provide detail on the ranking systems reviewed and numeric values for use in the recommended system.

Four alternative ranking systems are reviewed in this staff report. These include the two existing ranking systems, the State Water Board's Clean Water Strategy and the U.S. Environmental Protection Agency's Hazard Ranking System used for ranking Superfund sites. Two additional ranking systems developed specifically to address programmatic considerations of the BPTCP are presented. One of these, a modification of the Clean Water Strategy, is proposed for use by the BPTCP.

The site ranking criteria proposals were first discussed at the January 7, 1993 State Water Board Workshop. At that workshop, the State Water Board directed the staff to conduct a staff workshop to solicit public comment. Staff workshops were held on January 26 and 28, 1993. This staff report and the proposed ranking criteria have been revised as a result of the comments received on this subject.

The working definition of a toxic hot spot is presented below to provide the context for recommending site ranking criteria. The State Water Board staff do not recommend the adoption of this definition at this time. The State and Regional Water Board staff would like to gain additional experience with this definition before it is adopted by the State Water Board. After this definition is tested more fully, we will bring the definition before the State Water Board for consideration as a Statewide plan amendment or for consideration for adoption by resolution. The ranking criteria proposed in this staff report will be useable with any definition of a toxic hot spot.

BACKGROUND

The BPTCP is a comprehensive effort to regulate toxic pollutants in enclosed bays and estuaries of the State. The program consists of both short-term and long-term activities. The short-term activities include the identification and priority ranking of toxic hot spots, development and implementation of regional monitoring programs designed to identify toxic hot spots, development of narrative sediment quality objectives, development and implementation of cleanup plans, revision of waste discharge requirements as needed to alleviate impacts of toxic pollutants, and development of a comprehensive database containing information pertinent to describing and managing toxic hot spots. The long-term activities include development of numeric sediment quality objectives; development and implementation of strategies to prevent the formation of new toxic hot spots and to reduce the severity of effects from existing toxic hot spots; revision of water quality control plans, cleanup plans, and monitoring programs; and maintenance of the comprehensive database. The California Water Code, Section 13393.5, requires the State Water Board to develop and adopt criteria for the priority ranking of toxic hot spots in enclosed bays and estuaries. The criteria are to "take into account pertinent factors relating to public health and environmental quality, including but not limited to potential hazards to public health, toxic hazards to fish, shellfish, and wildlife, and the extent to which the deferral of a remedial action will result or is likely to result in a significant increase in environmental damage, health risks or cleanup costs."

The role of the ranking criteria is to provide a prioritized list of sites based on the severity of the identified problem. The Water Code calls for waste discharge requirements to be reevaluated in the ranked order. Water Code Section 13395 states, in part, that the Regional Boards shall "initiate a reevaluation of waste discharge requirements for dischargers who, based on the determination of the Regional Board, have discharged all or part of the pollutants which have caused the toxic hot spot. These reevaluations shall be for the purpose of ensuring compliance with water quality control plans and water quality control plan amendments. These reevaluations shall be initiated according to the priority ranking established pursuant to subdivision (a) of Section 13394 and shall be initiated within 120 days from, and the last shall be initiated within one year from, the ranking of toxic hot spots."

The priority ranking for each site is to be included in a Toxic Hot Spot Cleanup Plan which describes a number of factors including identification of likely sources of the pollutants that are causing the toxic characteristics and actions to be taken to remediate each site. The regional list of ranked hot spots will be consolidated into a statewide prioritized list of toxic hot spots, and included in the statewide Toxic Hot Spot Cleanup Plan.

Within specificed periods of time, waste discharge requirements for each source identified as contributing to a toxic hot spot are to be reviewed and revised (with certain exceptions) to prevent further pollution of existing toxic hot spots or the formation of new hot spots. The reevaluation of permits is to be conducted in the order established by the priority ranking of hot spots.

WORKING DEFINITION OF A TOXIC HOT SPOT

Water Code Section 13391.5 defines toxic hot spots as "...locations in enclosed bays, estuaries, or any adjacent waters in the 'contiguous zone' or the 'ocean'... the pollution or contamination of which affects the interests of the state, and where hazardous substances have accumulated in the water or sediment to levels which (1) may pose a substantial present or potential hazard to aquatic life, wildlife, fisheries, or human health, or (2) may adversely affect the beneficial uses of the bay, estuary, or ocean waters as defined in water quality control plans, or (3) exceeds adopted water quality or sediment quality objectives."

While the statutory definition provides the basis for identifying hot spots, practical implementation requires a more detailed definition. Accordingly, the BPTCP has developed a working definition that includes five "triggers" for determination of a known toxic hot spot:

Known Toxic Hot Spot

A site meeting any one or more of the following conditions is considered to be a known toxic hot spot:

1. Site exceeds water or sediment quality objectives for toxic pollutants that are contained in appropriate water quality control plans.

   This finding requires chemical measurement of water or sediment, or measurement of toxicity using tests and objectives stipulated in water quality control plans. Determination of a toxic hot spot employing this finding should rely on recurrent measures over time (at least separate sampling dates). Suitable time intervals between measurements must be determined by staff.

2. Water or sediment exhibits toxicity associated with toxic pollutants, based on confirmatory toxicity tests acceptable to the BPTCP.

   To determine whether toxicity exists, recurrent measures (at least 2 separate sampling dates) should demonstrate an effect. Appropriate reference and control measures must be included in the toxicity testing. The methods acceptable to and used by the BPTCP may include some toxicity test protocols not referenced in water quality control plans (Table 1). Toxic pollutants should be present in the media at concentrations sufficient to cause or contribute to toxic responses in order to satisfy this condition.

3. Tissue toxic pollutant levels of organisms collected from the site exceed levels established by the Office of Environmental Health Hazard Assessment (OEHHA), California Department of Health Services (DHS), United States Food and Drug Administration (FDA) for the protection of human health, or the National Academy of Sciences (NAS) for the protection of human health or wildlife, or a health warning against the consumption of such organisms has been issued by OEHHA or DHS.

   Acceptable tissue concentrations are measured either as muscle tissue (preferred) or whole body residues. Residues in liver tissue alone are not considered a suitable measure for known toxic hot spot designation. Animals can either be deployed (if a resident species) or collected from resident populations. Recurrent measurements are required. Residue levels established for the protection of human health can be applied to any consumable species.

   Shellfish: Except for existing information, each sampling episode should include a minimum of three replicates and the value of interest is the average value of the replicates. Each replicate should be comprised of at least 15 individuals. For existing State Mussel Watch information related to organic pollutants, a single composite (20-100 individuals) sample may be used instead of the replicate measures. When recurrent measurements exceed one of the levels referred to above, the site is considered a known toxic hot spot.

Fin-fish: A minimum of three replicates is necessary. The number of individuals needed will depend on the size and availability of the animals collected; however, a minimum of five animals per replicate is recommended. The value of interest is the average of the three replicates. Animals of similar age and reproductive state should be used.

4. Impairment is associated with toxic pollutants found in resident individuals.

Impairment means reduction in growth, reduction in reproductive capacity, abnormal development, histopathological abnormalities, or identification of adverse effects using biomarkers. Each of these measures must be made in comparison to a reference condition (the endpoint measured in the same species and tissue collected from an unpolluted site).

Growth Measures: Reductions in growth can be addressed using suitable bioassays acceptable to the BPTCP (Table 1) or through measurements of field populations.

Reproductive Measures: Reproductive measures must clearly indicate reductions in viability of eggs or offspring, or reductions in fecundity. Suitable measures include pollutant concentrations in tissue, sediment, or water which have been demonstrated in laboratory tests to cause reproductive impairment; significant differences in viability or development of eggs between reference and test sites; differences in sex ratios sufficient to decrease reproductive success.

Abnormal Development: Abnormal development can be determined using measures of physical or behavioral disorders or aberrations. Indications that the disorder can be caused by toxic pollutants, in whole or in part, must be available.

Histopathology: Abnormalities representing distinct adverse effects, such as carcinomas or tissue necrosis, must be evident. Indications that toxic pollutants are capable of causing or contributing to the disease condition must also be available.

Biomarkers: Direct measures of physiological disruption or biochemical measures representing adverse effects, such as significant DNA strand breakage or perturbation of hormonal balance, must be evident. Biochemical measures of exposure to pollutants, such as induction of stress enzymes, are not by themselves suitable for determination of known toxic hot spots. Indications that a toxic pollutant causes or contributes to the adverse effect are needed.

5. Significant degradation in biological populations and/or communities associated with the presence of elevated levels of toxic pollutants.

This condition requires a demonstration that diminished numbers of species or changes in the number of individuals of a single species (when compared to a reference site) are associated with concentrations of toxic pollutants. The analysis should rely on measurements from multiple stations. Care should be taken to ensure that at least one site is not degraded so that a suitable comparison can be completed.

Table 1. Toxicity Tests used by and acceptable to the Bay Protection and Toxic Cleanup Program. All of the toxicity tests listed in the California Enclosed Bays and Estuaries Plan are also acceptable.

Type of Toxicity Test	Organism Used		Reference
	Common Name	Scientific Name	
Solid Phase Sediment	Amphipod	Rhepoxinius	ASTM, 1991
	Amphipod	Eohaustorius	DeWitt et al., 1989
	Amphipod	Hyalella	Nebecker et., al 1984
	Polychaete	Neanthes	Johns et. al., 1990
Sediment Pore Water Tests	Bivalve larvae	Crassostrea	ASTM, 1987; Tetra Tech 1986, Chapman & Morgan, 1983
		Mytilus	ASTM, 1987
	Abalone larvae	Haliotis	Anderson et al., 1990
	Echinoderm fertilization	Strongylocentrotus	Dinnel et al., 1990; with modification by EPA, 1992
	Giant kelp	Macrocystis	Anderson et al., 1990
	Red alga	Champia	Weber et al., 1988
	Fish embryos	Atherinops	Anderson et al., 1990
		Menidia	Middaugh et al., 1988
		Pimephales	Spehar et al., 1982
	Cladoceran	Daphnia	Nebecker et al., 1984
		Cereodaphnia	Mount and Norberg, 1984; Horning and Weber, 1985
Elutriate* Tests	Bivalve larvae	Crassostrea	ASTM, 1987; Tetra Tech, 1986; Chapman and Morgan, 1983
		Mytilus	ASTM, 1987
	Abalone larvae	Haliotis	Anderson et al., 1990
	Echinoderm	Strongylocentrotus	Dinnel et al., 1987
	Giant kelp	Macrocystis	Anderson et al., 1991
	Red alga	Champia	Weber et al., 1988
	Mysid	Holmesimysis	Hunt et al., 1992
	Fish embryos	Atherinops	Anderson et al., 1990
		Menidia	Middaugh et al., 1988
		Pimephales	Spehar et al., 1982
	Fish larvae	Atherinops	Anderson et al., 1990
		Menidia	Peltier and Weber, 1985; Weber et al., 1988
		Pimephales	Peltier and Weber, 1985; Weber et al., 1988
	Cladocerans	Daphnia	Nebecker et al., 1984
		Cereodaphnia	Mount and Norberg, 1984; Horning and Weber, 1985

Table 1 is continued on the next page.

Table 1 (continued)

Type of Toxicity Test	Organism Used Common Name	 Scientific Name	Reference
Ambient Water	Bivalve larvae	Crassostrea	ASTM, 1987; Tetra Tech, 1986; Chapman and Morgan, 1983
	Abalone larvae	Haliotis	Anderson et al., 1990
	Echinoderm fertilization	Strongylocentrotus	Dinnel et al., 1987; with modifications by EPA, 1992
	Giant kelp	Macrocystis	Anderson et al., 1991
	Red alga	Champia	Weber et al., 1988
	Mysid	Holmesimysis	Hunt et al., 1992
	Fish embryos	Atherinops	Anderson et al., 1990
		Menidia	Middaugh et al., 1988
		Pimephales	Spehar et al., 1982
	Fish larvae	Atherinops	Anderson et al., 1990
		Menidia	Peltier and Weber, 1985 Weber et al., 1988
		Pimephales	Peltier and Weber, 1985 Weber et al., 1988
	Cladocerans	Daphnia	Nebecker et al., 1984
		Cereodaphnia	Mount and Norberg, 1984 Horning and Weber, 1985

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* Elutriate toxicity tests are of value in estimating the toxicity of disposed sediments to aquatic organisms. Elutriate test results can be used to qualify a site as a potential hot spot but should not be used to confirm a site as a known hot spot. Either a pore water or a solid phase test should be used to confirm toxicity.

Sites are designated as known hot spots after generating information which satisfies any one of the five conditions of the working definition. To utilize this working definition, a list of toxicity tests has been assembled. This list identifies toxicity tests that can be employed in monitoring and surveillance activities described in regional monitoring plans and partially satisfies the Water Code requirement [Section 13392.5(a)(2)] for standardized analytical methods (Department of Fish and Game Marine Pollutant Studies Laboratory, 1992). The BPTCP toxicity methods are listed in Table 1.

Potential Toxic Hot Spot

In addition to the identification of known toxic hot spots the statute requires the identification of suspected or potential hot spots (Water Code Section 13392.5). Sites with existing information indicating a possibility of impairment but without sufficient information to allow a finding consistent with the working definition of a known toxic hot spot are classified as potential hot spots. More specifically, four conditions sufficient to identify a potential hot spot have been determined. If any one of these conditions is satisfied a site can be designated a potential toxic hot spot. These are:

1. Concentrations of toxic pollutants are elevated above background levels but insufficient data are available on the impacts associated with such pollutant levels to determine the existence of a known toxic hot spot;

2. Water or sediments containing toxic pollutants exhibit toxicity in screening tests or tests other than those used by the BPTCP;

3. Tissue toxic pollutant levels in resident or test species are elevated but do not meet conditions for determination of the site as a known hot spot; tissue toxic pollutant levels exceed Maximum Tissue Residue levels (MTRLS) derived from water quality objectives contained in appropriate water quality control plans; or a health warning has been issued for the site by a local public health agency; and/or

4. The level of pollutant at a site exceeds Clean Water Act, Section 304(a) criterion, or sediment quality guidelines or EPA sediment toxicity criteria for toxic pollutants.

ASSUMPTIONS AND LIMITATIONS OF THE RANKING CRITERIA

The Water Code Section 13393.5 requires that the criteria take into account "pertinent factors relating to public health and environmental quality, including but not limited to, potential hazards to public health, toxic hazards to fish, shellfish, and wildlife, and the extent to which the deferral of a remedial action will result or is likely to result in a significant increase in environmental damage, health risks or cleanup costs."

In addition to the considerations stipulated in Water Code Section 13393.5, several assumptions were applied to the evaluation of the various alternative ranking systems.

Assumptions

1. Criteria should address broad programmatic priorities.

2. Criteria are to be used to organize internal work and program activities (i.e., the evaluation of the need to adjust permit limits or monitoring priorities).

3. Criteria are not designed to determine regulatory enforcement actions.

4. Ranking should be based on existing information at the time of ranking; additional studies should not be required for the purpose of prioritizing known or potential toxic hot spots (potential toxic hot spots will be identified and additional information will be needed before a potential site can be ranked as a known toxic hot spot).

5. Assessment of cost and feasibility of remedial actions for a site will be considered in toxic hot spot cleanup plans but factors that influence cost will be considered.

6. The priority list will be revised periodically.

7. All other factors being equal, sites that are well characterized (i.e., significant amounts of available data) will rank higher than sites that are less well characterized (i.e., few available data and greater uncertainty about the site).

8. The best available scientific information will be used to evaluate the data available for site ranking.

9. Sites for which cleanup or remediation has been implemented but which retain toxic hot spot characteristics will only be considered for reranking if circumstances change that would allow for further reducing adverse impacts at the site. A list of sites that have been remediated without complete removal of toxic hot spot characteristics will be maintained.

10. A site that has been remediated will be removed from the priority list.

Limitations

The ranking criteria are intended to provide the relative priority of a site within the group of sites considered to be known toxic hot spots. Since not all sites will have the same scope and quality of information available at the time of ranking, this relative placement should be founded in measures of the potential for adverse impacts. The determination that some adverse impacts are occurring at the sites will have been made previously to the ranking and in accordance with the definition of a toxic hot spot. While the ranking should reflect the severity of the demonstrated adverse impacts, the full scope of ecological and human health impacts will likely not be characterized at the time of ranking, and therefore, should not be the goal of the ranking criteria. These impacts may be addressed as part of the activities conducted pursuant to the cleanup plans. The ranking criteria should provide a mechanism to discriminate among all those sites considered to be toxic hot spots (using the water code definition or other more specific definition) and thereby provide for a placement of each site relative to other sites under consideration.

The ranking criteria are not to be used to define a toxic hot spot. The determination of whether a site qualifies to be considered a toxic hot spot is a separate and previous step. The BPTCP has establised a detailed working definition of a toxic hot spot, which is consistent with the statutory definition contained in Water Code Section 13391.5. The working definition presented above is not proposed for adoption by the State Water Board at this time.

The ranking criteria are not to be used to define cleanup actions or establish cleanup levels. The actions to be undertaken to cleanup or remediate a site will be developed on a case-by-case basis for each site. The considerations to be addressed at all sites, together with special considerations for each site, will be described in the cleanup plans required by Water Code Section 13394.

RANKING SYSTEM ALTERNATIVES

Four ranking systems are presented for consideration. Two of these systems were developed for purposes somewhat different than those of the BPTCP. These are the Clean Water Strategy used by the State Water Board for resource allocations, and the Hazard Ranking System used by US EPA for Superfund site prioritization. These systems are offered for consideration because they are established and have been used with success for their respective purposes.

I. Clean Water Strategy

The State Water Board's Water Quality Coordinating Committee, in 1990, has developed the Clean Water Strategy (Strategy) as a management tool to provide a common framework for applying the collective professional judgement of State and Regional Water Board staff to identify and prioritize water quality problems (Diaz, 1991). The Strategy consists of six phases which, to date, have been partially implemented. These phases are: (1) collecting water quality information, (2) comparing and ranking the importance and the condition of water bodies, (3) prioritizing work required to address threats and impairments of water quality identified in Phase 1, (4) allocation of staff and contract resources to the list generated in Phase 3, (5) implementation of the funded work, and (6) review and assessment of results and products. CWS rankings are developed through a collective professional judgement process. This process uses criteria and numerical ratings to allow statewide staff to separate and group waters in five levels of importance (value of the resource) and within each each level of importance, to group the severity of problems in five levels. The CWS does not rely on formulas or weighted criteria in developing rankings. The CWS process relies on a series of "bite size" judgements an d groupings, which when combined result in general concensus on final rankings.

Phases 1 and 2 of the Strategy might be applied to satisfy the Water Code requirements for Toxic Hot Spot ranking in the BPTCP. While the basic purpose of the Strategy is to prioritize responses to water quality problems (similar to Toxic Hot Spot ranking) there are some fundamental differences in purpose and approach between the Strategy and the requirements of the BPTCP. The most fundamental difference is that the Strategy creates priorities for work based on ranking of entire water bodies whereas the Hot Spot Ranking is intended to address hot spots which, except in extraordinary cases, are likely to be localized areas. In addition, the Strategy must consider a number of water quality impairments other than those caused by toxic pollutants. For instance, depressed levels of dissolved oxygen should be considered in the Strategy but would be excluded for BPTCP purposes. A third difference is that the Strategy generates independent ranked lists for several classes of water bodies (such as rivers, lakes, and wetlands), while the BPTCP is required to rank hot spots together, irrespective of the type of water body (such as wetlands; fresh, brackish, and marine portions of estuaries; and bays). Finally, the Strategy rankings are designed to support Phases 3 and 4; i.e., proposed responsive actions and allocation of resources. In the BPTCP, determination of likely responsive actions to hot spot designations are included as part of Toxic Hot Spot Cleanup Plans and are not included in the ranking process.

Since the Strategy was developed before the BPTCP was established, it will likely be modified to incorporate new information from the BPTCP. A likely outcome of this modification will be that the toxic hot spot rankings will be included as one of the many factors used to develop water body rankings in the Strategy. In any case, the Strategy will continue to be used for purposes beyond the scope of the BPTCP. A summary of the ranking process using the Strategy is provided in Appendix 1.

II. Hazard Ranking System

The Hazard Ranking System (HRS) was developed as part of the implementation of the national Superfund program (US EPA, 1990). The HRS is designed to score the relative threat associated with actual or potential releases of hazardous substances from specific sites and to rank the site on the National Priority List for superfund cleanup. The HRS provides a numerical value derived from the assessment of four different environmental pathways each evaluated for three specific factors. The pathways are: (1) ground water migration, (2) surface water migration, (3) soil exposure, and (4) air migration. The three factors are (1) the likelihood of release, (2) waste characteristics, and (3) targets. Through a series of steps, each pathway is assigned a numerical score which integrates the assessment of the three factors for that pathway. The pathway scores are then combined to produce the final site value. The site is ranked against other sites based on this final site value; larger numeric values receive a higher priority.

The actual derivation of a final site value is a rather complex process that requires a significant amount of site-specific information. Some steps in the process are common to all four pathways while others are specific to the particular pathway under consideration.

While the HRS provides a somewhat consistent treatment of sites for ranking purposes, the requirement of extensive evaluation makes it rather cumbersome and time consuming process. Furthermore, this system still requires a number of assumptions and professional judgement in order to complete the evaluation and ranking. The HRS was developed under guidance from Congress that the system "to the maximum extent feasible, . . . accurately assesses the relative degree of risk to human health and the environment posed by sites and facilities subject to review" (Fed. Reg. Vol 55, No. 241, pg 51532). Although this directive does not constitute a mandate for a full risk assessment before ranking, it has been interpreted to require a more detailed analysis (as evidenced by the HRS) than required for the purposes of the BPTCP. The level of details required to complete an HRS evaluation does not seem justified for BPTCP purposes.

Furthermore, the HRS is designed to emphasize threats to human health. For example, two of the three factors in the surface water-overland/flood migration path address human exposure (drinking water threat and human food chain threat), and one factor addresses environmental threats (sensitive environments). The scores for these factors further emphasize human health by allowing a maximum score for drinking water and food chain factors of 100 but only a maximum of 60 for environmental threats.

When scores are computed for the final site value, the emphasis clearly falls on human health considerations. This is in contrast to the BPTCP where human health and environmental (aquatic life and wildlife) considerations are given equal weight. Appendix II provides further information on the HRS criteria.

III. Simplified Toxic Hot Spot Ranking Criteria

In looking for the simplest approach to ranking, it becomes clear that using a single type of information greatly reduces the complexity of the problem. An approach using only chemical data is presented below. This approach satisfies Water Code requirements. It is quite easy and simple to use but loses detail in the rankings when compared to the weighted toxic hot spot ranking criteria discussed subsequently in this report.

SIMPLIFIED RANKING CRITERIA

1. Tissue residues:

   Assign values based on criteria listed below and using the average concentration of pollutants reported for any organisms collected from the site for a single sampling event. Assign a value for each substance that exceeds its MTRL. Select the substance providing the highest score.

   If a concentration of a toxic substance in tissue:

   Equals or exceeds MTRL[1] of 1000 ug/kg assign a value of 1
   Between MTRL of 10 ug/kg and 1000 ug/kg assign a value of 2
   Less than or equal to MTRL of 10 ug/kg assign a value of 3

   Multiply by 2 if more than one substance exceeds its MTRL in the same sample.

2. Water column quality:

   Assign values based on criteria listed below and using the concentration of pollutants reported for ambient waters collected from the site. Use the substance providing the highest score for exceeding water quality objectives in the appropriate statewide plan. Ranking values are assigned based on the values below:

   For water quality objective equal to or over 1 mg/l, assign a value of 1.

   For water quality objective between 100 ug/l and 1 mg/l, assign a value of 2.

   For water quality objective less than 100 ug/l, assign a value of 3.

   Multiply by 2 if more than one substance exceeds its applicable water quality objective.

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[1] MTRLs (Maximum Tissue Residue Levels) are calculated by multiplying the human health water quality objective in the appropriate statewide plan by the chemical's bioconcentration factor (BCF) (Cohen, 1993). The BCF is defined as the ratio of the contaminant concentration in tissue to contaminant concentration in water. MTRLs proposed for use in the ranking system are presented in Appendix 3.

3. Sediment values:

Assign values based on sediment weight-of-evidence guidelines recommended for the State of Florida and the criteria listed below and using the dry weight normalized concentration in bulk sediments collected from the site. Use the substance providing the highest score.

Above the Probable Effects Level (PEL) assign a value of 3.

Between the No Observed Effect Level (NOEL) and PEL assign a value of 2.

Multiply by 2 if more than one substance exceeds to NOEL.

4. Final Ranking Value:

Values should be generated for criteria 1 through 3 wherever possible. In some cases it will not be possible to generate a criterion. For example, a pollutant of concern may not have an associated sediment value. In these cases assign a value of zero for each criterion that cannot be fully developed.

Sum the values for criteria 1 through 3. The resulting sum is the final ranking value. The site with the highest score will be assigned rank #1.

IV. Weighted Toxic Hot Spot Ranking Criteria

The ranking system presented below has been designed to (1) provide a site-specific refinement of the Clean Water Strategy and (2) address specific requirements of the BPTCP (Water Code Sections 13390 et seq.). A value for each criterion described below should be developed provided appropriate information exists. Any criterion for which no information exists should be assigned a value of zero. The sum of the values for the six criteria will serve as the final ranking score. In developing the score for each criterion an initial value is identified and then adjusted by one or two correction factors as appropriate.

WEIGHTED RANKING CRITERIA

1. Human Health Impacts

Potential Exposure: Select from the following the applicable circumstance with the highest value:

Human Health Advisory issued for consumption of aquatic life from the site (assign a value of 5); Human Health advisory issued for sensitive populations consuming aquatic life from the site (4); Tissue residues in aquatic organisms exceed FDA/DHS action level or OEHHA trigger level (if available for the location) (3); Tissue residues in aquatic organisms exceed MTRL (2).

Potential Hazard: Multiply the exposure value selected by one of the following factors:

Pollutant(s) of concern is(are) known or suspected carcinogen[2] with a cancer potency factor or an other pollutant of concernwith a referbce dose (assign a value of 5); Pollutant(s) of concern is(are) not known or suspected carcinogens without a cancer potency factor or pollutant of concern without an RFD (3); other pollutants of concern (1).

2. Other Beneficial Use Impacts

A. Rare, threatened, or endangered species present: Select from the following the applicable circumstance with the highest value and one other value if applicable. Do not use any species twice:

Endangered species present at the site (assign a value of 5),
Threatened or rare species regularly present at the site (4),
Threatened or rare species occasionally present at the site (3).

Multiply each identified value by 2 if multiple species are present in any category. Add all resultant values for final Criteria 2A value.

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[2] These are substances suspected of being carcinogenic as classified in the EPA Integrated Risk Information System (IRIS), by the Office of Environmental Health Hazard Assessment or by the Department of Health Services. A list of the substances proposed for use in the ranking system is provided in Appendix 3.

B. Demonstrated aquatic life impacts: Select one or more value(s):

Community impairments associated with toxic pollutants (assign a value of 5), statistically significant toxicity demonstrated with acute toxicity tests acceptable to the BPTCP (4), Statistically significant toxicity demonstrated in chronic toxicity tests acceptable to the BPTCP (3), reproductive impairments documented (2), toxicity is demonstrated only occasionally and does not appear severe enough to alter resident populations (1).

Multiply each value by 2 if the demonstrated effects exceed 80 percent of the organisms in any given test or 80 pecent of the species in the analysis.

C. Chemical measures[3]:

i. Tissue residues exceed NAS guideline (assign a value of 3), at or above State Mussel Watch Elevated Data Level (EDL) 95 (2), greater than State Mussel Watch EDL 85 but less than EDL 95 (1).

ii. Water quality objective: Exceeded regularly (assign a value of 3), infrequently exceeded (2).

iii. Sediment values (sediment weight of evidence guidelines recommended for State of Florida)[4]: Above the Probable Effects Level[5] (PEL) (3), between the NOEL[6] and PEL (2). For a substance with no calculated PEL: Above the effects range median[7] (ER-M) (2), between the effects range lowest 10 percent[7] (ER-L) and ER-M (1).

If multiple chemicals are above their respective EDL 85, water quality objective or sediment value, select the chemical with the highest value for each of the criteria (i) through (iii) above. Add the values for (i) through (iii) (above) to derive the initial value. Multiply the initial value by 2 if multiple chemicals are suspected of contributing to the toxic hot spot.

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[3] The tissue residue guidelines and sediment values to be used in the ranking system should be the most recent version available. The guidelines and sediment values proposed for use in the ranking system are included in Appendix 3. Water quality objectives to be used are found in the California Enclosed Bays and Estuaries Plan, Inland Surface Waters Plan or California Ocean Plan (depending on which plan applies). Where a regional water quality control plan (Basin Plan) contains a more stringent value than the statewide plan. In such a case, the regional water quality objective will be used.

Footnotes 4, 5, 6 and 7 are listed on pages 20 and 21.

3. Areal Extent of Toxic Hot Spot

   Select one of the following values:

   More than 250 acres (assign a value of 10), 50 to 250 acres (8), 10 to less than 50 acres (6), less than 10 acres (4).

4. Pollutant Source

   Select one of the following values:

   Source of pollution identified (assign a value of 5), Source partially accounted for (3), Source unknown (2), Source is an historic discharge and no longer active (1).

   Multiply by 2 if multiple sources are identified.

5. Remediation Potential

   Select one of the following values:

   Site is unlikely to improve without intervention (4), site may or may not improve without intervention (2), site is likely to improve without intervention (1).

   Multiply the selected value by one of the adjustment factors listed below:

   Potential for immediate control of discharge contributing to the toxic hot spot or development of source control/waste minimization programs (assign a value of 4), potential for implementation of an integrated prevention strategy involving multiple dischargers (3), site suitable for implementation of identified remediation methods (2). If site can not be classified (assign a value of 1).

6. Involvement of multiple agencies

   If government agencies other than the State or Regional Water Boards have interests in assessing or managing the site, assign a value of 10.

Rationale for Criteria

This section decribes the rationale for each of the six criteria listed above.

1. Human Health Impacts

   The human health impacts criterion has two parts: An estimate of potential exposure and an estimate of potential hazard. For the exposure estimate the highest score is given if a general human health advisory has been issued. This type of advisory is an indication that aquatic life used for consumption is severly contaminated (i.e., the beneficial use is severely impaired). A human health advisory issued for a sensitive population (e.g., pregnant women, subsistence fisherpersons, etc.) is less severe than the general advisory because fewer people would generally be affected. The

FDA/DHS action levels receive a lower score because these values do not take into consideration the site-specific factors of the risk assesments used for human health advisory issued for a site. A tissue residue level above the MTRL does not by itself demonstrate a waterbody impairment. MTRLs receive the lowest scores because they are established for a specific consumption rate (6.5 g/day for the Inland Surface Waters Plan and the Enclosed Bays and Estuaries Plan and 23 g/day for the California Ocean Plan) and at a cancer risk level of one in one million.

The potential hazard factor assumes that the risk posed by known or suspected carcinogens with a cancer potency developed or an other pollutant of concern with a reference dose available is greater than the risk posed by pollutants without a cancer potency or reference dose available. This is consistent with the approach taken in the three Statewide Plans, EPA methods for calculating water quality criteria, and the approaches of OEHHA and DHS.

2. Other Beneficial Use Impacts

This criterion combines the various factors that should be considered in evaluating impacts on water quality, sediment quality, aquatic life and wildlife.

A. Rare, threatened or endangered species

This criterion evaluates the occurence of rare, threatened or endangered species at a known toxic hot spot. The highest value is assigned if an endangered species is present and lower scores if threatened or rare species is regularly or occasionally present at the site. Association with endangered species is considered more severe than regular or occasional presence of rare or threatened species.

If multiple species in the categories are present the value is multiplied by 2. This value was selected to reflect the additional complexity of the situation when more than one rare, threatened or endangered species is present.

B. Demonstrated Aquatic Life Impacts

This criterion is a measure of aquatic life impact from the most severe conditions to less severe conditions. Measurements of actual measured marine or bay community impairment indicates that there is a direct measurement of impact. These kinds of impairments are difficult to measure and would only be measureable at the most highly impacted sites. Lower values are assigned to acute (short-term) and chronic toxicity (long-term or sensitive life stage tests) which serve as indicators of actual impacts. Reproductive impairements and occasional toxicity are given the lowest values because of the difficulty in interpreting these effects on aquatic life populations.

If multiple species are effected the value is multiplied by 2 to reflect a more severe condition. This multiplier is also applied if over 80 percent of the test organisms are effected. This factor will allow for distinctions to be made between moderate and more severe reponses of organisms.

C. Chemical Measures

This criterion has three parts: (i) Tissue residues, (ii) water quality objectives, and (iii) sediment values. As described in the last section of this criterion, if multiple chemicals are suspected of contributing to the known toxic hot spot then the sum of (i) through (iii) is multipled by "2".

i. Tissue Residues and Water Quality Objectives

Tissue residue levels are very difficult to evaluate in terms of impact on aquatic life but some measures do exist to aid in the interpretation of chemicals bioaccumulated in fish or shellfish tissue. The NAS (1972) has evaluated tissue residues for several chemicals. In this criterion, if an NAS guideline is exceeded the highest score is received. Elevated data levels (EDLs) from State Mussel Watch, are given lower values depending on whether the EDL is above 95 percent or 85 percent. EDLs are given lower scores because they do not measure actual effect on organisms. EDLs are included because State Mussel Watch information is generally available and these data are valuable in assessing the relative exposure of organisms to toxic pollutants.

The "water quality objective" criterion gives a higher value when a water quality objective from the appropriate water quality control plan is exceeded regularly. If an objective is infrequently exceeded a lower score is given.

ii. Sediment Values

The inclusion of sediment values in evaluating chemical constituent concentrations deserves some clarification. A major focus of the Bay Protection statutes is the assessment of sediment quality. At this point in time, a comprehensive collection of numeric values for toxic pollutants in sediment, similar to water quality objectives, does not exist. However, two related efforts have been completed that provide an overview of sediment quality. These are the National Oceanic Atmospheric Administration (NOAA) technical memorandum NOS OMA 52 by Long and Morgan (1990), and the sediment weight-of-evidence guidelines developed for the Florida Coastal Management Program (1993).

Long and Morgan (1990) assembled data from throughout the country for which chemical concentrations had been correlated with effects. These data included spiked bioassay results and field data of matched biological effects and chemistry. The product of the analysis is the identification of two concentrations for each substance evaluated. One level, the Effects Range-Low (ER-L) was set at the 10th percentile of the ranked data and was taken to represent the point below which adverse effects are not expected to occur. The second level, the Effects Range-Median (ER-M), was set at the 50th percentile and interpreted as the point above which adverse effects are expected. A direct cause and effect linkage in the field data was not a requirement for inclusion in the analysis. Therefore, adverse biological effects recorded from a site could be attributed to both a high concentration of one substance and a low concentration of another substance if both substances were measured at the site. The adverse effect in field data could be caused by either one, or both, or neither of the two substances of concern. This introduces a certain degree of ambiguity into the analysis. Additionally, both fresh and salt water sites were included in the analysis and no attempt was made to distinguish between these two types of sites. Finally, sites not demonstrating any adverse effects were excluded from the derivation of the ER-L and ER-M.

The project funded by the State of Florida (1993) revised and expanded the Long and Morgan (1990) data set and then identified two levels of concern for each substance: the "NOEL" or no observable effect level, and the "PEL" or probable effect level. Some aspects of this work represent improvements in the original Long and Morgan analysis. First, the data was restricted to marine and estuarine sites, thereby removing the ambiguities associated with the inclusion of freshwater sites. Second, a small portion of the original Long and Morgan (1990) database was excluded, while a considerable increase in the total data was realized due to inclusion of new information. The basic criteria for data acceptance and for classifying the information within the database were essentially the same as used by Long and Morgan (1990).

The development of the NOEL and PEL differ from Long and Morgan's development of ER-L and ER-M in that data showing no effects were incorporated into the analysis. In the weight-of-evidence approach recommended for the State of Florida, two databases were assembled; a "no-effects" database and an "effects" database. The PEL was generated by taking the geometric mean of the 50th percentile value in the effects database and the 85th percentile value of the no-effects database. The NOEL was generated by taking the geometric mean of the 15th percentile value in the effects database and the 50th percentile value of the no-effects database and dividing by a safety factor of 2. By including the no effect data in the analysis, a clearer picture of the chemical concentrations associated with the three ranges of concern; no-effects, possible effects, and probable effects, can be established. The ER-M values from Long and Morgan (1990) and PEL values from the weight-of-evidence approach recommended for the State of Florida are presented in Table 2. The weight-of-evidence approach recommended for the State of Florida has not yet established guidelines for five substances included in the Long and Morgan (1990) analysis (Table 2). Even though the Long and Morgan (1990) approach may have limitations, it is important to include it in evaluating ranking for the six pollutants listed in Table 3 if the data are available. Because of the limitations in using the ER-M and ER-L, lower values have been assigned as compared to when a PEL and NOEL are available.

3. Areal Extent of Toxic Hot Spot

The rationale for this criterion is to discount smaller sites because these sites will be difficult or perhaps may not be practical to remediate. This criterion is an estimate only. If the areal extent is completely unknown this criterion should be assigned a value of zero. While this estimate may over- or under-estimate the size of the toxic hot spot, we assume that one of the first steps in planning for a cleanup of a known toxic hot spot will be a charaterization of the size of the hot spot before any remedial activity occurs.

4. Pollutant Source, Remediation Potential and Involvement of Multiple Agencies

These three criteria involve judgments of whether the sources of pollutants are identified, the likely remediation potential, and whether the State and Regional Water Boards are likely to be joined in site remediation by other agencies and the responsible parties. These criteria will be based on the experience and judgement of the State and Regional Water Board staff.

The "pollutant source" criterion scores a site on the basis of knowledge of whether the source of pollutant is known. If the source is a result of a historic discharge (no longer active) a site is given the lowest score because it will be impossible to improve the site by modifying existing practices. The "remediation potential" criterion is an estimate of whether the site is amenable to intervention and whether waste minimization or prevention programs (implemented through permits) could be used to solve identified problems. Sites requiring sediment or other remediation or other expensive approaches receive a lower score. The "involvement of other agencies" criterion is an estimate of the potential for other agencies to assist the State and Regional Boards in implementing or initiating site cleanup or characterizing a site. The rationale of this criterion is that if other agencies are involved in addressing the problem at a site the State and Regional Board's involvement may more expeditiously cleanup the site.

Table 2: Comparison of sediment screening[4] levels developed by NOAA (Long and Morgan, 1990) and the weight-of-evidence approach recommended for the State of Florida (1993).

	State of Florida		NOAA
SUBSTANCE	NOEL[6]	PEL[5]	ER-M[7]
<u>Organics</u>		<u>ug/kg</u>	
Total PCBs	25	270	380
Acenaphthene	30	450	650
Acenaphthylene	35	500	
Anthracene	80	800	960
Fluorene	25	450	640
2-methyl naphthalene	25	330	670
Naphthalene	140	1100	2100
Phenanthrene	150	1300	1380
Total LMW-PAHs	250	2500	
Benz(a)anthracene	160	1500	1600
Benzo(a)pyrene	220	1900	2500
Chrysene	200	1800	2800
Dibenzo(a,h)anthracene	60	300	260
Fluoranthene	380	3900	3600
Pyrene	300	1900	2200
Total HMW-PAHs	900	9000	
Total PAHs	2900	29000	35000
p,p'-DDE	1.7	100	15
Total DDT	2.3	300	350
<u>Metals</u>		<u>mg/kg</u>	
Arsenic	10	70	85
Cadmium	1	8.6	9
Chromium	35	230	145
Copper	30	200	390
Lead	25	170	110
Mercury	0.15	1.4	1.3
Silver	2.2	3.5	2.5
Zinc	270	70	280

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[4] Values are for bulk sediment chemistry on a dry weight basis.
(footnotes continued on next page)

Table 3: Screening levels developed by NOAA (Long and Morgan, 1990) for which no PEL or NOEL is established.

SUBSTANCE	ER-L[7] ug/kg	ER-M[7] ug/kg
Chlordane	0.5	6
Dieldrin	0.02	8
Endrin	0.02	45
2-methylnaphthalene	65	670
Antimony	2000	25000
Nickel	30	50

STAFF RECOMMENDATION

The Weighted Toxic Hot Spot Ranking Criteria are recommended for use for the BPTCP. An example of the application of this method is presented below.

TRIAL APPLICATION OF THE RANKING CRITERIA

Evaluation of the weighted toxic hot spot ranking criteria was accomplished by applying the criteria to two known hot spots: the Sacramento River stretching from Freeport to Hood and Cabrillo Pier in Los Angeles Harbor. The information available for the sites is mostly contained in two documents (Montoya 1991 and Birosik 1991) and is summarized below. A table listing the values assigned to the two sites for each criterion is also presented.

Where information suggests that natural background metals concentrations exceed the PEL, normalizing factors (e.g., Acid Volatile Sulfide: Simultaneously extracted metals [Di Toto et al., 1990]) may need to be applied.

[5] PEL is that concentration above which adverse biological effects are likely to occur. It is developed by taking the geometric mean of the 50th percentile value of the effects database and the 85th percentile value of the no-effects database.

[6] NOEL is defined as the sediment concentration below which adverse effects are not likely to occur. The value is derived by taking the geometric mean of 15th percentile of the effects database and the 50th percentile of the no-effects database and dividing by a safety factor of 2.

[7] The ER-M is analogous to the PEL. It is that concentration above which adverse effects are likely. It is developed by taking the 50th percentile of the ranked adverse effects data in the Long and Morgan database. The ER-L is developed by taking the 10th percentile of the ranked adverse effects data.

As summarized by Montoya (1991), the U.S. Geological Survey has reported water hardness and both dissolved and total concentrations of a variety of metals at the Sacramento River site for a number of years in both wet and dry seasons. Similar data has been produced by the Central Valley Regional Water Quality Control Board as recently as 1991, and the Regional Water Board has performed three-species water toxicity testing in recent years. The State Water Board's Toxic Substances Monitoring Program has reported levels of organic chemicals and metals in game and other fish collected annually at Hood since 1977. The FDA Action Levels are not exceeded but there is a human health warning for mercury (Hg) in Striped Bass. Other relevant information is the presence of an endangered species, winter run chinook salmon (Steinhart, 1990); demonstrated chronic toxicity in multiple species; exceedance of NAS DDT levels; and regularly exceeded water quality objectives for metals.

Data for the Cabrillo Pier area of Los Angeles Harbor consists largely of a recent human health risk assessment (Pollock et al., 1991). Human health impacts are demonstrated by a sportfishing health advisory against the consumption of resident species caught in the vicinity of Cabrillo Pier. The hazardous substance of concern is DDT, a carcinogen. An endangered species, California Least Tern, is present in the area, and exceedance of NAS DDT levels have been reported.

Areal extent of both sites is relatively difficult to judge because the media used to qualify the sites (water in the Sacramento River and fish at Cabrillo Pier) show greater movement than sediment. Nevertheless, it is safe to assume that both are larger than 50 acres. Both sites are also similar in that the pollutant sources are multiple and partially accounted for. Metals in the Sacramento River can originate from urban runoff, point source discharges, agricultural practices, acid mine drainage, and other sources. DDT and PCB in fish caught from Cabrillo Pier can originate from widely scattered reservoirs in sediment, urban runoff, and perhaps aerial deposition. Both sites are similar in that improvement is unlikely to occur soon without intervention.

The two sites differ, however, in their potential for implementation of an integrated prevention strategy. Controlling metals in the river may be successful because the variety of sources can be controlled through waste discharge requirements; controlling the sources of DDT and PCB is probably not possible with waste discharge requirements. Finally, due to widespread interest in the health of the Delta and concern for threats to human health at Cabrillo Pier, both of these sites are likely to gain the interest of multiple agencies.

Ranking criteria scores for these two known toxic hot spots are presented in Table 4. In summary, the Sacramento River hot spot scored higher than the Cabrillo Pier site. This was due in large part to the greater chemical and aquatic life impacts and a greater the likelihood of success of an integrated control strategy, these higher values were somewhat compensated for by a greater human health impact at Cabrillo Pier.

Table 4: Ranking Criteria Scores for Two Known Hot Spots the Sacramento River (Freeport to Hood) and Cabrillo Pier

	Known Hot Spot			
Criteria	Sacramento River, Freeport to Hood		L.A. Harbor, Cabrillo Pier	
1. Human health impact				
a. Potential exposure	Human Health Advisory (Hg)	5	Human health advisory	5
b. Hazard	Non-Carcinogen with RFD	3	Carcinogen with cancer potency	5
c. Total score (a x b)		15		25
2. Beneficial use impacts				
a. Endangered species	Endangered species present	5	Endangered sp. present	5
b. Aquatic life	Chronic toxicity	3 x 2 = 6	Not demonstrated	0
c. Chemical measures				
i. Tissue residues	DDT NAS level exceeded	3	DDT NAS level exceeded	3
ii. Water objective	Metals regularly exceeded	4	No data	0
iii. Sediment values	No data	0	No data	0
Total score	7 x 2	= 14	3 x 2	= 6
3. Areal extent	>50 acres	8	>50 acres	8
4. Pollutant source	Metals in river water from multiple sources	3 x 2 = 6	DDT & PCB in fish from multiple sources	3 x 2 = 6
5. Remediation potential	Improvement unlikely without intervention by an integrated strategy	4 x 3 = 12	Improvement unlikely without intervention but strategy is unclear	4 x 1 = 4
6. Multiple agencies	Avoiding Delta impacts will likely interest multiple agencies	10	Remediating the identified problems interests NOAA	10
Cumulative Score		86		64

RANKING OF POTENTIAL HOT SPOTS

The BPTCP will conduct confirmatory work on potential hot spots to determine if they are known toxic hot spots. Since a large number of potential hot spots are likely to be identified, some manner of scheduling the confirmatory work is needed.

In contrast to known hot spot ranking, Potential Hot Spots have substantially less information available for ranking purposes. Furthermore, since monitoring costs are much lower than probable remediation costs, the ranking of sites for monitoring purposes does not justify the level of detail used for known toxic hot spot ranking. Consequently, ranking of these sites is less quantitative, consisting simply of the grouping of sites into high, medium, and low probability of qualifying as a known hot spot. The predominant types of information available for ranking are State Mussel Watch (SMW) tissue levels, sediment contaminant levels, and, less frequently, toxicity testing. Other kinds of data which are only occasionally available include organism impairment, community degradation, and water contaminant levels.

The highest rank is reserved for sites that are most likely to qualify as known hot spots due to the existence of data indicative of high risk and falling into one of the five conditions for qualification as a known toxic hot spot. Such data will include positive toxicity testing results, tissue contaminant levels approaching NAS, FDA, or OEHHA protective levels, and occasionally other appropriate data. Sediment contaminant data are not included because no chemical-specific sediment quality objectives have been adopted in water quality control plans. Generally, old information will have less importance than recent data, unless the recent data is not particularly useful in judging the likelihood for known hot spot qualification. For example, recent positive toxicity tests will probably be considered equivalent to screening and therefore require confirmatory toxicity testing. Conversely, recent SMW results below NAS, FDA, or OEHHA protective levels will probably be judged unworthy of further tissue testing if territorial fish are unavailable at that site.

The "medium" rank consists of sites with high sediment contaminant levels, as judged first using the PEL sediment screening values, and the values from Long and Morgan (1990) for additional substances where an ER-M is available. Sampling and analysis of fish tissue will focus on SMW sites with EDLs over 85 unless the results of high rank sites show that fish are unavailable or incapable of concentrating pesticides, PCB, or mercury above protective levels.

Remaining sites are of low rank and consist predominantly of sediment contaminant levels below ER-M, PEL values and/or SMW EDL 85.

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APPENDIX 1

THE CLEAN WATER STRATEGY

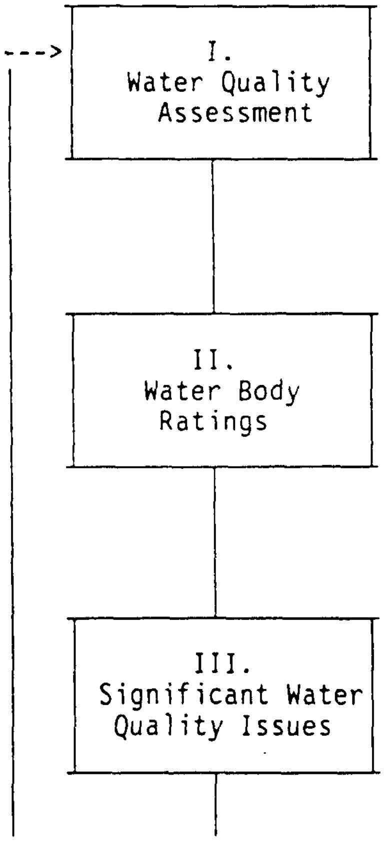
GUIDANCE FOR WATER BODY BASED DECISION MAKING

SUMMARY

The Clean Water Strategy (CWS) is a renewed commitment by the State and Regional Boards to focus efforts on the highest priority water quality needs. As part of this commitment, the way priorities are determined and decisions made was reviewed. That review revealed a need to more fully consider water body information in deliberations. To accomplish this, an enhanced Water Quality Assessment was developed, and improvements were made to reinforce water body based decision making. These features include greater reliance on information from the Water Quality Assessment, a comprehensive evaluation of needs, and a systematic way of weighing considerations such as risk, feasibility, cost/benefit, and trade-offs. Applying these features ensures water body based decision making at the program, region, and statewide levels. This ensures that California's highest priority water quality needs are addressed.

INTRODUCTION

The following provides an outline of how water quality issues are addressed. Each component involves State and Regional Board staff participation and is described in seven phases as follows:



Phase I: Obtaining Information

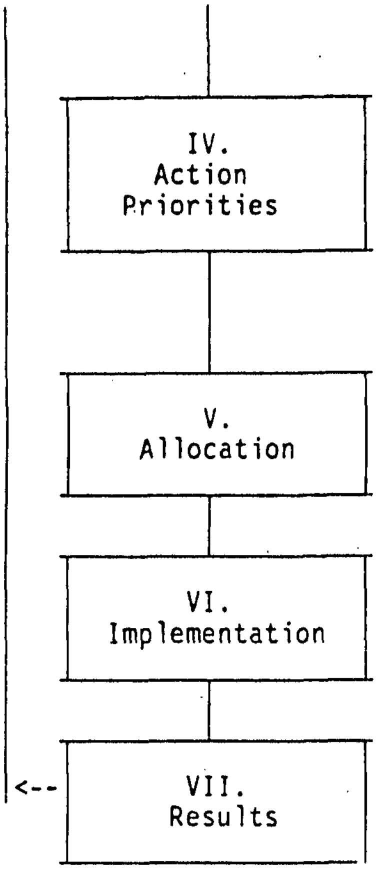
This phase is accomplished primarily through the Water Quality Assessment (WQA). The WQA is a periodic review and inventory of water quality conditions in the State. The WQA provides the source and type of threats to and impairments of each water body assessed. Waters selected by the Regional Boards and waters which appear on selected federal lists have more comprehensive information provided on fact sheets.

Phase II: Prioritizing Water Bodies

In this phase, water bodies are rated with respect to their resource value and the severity of the threats and impairments which may affect them. Resource value is the relative importance of a water body, and is rated through the factors; magnitude of beneficial uses, size, and uniqueness. Impairments and threats are rated in accordance with detailed condition criteria.

Phase III: Identifying Statewide Water Quality Issues

To compliment the water body specific perspective provided by Phases I, and II, Phase III presents an analysis of statewide priority issues relating to pollutants, problem sources, and trends. This analysis is done using the WQA and water body ratings. The resulting guidance to address significant issues is issued annually by the Executive Director.



Phase IV: Prioritizing Actions

Actions to address the water body priorities and significant issues identified in Phases II and III are evaluated for feasibility, cost/benefit, and risk concerns. Priorities are then determined by balancing issues such as prevention vs. restoration efforts, work dealing with different pollutants and problem sources and the level of efforts in each type of water body.

Phase V: Allocation

The allocation or adjustment of resources reflecting Phase IV priorities is made through budgeting decisions.

Phase VI. Implementation

Resources are deployed by appropriate organizations according to the allocation in Phase V.

Phase VII: Results

Results are determined through water quality monitoring and management tracking of programs and contracts. This final phase enables measurement of the progress and effectiveness of the actions taken.

The remainder of this document deals with Phases I through IV where initial Clean Water Strategy efforts have concentrated.

PHASE I: OBTAINING INFORMATION

The Water Quality Assessment (WQA) provides information on water quality conditions and the pollutants and sources of concern. It is a single integrated data base applicable to all water quality program needs.

The WQA includes the most important waters in the state (2500 were included in 1991). Information includes size, resource value and condition ratings, description of concerns (location, pollutants, and probable sources), and an accounting of the federal lists. All information is maintained by the Regional Boards.

The WQA data base can be used to provide various reports related to waters, pollutants and sources, etc. These reports assist program targeting on waters and the analysis of statewide issues.

PHASE II: PRIORITIZING WATER BODIES

Water quality information obtained in Phase I is translated into water body ratings in Phase II. Lists of these rated waters assist the development of program, regional, and general statewide priorities.

RATINGS 1	 3	 5
Many important beneficial uses. High use.	Several important beneficial uses. Moderate use.	A few beneficial uses. Low use.

2b. Water Body Size

This is the aerial extent of the water body. The rating scale varies by water body type using the units in the Water Quality Assessment.

	RATINGS 1	 2	 3	 4	 5
Rivers and Streams (mi)	> 100	70-100	40-70	15-40	0-15
Lakes, Reservoirs, & Saline Lakes (ac)	> 5000	2500-5000	1000-2500	200-1000	0-200
Ground Water (sq-mi)	> 500	200-500	100-200	50-100	0-50
Bays & Harbors (ac)	>10000	2500-10000	1000-2500	200-1000	0-200
Estuaries (ac)	> 2500	1000-2500	500-1000	200-500	0-200
Wetlands (ac)	> 2500	1000-2500	500-1000	200-500	0-200

2c. Uniqueness (surface waters only)

An indicator of unique or exceptional characteristics of the water body not accounted for in other resource value factors. The criteria and range of ratings for this factor are:

RATINGS 1	 2	 3	 5
Water body supports critically important or unique ecosystem. Examples include National Estuarine Sanctuaries, Wild and Scenic Rivers (only Wild and Scenic portion receives "1" rating).	Presence of threatened or endangered species (RARE BU), or slightly less important example of "1".	Regionally Uncommon	Common

2d. Dependence (ground water only)

An indicator of the extent to which the overlying community or the state depends on the ground water basin. The criteria and range of ratings for this factor are:

RATINGS			
1	2	3	5
. Overlying area entirely dependent on ground water for municipal purposes (sole source), or . All ground water is used and is predominantly for municipal uses in overlying area, export areas, or both.	High municipal dependence on ground water basin, or total dependence for purposes, other than municipal.	Moderate to significant dependence on ground water basin.	Ground Water not heavily relied on.

3. Each water body is assigned a CONDITION rating reflecting the level of threat to or impairment of beneficial uses. Like resource value, condition is rated on a scale from one to five. One represents highly threatened or grossly impaired.

Condition ratings are assigned for each threat to or impairment of a water body. These are recorded on Water Quality Assessment fact sheets. Where multiple concerns exist, an overall condition rating is assigned to enable statewide comparisons.

The following criteria is used to provide consistent statewide condition ratings.

3a. Degree of Impairment. This is an indication of the magnitude of impairment of water quality. If unknown, indicate "UNK."

	RATINGS		
	1	3	5
Bacteria	. Longstanding continuous declared health warnings.	Periodic health warnings.	Objectives sometimes or slightly violated.
BOD	. Severe DO Sag causing fish kills.	Occasional DO Sags.	Objectives sometimes or slightly violated.
Metals & Trace Elements & Organics	. Health warnings for fish or shellfish consumption.	No health warnings, but elevated levels in fish or shellfish.	Minor elevation of levels in fish and shellfish

	RATINGS 1	 3	 5
Metals & Trace Elements & Organics (cont'd)	. Drinking water standard exceeded in existing public water supply.	Drinking water standard exceeded, existing public water supply not affected.	Objectives sometimes or slightly violated.
	. Critical life stages completely unsupported.	Critical life stages only partially supported.	Objectives sometimes or slightly violated.
	. Overall absence of benthic organisms.	Benthic organisms adversely affected.	Sediments contaminated, but no noticeable change in benthic population.
Nitrate	. Drinking water standard exceeded in existing public water supply.	Drinking water standard exceeded, public water supply not affected, individual drinking supplies affected.	Objectives sometimes or slightly violated.
Nutrients	. Severe constant DO Sag causing fish kills, severe odors, significant public complaints.	Occasional DO Sags, Frequent Algal Blooms, Taste and odor problems in drinking water.	Objectives sometimes or slightly violated.
Salinity	. Restricted use of existing public water supply.	Restricted use of existing Ag supply.	Objectives sometimes or slightly violated.
	. Widespread fish kills.	Periodic fish kills & overall population decline.	Objectives sometimes or slightly violated.
	. Critical life stages completely unsupported.	Critical life stages only partially supported.	Objectives sometimes or slightly violated.
Siltation	. Widespread distruction of spawning areas.	Siltation of some spawning areas.	Abnormal turbidity.

	RATINGS		
	1	3	5
Siltation (cont'd)	. Severe and repeated fish kills.	Infrequent, limited fish kills & population decline.	Abnormal turbidity.
Temperature	. Widespread fish kills.	Marked decline in fish/plant populations.	Objectives sometimes or slightly violated.
	. Critical life stages completely unsupported.	Critical life stages only partially supported.	Objectives sometimes or slightly violated.
Toxicity	. Acute or chronic toxicity w/ widespread adverse impacts on resident population.	Acute or chronic toxicity w/ some impacts on resident populations.	Acute or chronic toxicity w/ no noticeable impacts on resident population.

3b. <u>Degree of Threat</u>. This is an indication of the magnitude of a threat to water quality. If unknown, indicate "UNK."

	RATINGS		
	1	3	5
Land Use	. Dramatic, widespread land use changes in watershed, including draining and filling	Gradually expanding land use changes, including draining and filling	Static land use.
	. Dramatic, widespread increase in traffic, visitation etc.	Moderate increase in traffic, visitation etc.	Minor or no change in traffic, visitation etc.
	. Static land use with high concentration of sites involving potential pollutants	Static land use with moderate concentration of sites involving potential pollutants	Static land use with low concentration of sites involving potential pollutants
Point Source Discharges	. Effluent dominated receiving water and Category I dischargers.	Discharge accounts for 1/4 receiving water volume and Category I/II dischargers.	Discharge volume minor compared to receiving water volume and Category II or III dischargers.

	RATINGS		
	1	3	5
Trends	Dramatic constituent level increase in short time period.	Moderate constituent level increase over time.	Minor or no constituent level increase over time.

4. Upon completion of the resource value and condition ratings, the rated water bodies are listed in descending order of resource value for each water body type. This emphasizes resource value as the first priority consideration. Waters with the same resource value are arranged in descending order of condition ratings to provide further rankings as follows:

WATER BODY TYPE

Waters with Resource Value of:	Impaired List	Threatened List
1	Waters in descending severity of impairment or threat with a resource value of 1.	
2	as above for RV=2	
3	as above for RV=3	
4	as above for RV=4	
5	as above for RV=5	

PHASE III: STATEWIDE WATER QUALITY ISSUES

Phase III involves an analysis of the WQA and the water body rankings. This analysis is used to assist the annual preparation of guidance to staff on significant water quality issues. This guidance, in conjunction with Phase II water body priorities, is used to solicit action proposals, direct program activities, and to screen and evaluate actions proposed.

Significant issues guidance includes:

a. Identification of the most significant pollutants and sources of pollution affecting California's waters.

b. Identification of issues requiring short and long term strategies.

c. Identification of general actions to address the significant issues.

Issues are identified by the Division of Water Quality Monitoring and Assessment Unit. Every January the Executive Director issues guidance to address issues.

Phase III products are not limited to the annual significant issues guidance. On an ongoing basis, the Monitoring and Assessment Unit prepares distillations and summaries of Water Quality Assessment information. These provide an additional level of detail and perspective to compliment the Executive Director's guidance. Staff should access this information as appropriate.

PHASE IV: PRIORITIZING ACTIONS

Phase IV is preceded by the solicitation of actions which reflect the priorities determined through Phases II and III. This assists the focusing of actions on the most significant concerns.

In Phase IV, the proposed actions addressing the needs of water bodies and pollutant/source concerns are evaluated and prioritized within available resources. Priorities are arrived at through combining Phase II and III rankings and guidance with feasibility, cost/benefit, and risk considerations. Funding lines are drawn based on balancing issues such as prevention vs. restoration efforts, work dealing with different pollutants and problem sources and the level of efforts in each type of water body (Figure 1).

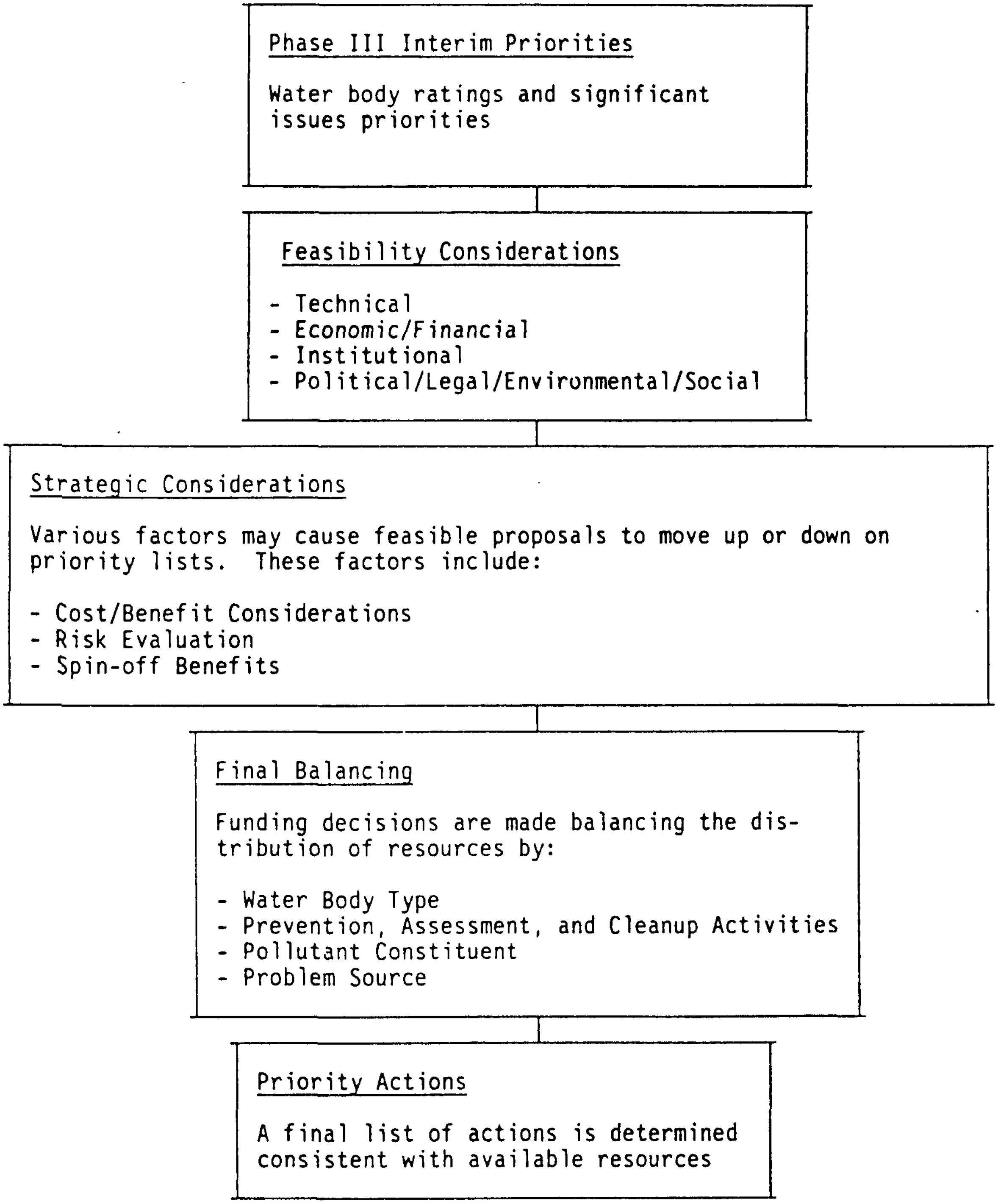
The following sequence of actions occurs during Phase IV (see Figure One):

1. Phase II and Phase III priorities are distributed.

2. Actions are initially ranked in accordance with the resource value and condition ratings of the water body(s) with which they deal. The result is a listing formatted the same way as described in Phase II. However, these lists include only the water bodies for which actions are proposed. For example, assume a program needs to rank actions pertaining to five rivers; a, b, c, d, e. The following list results:

Phase IV

Figure 1



Phase III Interim Priorities

Water body ratings and significant issues priorities

Feasibility Considerations

- Technical
- Economic/Financial
- Institutional
- Political/Legal/Environmental/Social

Strategic Considerations

Various factors may cause feasible proposals to move up or down on priority lists. These factors include:

- Cost/Benefit Considerations
- Risk Evaluation
- Spin-off Benefits

Final Balancing

Funding decisions are made balancing the distribution of resources by:

- Water Body Type
- Prevention, Assessment, and Cleanup Activities
- Pollutant Constituent
- Problem Source

Priority Actions

A final list of actions is determined consistent with available resources

Rivers and Streams

Water Body Name	Resource Value	Condition	
		Impaired	Threatened
b	1		2
e	1	2	
c	2	1	
a	2	2	
d	2		4

3. Next, actions dealing with significant issues may warrant special consideration on the priority lists. These actions are elevated or flagged for elevation later in deliberations.*

4. The actions are next subjected to the following FEASIBILITY considerations to further adjust the priority list:

Technical Feasibility:

- Is this action technically sound?
- Will this action result in an assured solution or constructive partial solution to the problem?
- Other?

Economic/Financial Feasibility:

- Does the action cost an inordinate amount with respect to identified funds?
- At culmination of a project, do we anticipate inordinate implementation costs which haven't been recognized?
- Is the action suitable for funding by others or matching funding?
- Does the action fit best with the proposed program funds?
- Is the action duplicative?
- Other?

Institutional Feasibility:

- Does the action have the support from others who will play an active role in Implementation?
- Are there institutional obstacles which could severely impede the effectiveness of the action?
- Should the action be managed by an entity other than what is being proposed?
- Does the action consider all appropriate cooperators?
- Other?

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* For actions which fail and are of significant concern, guidance and feedback to the proposer should indicate issues to be resolved and encourage resubmission of the action proposal.

Political, Environmental, Social, Legal Feasibility:

- Are there severe political, environmental, social, or legal difficulties with respect to the action?
- Are there legislative aspects which have not been recognized and which could limit the success of the action?
- Other?

Should an action be judged infeasible, that action will be crossed off the priority list(s) and the reasons documented.* In instances where the staff is concerned about one feasibility component but is not in a good position to make an ultimate judgement (such as political feasibility) that concern will be documented and referred for higher level review.

5. Strategic concerns are evaluated and may elevate or lower actions on the priority lists. The following are considered:

   - Cost/Benefit: Will a low cost action yield relatively high benefits with respect to other actions? For example, it may be advantageous to fund several low ranked actions rather than one more expensive high raked action. In order to achieve the most benefits with available funds, actions which leverage benefits may be elevated on priority lists for each type of water body.

   - Risk: Is the action being considered something that has to be done immediately, or can it wait? As a result of inaction now, will inordinate costs or harm occur later?

   - Spin-off Benefits: Sometimes an action in one program or region can yield information useful throughout the organization, or be on the critical path for several other actions statewide, or it may leverage significant participation by other parties. Actions resulting in such spin-off benefits should be considered for elevation on priority lists.

   - Additional Considerations: Any concern or programatic need not covered above.

6. The final step in determining priorities involves balancing the distribution of resources by:

   - Water Body Type
   - Prevention, Assessment, and Cleanup Activities
   - Problem Source
   - Pollutant Constituent

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* For actions which fail and are of significant concern, guidance and feedback to the proposer should indicate issues to be resolved and encourage resubmission of the action proposal.

This ensures that level of efforts are balanced with respect to reducing risks in each type of water body, for each type of pollutant or problem source, and in protection/restoration activities.

Staff recommendations based on the above considerations are then forwarded to management.

NOTE: This phase involves a high degree of best professional judgement. While the above outlines an iterative process involving several considerations, the most important aspect is the assurance that important considerations have been made. In practice many of the iterations described above will occur simultaneously.

Examples of Water Body Based Decision Making

Example One: Statewide Cutbacks

It is 1993 and we have been successful in adding 100 positions for critical work this year. However, a call comes from the Department of Finance--we face another general five percent cut. How do we take the cut? Implementation of the Clean Water Strategy (CWS) will assist in making this decision.

While the CWS emphasizes water body based decision making, the ultimate goal is efficiency in reducing risk. That is, ensuring that program actions on higher overall risk situations are covered and that the lower overall risk situations are recognized and addressed subject to available funds. The CWS water body ratings provide important comparative relationships between waters in the State. By understanding the relationships between water bodies, it is possible to compare actions to reduce risk, determine priorities, and adjust resources accordingly. The following represents a possible outcome of the 1993 situation:

As programs have increasingly focused on higher priority risk reduction situations, a compaction of work efforts has occurred. For program THIN, instead of barely addressing 100 situations, efforts have been concentrated on 40 situations and the same funds are being used to accomplish more overall risk reduction in the State. In this scenario the number 41 situation is unfunded. Program FAT has also seen compaction and its unfunded situations can now be compared with number 41 in program THIN. If the highest priority unfunded situations in each program represent the same risk, then five percent reductions would be equal in both programs. If program FAT is addressing lower risk priorities, then this program would be targeted for reduction. Conversely, program THIN may be targeted for budget increases or redirection augmentations from programs such as FAT.

Example Two: Allocation of New Resources

The Abandoned Mine Program Manager has been directed to make recommendations regarding $3 million in new program resources. The manager must request proposals from the Regional Boards and draft staff recommendations on how the funds should be used. How can water body rankings and significant issues guidance be used to help make recommendations on resource allocation?

First, the program manager should request that proposers give first consideration to actions addressing high resource value water bodies with the most severe threats or impairments. If the significant issues guidance indicates any abandoned mines priorities, then these should also be highlighted in the solicitation.

Once proposals are received, the program manager preliminarily ranks proposals based on water body rankings. For example, if proposals were received relating to the Eel River and the Sacramento River, both resource value "1" water bodies, the Sacramento River project would initially be ranked higher due to the river's higher level of impairment (a "1" impaired rating versus a "3" threat). Next, guidance on significant water quality issues is considered. For instance, if the guidance indicates that mercury problems are most important, then proposals addressing mercury should be considered for elevation on priority lists. Similarly, if guidance is focused on abandoned mine problems affecting ground water, then this information should be kept in mind when balancing decisions between different water body types are eventually made.

Next the actions proposed are screened for feasibility. This includes institutional, political, legal, economic, environmental, technical, and social aspects. If a proposed project is feasible, then the benefits of the proposals are weighed through cost/benefit, timing, and risk considerations. For example, if the proposed Eel River project was to yield the same benefits as the proposed Sacramento River project for significantly lower cost, the Eel River project might be elevated above the Sacramento River project.

Finally, balancing decisions are made to distribute the $3 million. Distribution by water body type, problem source, pollutant constituent, and prevention versus remediation efforts are all considered. Recommendations are forwarded for management review and approval.

Example Three: Managing Current Resources

Region Ten's Stormwater Program is preparing its annual workplan. Stable funding is expected but it's inadequate to address all program needs. How can the CWS improvements assist the program manager prioritize the workload.

By examining the Water Quality Assessment (WQA) the program manager can identify waters with threats and impairments related to stormwater. Reports can be accessed through the WQA which provide specific program targeting lists (see the Monitoring and Assessment Unit). If more detail is needed, water body fact sheets might be of assistance.

The manager would then consider the ratings of the waters (included in the WQA data base) identified above. These ratings provide the manager with water body relationships. In turn, the manager ensures protection of the highest resource value waters through safeguards such as the permitting of stormwater discharges, inspections and enforcement. Similarly, for waters impaired by stormwater, the manager ensures that consideration for priority actions first address the highest valued, most severely impaired waters. After all costs and needs are considered, the manager aligns fiscal resources with water body priorities. Again, the Executive Director's significant issues guidance should also be consulted for related concerns.

APPENDIX 2

HAZARD RANKING SYSTEM

The Hazard Ranking System (HRS) was developed as part of the implementation of the national superfund program. The HRS is designed to score the relative threat associated with actual or potential releases of hazardous substances from specific sites and to assign the site to the National Priority List for Superfund cleanup. The HRS provides a numerical value derived from the assessment of four different environmental pathways each evaluated for three specific factors. The pathways are (1) ground water migration, (2) surface water migration, (3) soil exposure, and (4) air migration. The three factors are (1) the likelihood of release, (2) waste characteristics, and (3) targets. A summary of the HRS is provided below beginning with steps common to the four pathways, followed by a brief description of an evaluation of the surface water pathway.

The first step in developing a pathway score is to identify sources of hazardous substances. In the context of the HRS, sources mean "any area where a hazardous substance has been deposited, stored, disposed, or placed, plus those soils that have become contaminated from migration of a hazardous substance" (Federal Register, Vol. 55, No. 241, December 14, 1990). The specific substance(s) of concern are then identified by either documentation (labels, manifests, monitoring report, etc.) or observation.

At this point the factor assessment begins with the evaluation of the likelihood of release. When an observed release is demonstrated, a maximum value (550) is assigned for this factor. An observed release is defined explicitly but generally can be considered to be samples with substances at concentrations three times the background concentration or, if no background value exists, concentrations above the quantitative limit. If an observed release is not identified then the potential for release is evaluated on a pathway specific basis (summarized below for the surface water pathway).

The next step is evaluation of waste characteristics factor. This involves evaluating and scoring toxicity and quantity, and then multiplying the scores for these characteristics together. The final waste characteristics value for a pathway is derived from a table provided in the regulations. Waste characteristics are evaluated for the substance with the greatest hazard for the pathway.

To determine which substance poses the greatest hazard, a toxicity factor value is combined with the mobility, persistence, bioaccumulation factor. The toxicity factor is derived from one of three information sources: (1) for carcinogens the cancer potency factor combined with the substance classification as known or potential carcinogen is used, (2) for noncarcinogens a reference dose (RfD) is used where available, or (3) for noncarcinogens where an RfD is not available, an acute toxicity value is used. The value of the toxicity factor is dependent on the numerical value of each of these characteristics (carcinogenicity, reference dose, acute toxicity) and is derived from a table provided in the regulations. Several clarifying conditions apply to this evaluation.

Once a toxicity factor is identified it is multiplied by a mobility, persistence, and/or bioaccumulation factor. The choice and characterization of this second factor is pathway specific. Each toxicity, factor is multiplied by its respective mobility, persistence, bioaccumulation factor, and the substance yielding the highest product is selected as the hazardous substance of concern for waste characterization.

The second major factor to evaluate for waste characterization is waste quantity. This factor is evaluated using a hierarchy of four measures: (1) hazardous constituent quantity, (2) hazardous waste stream quantity, (3) volume, and (4) area. The first of the measures (in order presented) for which there is adequate information is used to develop the quantity factor. With some exceptions, the hazardous wastes identified for CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) purposes constitute the substances of concern for quantity assessments. The quantity associated with each source is characterized (assigned a value according to tables provided) and the sum of the scores for all sources is used to select a final quantity factor for the pathway. Several specific conditions are considered when determining whether adequate information is available to invoke one of the hiearchical measures.

The final value for the waste characteristics factor is obtained by multiplying the toxicity factor, adjusted according to the mobility, persistence, and/or bioaccumulation factor, by the quantity factor. The product of this multiplication is then applied to a table to select the final waste characteristics factor. Special adjustments are made when considering bioaccumulative substances.

The final factor score needed for developing a site score is a target score. The evaluation of targets is divided into four classes: (1) individual, (2) human population, (3) resources, and (4) sensitive environments. Each class is evaluated on the basis of actual or potential releases and the intensity of the exposure. The intensity of the exposure is divided into Level I or Level II exposures. Generally, Level I exposures are where the concentrations of hazardous substances in specific media (i.e., water, tissue, sediment) meet or exceed available regulatory limits (benchmarks) such as water quality standards or public health warnings or an established dietary risk. Level II exposures are again assigned to observed releases, but in this case, the appropriate benchmark value for the media-specific concentration has not been exceeded, or a benchmark does not exist. The final target score is developed differently for each pathway and will be illustrated below for surface water.

The development of a value for the surface water migration pathway is summarized below to illustrate the complexity and comprehensiveness of the assessment. Each of the four pathways are treated similarly, although not all pathways contain as many subdivisions as the surface migration path.

Two basic components are included in the surface migration path: (1) Overland/flood migration, and (2) Ground water to surface water migration. The Overland/flood path will be summarized for this illustration. A source or a site of contaminated sediments is identified and a target distance is defined (generally as 15 miles down gradient from the site of contamination). The evaluation is then broken down into three parts, threat to drinking water, threat to the human food chain, and threat to sensitive environments. Each of these components is further subdivided to evaluate the likelihood of release, waste characteristic, and targets. The treatment of these evaluations is substantially the same but the specific information applied within the individual evaluations differs. The threat to drinking water evaluation will be described as an illustration.

The likelihood of release evaluation for the drinking water threat is divided into observed releases and potential releases. If an observed release can be established, the maximum score is applied to this factor, otherwise a potential release is evaluated. Observed release is explicitly defined for this evaluation. A potential release is evaluated based on three components: (1) containment, (2) runoff, (3) distance to surface waters. For BPTCP purposes, known toxic hot spots would fall under the observed release category.

Waste characteristics for the threat to drinking water are evaluated next. This evaluation is based on two factors: toxicity/persistence and quantity. An evaluation is conducted for each substance capable of migrating from the source to surface water. The toxicity factor is developed as described above. Persistence is based on environmental half-life (the result of the combination of decay processes, biodegradation, hydrolysis, photolysis, and volatilization) and sediment sorption (based on log K_{OW}). The value for the half-life of the substance of concern is generated from an equation provided in the regulations. The persistence factor is then selected from a table, using the appropriate values for half-life and certain conditional characteristics of the water body and drinking water sources present. Toxicity and persistence are combined into a single value using another table provided. The toxicity/persistence value is multiplied by a quantity value (see above) and this product is applied to another table to select the drinking water threat - waste characteristics value.

The drinking water targets value is derived next. This value is based on three factors: nearest intake, population, and resources. For the intake target and population target a determination is made of whether the target is subject to observed or potential releases of hazardous substances and whether concentrations meet Level I (exceed specified benchmarks) or Level II (below specified benchmarks) criteria. A score for the nearest intake is then developed. The drinking water intake nearest to the source and within the migration path defined is identified. If this intake is subject to measured concentrations of the substances of concern (Level I or II) it is assigned a score. Otherwise a score is assigned based on a dilution weight selected from a table provided in the regulations.

The population serviced by each intake within the migration path is identified (adjusted for blended drinking water). The population size subject to Level I, Level II, and potential contamination is determined for the total migration path (summing individual intakes) and the sum of these three categories is used as the population target value. A resource value is assigned based on the use of water for irrigation, livestock watering, water recreation area, actual or designated drinking water source, or for commercial food preparation.

The drinking water threats-targets factor is developed by summing the values for intake, population, and resources. The final drinking water threat factor score is derived by multiplying the likelihood of release value, waste characteristics value, and targets values and dividing by 82,500. The resulting value is then used to select the drinking water threat score from a table provided. This score is then combined with scores for Threat to Human Food Chain and Environmental Threat to arrive at the score for final score for overland/flood migration component. This score is in turn combined with a score for ground water to surface water migration to arrive at the final Surface Water Migration Path score. The Surface Water Migration Path score is combined with the other three path scores using an equation provided to generate the final site score.

APPENDIX 3

CHEMICAL SPECIFIC VALUES FOR CARCINOGENS USED FOR RANKING TOXIC HOT SPOTS.

SUBSTANCE	PEL[1] (dry) mg/kg	MTRL[2] (Fresh) ug/kg	MTRL[2] (Estuarine) ug/kg	WQO[3] (Fresh) ug/l	WQO[3] (Marine) ug/l
acrylonitrile		0.96	11		
aldrin		0.05	0.33	0.13	0.14
arsenic	64	200		5.0	9.3
benzene		1.8	110	0.34	21
benzidine		0.005	0.02		
beryllium		0.15	2.5		
bis(2-chloroethyl)ether		0.09	4.3		
bis(2-ethylhexyl)phthalate		380	1300		
carbon tetrachloride		4.1	72		
chlordane		1.1	1.2	0.00008	0.00008
chloroform		NA	1800	100	480
4,4' DDE	0.13	32.0	32.0		
DDT, total	0.27	32.0	32.0	0.00059	0.0006
1,4-dichlorobenzene		550	3600	9.9	64.0
3,3'-dichlorobenzidine		4.5	9.0		
1,2-dichloroethane		0.6	150.0		
1,1-dichloroethylene		0.32	18.0		
dichloromethane		4.2	1400	4.6	1600.0
1,3-dichloropropene		0.4	60		
dieldrin		0.65	0.7	0.00014	0.00014
2,4-dinitrotoluene		0.42	35.0		
1,2-diphenylhydrazine		1.0	14		
halomethanes		NA	1800	100.0	480.0
heptachlor		1.8	1.9	0.00016	0.00017
heptachlor epoxide		0.8	0.8	0.00007	0.00007

APPENDIX 3 (continued)
CHEMICAL SPECIFIC VALUES FOR CARCINOGENS USED FOR RANKING TOXIC HOT SPOTS.

SUBSTANCE	PEL (dry) mg/kg	MTRL (Fresh) ug/kg	MTRL (Estuarine) ug/kg	WQO (Fresh) ug/l	WQO (Estuarine) ug/l
hexachloroethane		170	760		
hexachlorobenzene		6	6	0.00066	0.00069
hexachlorobutadiene		1.2	140		
hexachlorocyclohexane (gamma)		2.5	8.1	0.019	0.062
hexachlorocyclohexane (alpha)		0.5	1.71	0.0039	0.013
hexachlorocyclohexane (beta)		1.8	6	0.014	0.046
isophorone		38	27		
N-nitrosodimethylamine		0.00006	0.7		
N-nitrosodiphenylamine		370	1200		
pentachlorphenol		3.1	90.0	0.28	8.2
PAH's (total)	28.00	0.08	0.93	0.0028	0.031
acenaphthene	0.45				
anthracene	0.74				
fluorene	0.46				
naphthalene	1.10				
phenanthrene	1.20				
LMW-PAH, total	2.40				
benz(a)anthracene	1.30				
benzo(a)pyrene	1.70				
chrysene	1.70				
dibenzo(a,h)anthracene	0.32				
fluoranthene	3.20				
pyrene	1.90				
HMW-PAH, total	8.50				
PCB's (total)	0.26	2.2	2.2	0.00007	0.00007
2,3,7,8-tetrachlorodibenzo-p-dioxin		0.00007	0.00007		
TCDD equivalents				0.000000013	0.000000014
toxaphene		8.8	9	0.00067	0.00069
1,1,2-trichloroethane		2.7	190		
1,1,2,2-tetrachloroethane		0.86	54.0		
trichloroethylene		33	980		

APPENDIX 3 (continued)
CHEMICAL SPECIFIC VALUES FOR NONCARCINOGENS USED FOR RANKING TOXIC HOT SPOTS.

SUBSTANCE	PEL (dry) mg/kg	MTRL (Fresh) mg/kg	MTRL (Estuarine) mg/kg	WQO (Fresh) ug/l	WQO (Estuarine) ug/l
tetrachloroethylene		19	210		
2,4,6-trichlorophenol		50	150		
vinyl chloride		0.15	40		
acrolein		69	170		
antimony		0.014	4.3		
cadmium	7.5	0.64	NA	10**	9.3
chlorobenzene		NA	46		
4-chloro-3-methylphenol		NA	NA	3000.0	
bis(2-chloroisopropyl)ether		3.4	430.0		
chromium (VI)	240*	NA	NA	50.0**	
Chromium (III)		530	11000		
copper	170	NA	NA	**	2.9
cyanides		0.7	220.0		
di-n-butylphthalate		240	1100		
1,2-dichlorobenzene		150	970	2700.0	18000.0
1,3-dichlorobenzene		22	150	400.0	2600.0
2,4-dichlorophenol		NA	32	0.3	
diethylphthalate		1700	8600		
2,4-dimethylphenol		NA	220		
dimethylphthalate		11000	110000		
4,6-dinitro-2-methylphenol		0.07	4.2		
2,4-dinitrophenol		0.11	22		
endosulfan-total		0.25	0.5	0.056	0.0087
endrin, total		3.0	3.2	0.0023	0.0023
ethylbenzene		NA	1100		
fluoranthene		49	62	42.0	42.0

APPENDIX 3 (continued)
CHEMICAL SPECIFIC VALUES FOR <u>NONCARCINOGENS</u> USED FOR RANKING TOXIC HOT SPOTS.

SUBSTANCE	PEL (dry) mg/kg	MTRL (Fresh) mg/kg	MTRL (Estuarine) mg/kg	WQO (Fresh) ug/l	WQO (Estuarine) ug/l
hexachlorocyclopentadiene		NA	75		
lead	160	NA	NA	50**	5.6
mercury	1.4	1.0	1.0	0.012	0.025
nickel		28	220	600**	8.3
nitrobenzene		0.05	5.4		
phenol		NA	6500	300	
selenium		NA	NA	5.0	71.0
silver	2.5	NA	NA	50.0**	2.3
thallium		0.20	0.7		
toluene		110	3200	10000.0	30000.0
tributyltin			0.3	20.0	0.005
1,1,1-trichloroethane		1.1	62		
zinc	300	NA	NA	5000.0*	86.0

* The PEL is based on total chromium rather than Cr(VI).

** indicates an aquatic life objective exists that may be a lower value than listed, due to its dependance on water hardness and/or acidity. The lower value of the listed or calculated value should be used.

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1 PEL is that concentration above which adverse biological effects are likely to occur. It is developed by taking the geometric mean of the 50th percentile value of the effects database and the 85th percentile value of the no-effects database.

2 MTRL-Maximum Tissue Residue Level. The MTRL is calculated by multiplying the human health water quality objective in the appropriate Statewide Plan by the chemical's bioconcentration factor (BCF) (Cohen, 1993). MRTLs proposed for use in the ranking system are based on the standards contained in the most recent version of the California Enclosed Bays and Estuaries Plan.

3 WQO--Water Quality Objectives are the standards contained in statewide water quality control plans for freshwaters or enclosed bays and estuaries. These columns do not contain the water quality objectives adopted by the State Water Board in November 1992 because these WQO have not been approved by the Office of Administrative Law. The water quality objectives in the most recent version of the Statewide Plans should be used.

NAS, FDA, and OEHHA Limits Relevant to the BPTC Program
Marine Organisms
(ng/g or ppb wet weight)

Chemical	NAS Recommended Guideline (whole fish) (A)	FDA Action Level or Tolerance (edible portion) (B)	OEHHA Trigger or Health Advisory Level (edible portion) (C)
Total PCB	500	2000*	100
Total DDT	50	5000	100
aldrin)	(D)	300*(E)	-
dieldrin)	(D)	300*(E)	-
heptachlor)	(D)	300*(E)	-
heptachlor epoxide)		300*(E)	-
lindane	50	-	-
chlordane	50	300	23
endosulfan	50	-	-
methoxychlor	50	-	-
mirex	50	-	-
toxaphene	50	5000	-
hexachlorobenzene	50	-	-
any other chlorinated hydrocarbon pesticide	50	-	-
mercury	-	1000* (as methyl mercury)	500 (as total mercury)

A National Academy of Sciences. 1973. Water Quality Criteria, 1972 (Blue Book). The recommendation applies to any sample consisting of a homogeneity of 25 or more fish of any species that is consumed by fish-eating birds and mammals, within the same size range as the fish consumed by any bird or mammal. No NAS recommended guidelines exist for marine shellfish.

B U.S. Food and Drug Administration. 1984. Shellfish Sanitation Interpretation: Action Levels for Chemical and Poisonous Substances. A tolerance, rather than an action level, has been established for PCB.

C Office of Environmental Health Hazard Assessment. 1991. A Study of Chemical Contamination of Marine Fish from Southern California. II. Comprehensive Study. A health advisory level, rather than a trigger level, has been established for mercury. These values should only be used if they specifically apply to the waterbodies for which they were developed.

D Limit is 5 ng/g wet weight. Singly or in combination with other substances noted by footnote D.

E Singly or in combination for shellfish.

* Fish and shellfish.

APPENDIX F

Senate Bill 1084 (Calderon)
(Statutes 1993, Chapter 1157)

Bay Protection and Toxic Cleanup Program Amendments and Additions to the Water Code

Chapter 5.6 of the Water Code

Amendments to
Sections 13392.5, 13393, 13393.5, 13394, and 13396.5

Added
Sections 13394.6 and 13396.7

Senate Bill No. 1084

CHAPTER 1157

An act to amend Sections 13392.5, 13393, 13393.5, 13394, and 13396.5 of, and to add Sections 13394.6 and 13396.7 to, the Water Code, relating to water.

[Approved by Governor October 10, 1993. Filed with
Secretary of State October 11, 1993.]

LEGISLATIVE COUNSEL'S DIGEST

SB 1084, Calderon. Bays and estuaries.

(1) Existing law, which is to be repealed on January 1, 1994, requires the State Water Resources Control Board to impose annual fees applicable to all point and nonpoint dischargers who discharge into enclosed bays, estuaries, or any adjacent waters in the contiguous zone or the ocean, as defined. Existing law requires the state board, on or before January 1, 1993, to make a prescribed report to the Legislature.

This bill would extend that repeal date to January 1, 1998. The bill would prohibit the state board from imposing a fee on any agricultural nonpoint source discharger. The bill would extend the due date applicable to the report to January 1, 1996.

(2) Existing law requires each California regional water quality control board that has regulatory authority for any enclosed bay or estuary to develop, by January 1, 1992, for each such bay or estuary, a consolidated data base that identifies and describes all suspected toxic hot spots.

This bill would instead require those regional boards to develop, by January 30, 1994, a consolidated data base that identifies and describes all potential hot spots.

(3) Existing law requires the state board to adopt, by July 1, 1992, general criteria for the assessment and priority ranking of toxic hot spots.

This bill would extend that date to January 30, 1994.

(4) Existing law requires each regional board to complete and submit to the state board, by July 1, 1993, a toxic hot spots cleanup plan. Existing law requires the state board to submit to the Legislature, by January 1, 1994, a consolidated statewide toxic hot spots cleanup plan.

This bill would extend the due date applicable to the toxic hot spots cleanup plan to January 1, 1998, and the due date applicable to the consolidated statewide toxic hot spots cleanup plan to June 30, 1999.

(5) Existing law requires the state board to adopt sediment quality objectives for toxic pollutants.

This bill would require the state board to consider prescribed federal sediment criteria for toxic pollutants, and to take specified action, in connection with the adoption of sediment quality objectives.

The bill would require the state board to establish a prescribed advisory committee to assist the state board in carrying out specified water quality functions relating to bays and estuaries.

(6) The bill would require the state board, in consultation with the State Department of Health Services, to contract with an independent contractor to conduct a study to determine the adverse health effects of urban runoff on swimmers at urban beaches, as prescribed. The bill would make legislative findings and declarations.

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares all of the following:

(a) A significant source of beach contamination results from urban runoff.

(b) The public use of beaches has declined 25 to 30 percent. That decline is attributable in part to concerns about contamination.

(c) The number of beach closures by local public officials continues to increase each year.

SEC. 2. Section 13392.5 of the Water Code is amended to read:

13392.5. (a) Each regional board that has regulatory authority for one or more enclosed bays or estuaries shall, on or before January 30, 1994, develop for each enclosed bay or estuary, a consolidated data base which identifies and describes all known and potential toxic hot spots. Each regional board shall, in consultation with the state board, also develop an ongoing monitoring and surveillance program that includes, but is not limited to, the following components:

(1) Establishment of a monitoring and surveillance task force that includes representation from agencies, including, but not limited to, the State Department of Health Services and the Department of Fish and Game, that routinely monitor water quality, sediment, and aquatic life.

(2) Suggested guidelines to promote standardized analytical methodologies and consistency in data reporting.

(3) Identification of additional monitoring and analyses that are needed to develop a complete toxic hot spot assessment for each enclosed bay and estuary.

(b) Each regional board shall make available to state and local agencies and the public all information contained in the consolidated data base, as well as the results of new monitoring and surveillance data.

SEC. 3. Section 13393 of the Water Code is amended to read:

13393. (a) The state board shall adopt sediment quality objectives pursuant to the workplan submitted pursuant to Section 13392.6.

(b) The state board shall adopt the sediment quality objectives pursuant to the procedures established by this division for adopting or amending water quality control plans. The sediment quality objectives shall be based on scientific information, including, but not limited to, chemical monitoring, bioassays, or established modeling procedures, and shall provide adequate protection for the most sensitive aquatic organisms. The state board shall base the sediment quality objectives on a health risk assessment if there is a potential for exposure of humans to pollutants through the food chain to edible fish, shellfish, or wildlife.

(c) (1) Notwithstanding subdivision (a), in adopting sediment quality objectives pursuant to this section, the state board shall consider the federal sediment criteria for toxic pollutants that are being prepared, or that have been adopted, by the Environmental Protection Agency pursuant to Section 1314 of Title 33 of the United States Code.

(2) If federal sediment criteria have been adopted, the state board shall review the federal sediment criteria and determine if the criteria meet the requirements of this section. If the state board determines that a federal sediment criterion meets the requirements of this section, the state board shall adopt the criterion as a sediment quality objective pursuant to this section. If the state board determines that a federal sediment criterion fails to meet the requirements of this section, the state board shall adopt a sediment quality objective that meets the requirements of this section.

SEC. 4. Section 13393.5 of the Water Code is amended to read:

13393.5. On or before January 30, 1994, the state board, in consultation with the State Department of Health Services and the Department of Fish and Game, shall adopt general criteria for the assessment and priority ranking of toxic hot spots. The criteria shall take into account the pertinent factors relating to public health and environmental quality, including, but not limited to, potential hazards to public health, toxic hazards to fish, shellfish, and wildlife, and the extent to which the deferral of a remedial action will result, or is likely to result, in a significant increase in environmental damage, health risks, or cleanup costs.

SEC. 5. Section 13394 of the Water Code is amended to read:

13394. On or before January 1, 1998, each regional board shall complete and submit to the state board a toxic hot spots cleanup plan. On or before June 30, 1999, the state board shall submit to the Legislature a consolidated statewide toxic hot spots cleanup plan. The cleanup plan submitted by each regional board and the state board shall include, but not be limited to, the following information:

(a) A priority ranking of all hot spots, including the state board's recommendations for remedial action at each toxic hot spot site.

(b) A description of each hot spot site including a characterization of the pollutants present at the site.

(c) An estimate of the total costs to implement the plan.

(d) An assessment of the most likely source or sources of pollutants.

(e) An estimate of the costs that may be recoverable from parties responsible for the discharge of pollutants that have accumulated in sediment.

(f) A preliminary assessment of the actions required to remedy or restore a toxic hot spot.

(g) A two-year expenditure schedule identifying state funds needed to implement the plan.

(h) A summary of actions that have been initiated by the regional board to reduce the accumulation of pollutants at existing hot spot sites and to prevent the creation of new hot spots.

(i) The plan submitted by the state board shall include findings and recommendations concerning the need for establishment of a toxic hot spots cleanup program.

SEC. 6. Section 13394.6 is added to the Water Code, to read:

13394.6. (a) The state board shall establish an advisory committee to assist in the implementation of this chapter. The members of the advisory committee shall be appointed by the state board to represent all of the following interests:

(1) Trade associations whose members are businesses that use the bay, estuaries, and coastal waters of the state as a resource in their business activities.

(2) Dischargers required to pay fees pursuant to Section 13396.5.

(3) Environmental, public interest, public health, and wildlife conservation organizations.

(b) The members of the advisory committee shall select a member as the chairperson of the committee. The chairperson shall convene meetings of the committee every three months in any calendar year. The members of the advisory committee shall serve without compensation.

(c) The advisory committee shall have access to all information and documents, except for internal communications, that are prepared to implement this chapter and may provide the state board with its views on how that information should be interpreted and used.

SEC. 7. Section 13396.5 of the Water Code is amended to read:

13396.5. (a) The state board shall establish fees applicable to all point and nonpoint dischargers who discharge into enclosed bays, estuaries, or any adjacent waters in the contiguous zone or the ocean as defined in Section 502 of the Federal Water Pollution Control Act (33 U.S.C. Sec. 1362), which shall be collected annually.

(b) The fees shall create incentives to reduce discharges to the ocean, bays, and estuaries and shall be based on the relative threat to water quality from point and nonpoint dischargers. The schedule of fees shall be set at an amount sufficient to fund the responsibilities and duties of the state board, the Office of Environmental Health Hazard Assessment, and the Department of Fish and Game established by this chapter. The total amount of fees collected pursuant to this section shall not exceed four million dollars ($4,000,000) per year. Nothing in this section limits or restricts the funding of activities required by this chapter from sources in addition to the fees established by this section.

(c) Fees collected pursuant to this section shall be deposited in the Bay Protection and Toxic Cleanup Fund which is hereby created, and shall be available for expenditure by the state board, upon appropriation by the Legislature, for the purposes of carrying out this chapter.

(d) Fees collected pursuant to this section shall be in addition to fees established pursuant to Section 13260 and shall not be subject to the maximum fee established in subdivision (d) of Section 13260, provided that the annual fee under this section shall not exceed the amount of thirty thousand dollars ($30,000) per discharger.

(e) Any person failing to pay a fee established under this section when so requested by the state board is guilty of a misdemeanor and may be liable civilly in accordance with subdivision (d) of Section 13261.

(f) On or before January 1, 1996, the state board shall report to the Legislature on the progress made toward meeting the requirements of this chapter and the adequacy of the fee levels established in subdivisions (b) and (d).

(g) No fee may be imposed pursuant to this section on any agricultural nonpoint source discharger.

(h) This section shall remain in effect only until January 1, 1998, and as of that date is repealed, unless a later enacted statute, which is enacted before January 1, 1998, deletes or extends that date.

SEC. 8. Section 13396.7 is added to the Water Code, to read:

13396.7. (a) The state board, in consultation with the State Department of Health Services, shall contract with an independent contractor to conduct a study to determine the adverse health effects of urban runoff on swimmers at urban beaches. The contract shall include a provision that requires the study to be conducted as prescribed in the study proposal approved by the Santa Monica Bay Restoration Project. The study shall be paid for by using available resources or state funds appropriated in the annual Budget Act.

(b) It is the intent of the Legislature that the state board and the State Department of Health Services use the results of the study undertaken pursuant to subdivision (a) to establish recreational water quality standards.

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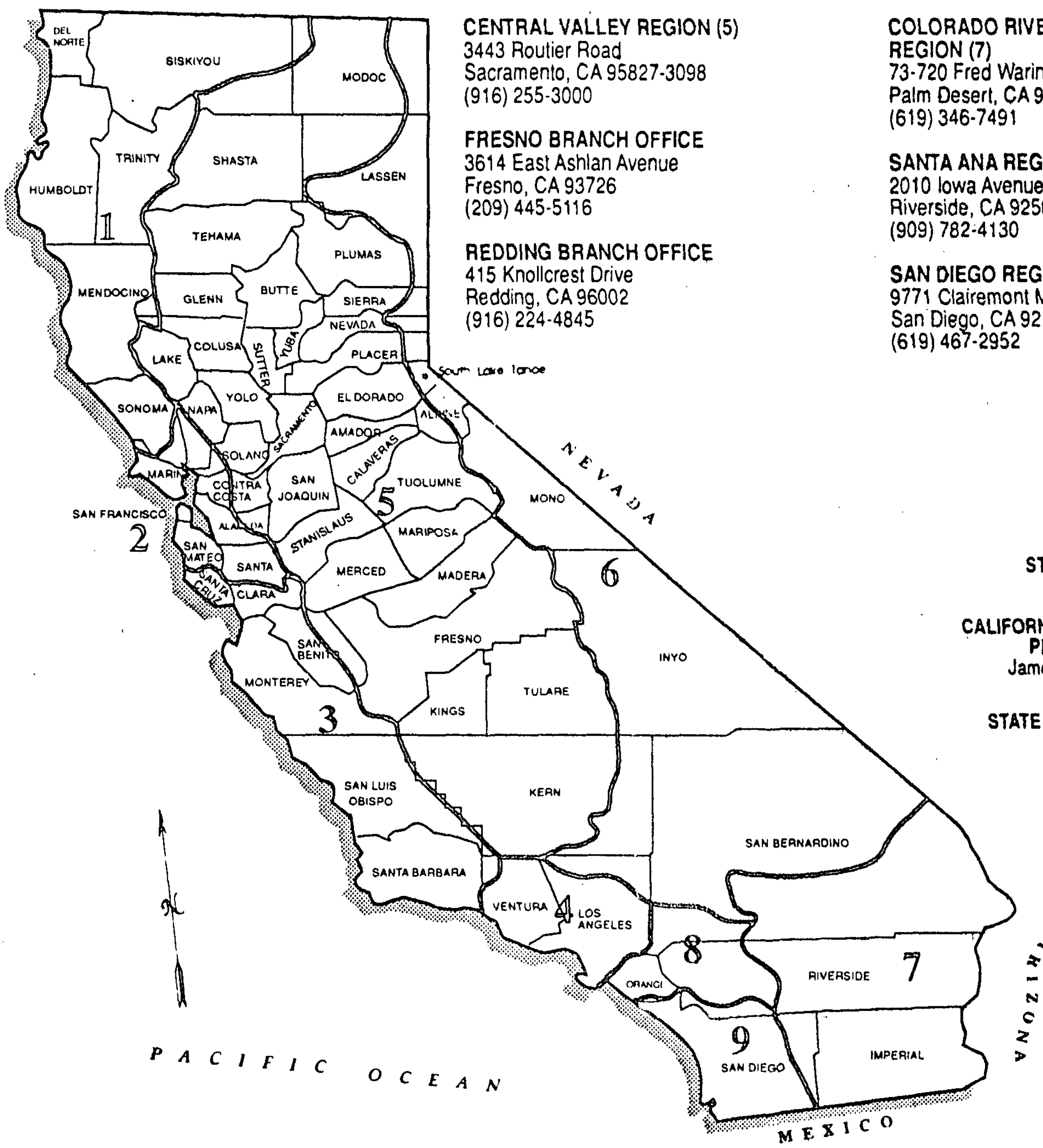

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9/14/93