INTRODUCTION

>> Chapter 1

1.0 INTRODUCTION

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1.1 Program Structure and Objectives

The San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) is the principal source for information on chemical contamination in the Estuary. The RMP is an innovative collaborative effort between the scientific community, the San Francisco Bay Regional Water Quality Control Board (Regional Board), and the regulated discharger community. The RMP is a $3 million program that is funded by the discharger community through wastewater discharge permits issued by the Regional Board (see Table 1.1 for a list of the 2002 RMP participants).

The RMP benefits the scientific, regulatory, stakeholder, and discharger communities by collecting high-quality contaminant and contaminant toxicity data, promoting collaborative research efforts, enabling dialogue between scientists, regulators and stakeholders, and facilitating environmental management based on scientific interpretation of the data. Oversight and guidance for the program is provided by representatives from each of these entities through quarterly Technical Review and Steering Committee meetings. Additionally, an external review of the RMP's technical and administrative structure and performance is conducted every five years to ensure that the RMP's adaptive management strategy remains current and useful to the regulatory and scientific communities.

The RMP's focus is on long-term contaminant monitoring and understanding contaminant impacts on beneficial uses of the Estuary, and is addressed by the following five objectives:

1. Describe patterns and trends in contaminant concentration and distribution.
2. Describe general sources and loading of contamination to the Estuary.
3. Measure contaminant effects on selected parts of the Estuary ecosystem.
4. Compare monitoring information to relevant water quality objectives and other guidelines.
5. Synthesize and distribute information from a range of sources to present a more complete picture of the sources, distribution, fates, and effects of contaminants in the Estuary ecosystem.

The Annual Monitoring Results describe patterns and trends of contaminants in the Estuary (Objective 1) and compare results to water quality objectives and other guidelines (Objective 4) for the RMP's Status and Trends monitoring component. In addition, the Episodic Aquatic Toxicity Monitoring Study (part of the Status and Trends program) investigates the potential for loadings of toxic contaminants through storm-water runoff (Objective 2). Contaminant sources, loadings, and effects (Objectives 2 and 3) are largely addressed through focused pilot and special studies briefly described in this section. The RMP synthesizes and distributes information through literature reviews, technical reports, newsletters, and the *Pulse of the Estuary* (Objective 5).

A brief introduction to the 2002 RMP Status and Trends monitoring effort, Pilot and Special Studies, and USGS Studies are described below. For more information on the RMP, refer to the RMP website (http://www.sfei.org/rmp/RMPproginfo.htm) and the technical report, *A Regional Board Perspective on the RMP: Ten Years of Benefits and Challenges for the Future,* prepared by Karen Taberski at the Regional Board (contact Jay Davis at jay@sfei.org for a copy of the report).

1.2 Status and Trends Monitoring

2002 marks the first year of the new sampling design for water and sediment developed by the RMP Redesign Workgroup (1999-2001). The 2002 sampling site information is presented in Table 1.2 and maps of the site locations are presented in each section. Subcontracting agencies perform the logistical planning, sampling, and laboratory analyses for trace contaminants and ancillary measures of the Status and Trends component. SFEI provides technical oversight, participates in field sampling, manages the data, performs a rigorous quality assurance and control (QA/QC) evaluation, and synthesizes and reports the information. The 2002 participating contractors are listed in Table 1.3.

1.2.1 Random Sampling Design for Water and Sediment

The EMAP-style (Environmental Monitoring and Assessment Program) stratified-random sampling design adopted by the RMP for water and sediment monitoring will provide a better statistical basis to evaluate regulatory questions such as "what proportion of the Estuary is above the water quality guidelines", or "what proportion of Estuary sediments is toxic to standard laboratory test organisms?"

The Redesign Workgroup divided the Estuary into five hydrographic regions based on a survey of scientific expert opinion and a statistical evaluation of water and sediment quality parameters. Those five regions are: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay (see site location maps in Sections 2.0 & 3.0). The number of samples allocated to each region was determined by a power analysis that focused on contaminants and regions of greatest concern to the Regional Board at the time of the redesign effort.

75 water and sediment samples were randomly allocated into the five hydrographic regions in the Estuary, including shallow areas, deep channels, and near and far from shore habitats, in order to provide spatially representative coverage of the Estuary downstream from the Delta. Sampling sites were allocated into each region using a sophisticated site selection framework developed for the federal Environmental Monitoring and Assessment Program (EMAP) (Stevens, 1997; Stevens and Olsen, 1999; Stevens and Olsen, 2000). The sampling frame for water and sediment monitoring is the 3-foot and 1-foot contour at mean lower low water, respectively. Every year a subset of the random sites is sampled (sequentially) increasing the spatial coverage of the Estuary over time. Several "historical" sites were maintained in the program to provide continuity with data from the original RMP monitoring design of sampling fixed sites located in the deeper channels, primarily along the "spine" of the Estuary. Sampling occurs once a year

during the dry season when Estuary conditions are most consistent on an interannual basis.

To evaluate long-term trends, the sediment sampling design incorporates repeated measurements at two random sites per region on an annual, five-year, and ten-year cycle. Repeated sampling reduces within-population variation if a population element retains much of its identity through time. While this can be assumed to be true for sediment samples, it cannot for water due to the constantly moving water masses within the Estuary. Therefore, the water sampling design does not include repeated sampling of randomly allocated sites, and trends in water will be tracked for each region as a whole based on estimates of population statistics.

The new sampling design for water and sediment will allow the RMP to better address Objectives 1 and 4 (above) and will provide the Regional Board with a statistical basis from which to characterize contamination in each region, or the Estuary as a whole.

With the new sampling design, the RMP will be able to estimate the spatial and temporal distribution of water and sediment contaminants in the Estuary, determine if the mean contaminant concentration within a region is above a regulatory guideline, estimate what proportion of the Estuary is toxic to laboratory test organisms, and provide a solid foundation for evaluating progress in reducing contaminant concentrations in water and sediment.

For more information on the new Status and Trends monitoring design, refer to articles in the *2000 Pulse of the Estuary* (http://www.sfei.org/rmp/2000/pulse_2000.pdf) and *RMP News: Winter 2001/2002* (http://www.sfei.org/rmp/rmpnews.htm). A technical report documenting the re-design process is also being prepared and will be available later this year.

1.3 2002 Status and Trends Monitoring Overview

1.3.1 Reporting

Only results that passed a rigorous QA/QC evaluation are reported. Values that were reported as below the method detection limit (MDL) were estimated to be ½ of the MDL in all calculations and graphics. Totals are reported as the sum of the analytes within a specific compound group (e.g., Sum of PBDEs, Sum of PAHs). When laboratory or field replicate data were reported, average of all replicate concentrations were calculated and utilized in this report.

Water and sediment monitoring results are presented graphically (as bubble-plots) for many trace contaminants and important ancillary measures. Simple summary statistics are reported in the form of schematic boxplots for the random samples by region. The bubble-plots depict five range-bins that represent percentiles of the reported data. When a water or sediment guideline fell within the reported range, the guideline value replaced

the nearest percentile range-bin in order to show which sites were below or above the guideline value.

The schematic boxplots (see Figure 1.1) summarize the random sample data as follows. The horizontal line inside the box represents the median, and the mean is indicated by the green dot. The top and bottom of the box represent the 3rd quartile (75th percentile) and the 1st quartile (25th percentile), respectively. The distance between these two is the interquartile range (IQR). A whisker is drawn from the upper edge of the box to the largest value within the upper fence and from the lower edge of the box to the smallest value within the lower fence. The term fence refers to the distance from the 25th and 75th percentiles expressed in terms of the IQR. For example, the lower fence is located at 1.5×IQR below the 25th percentile; the upper fence is located at 1.5×IQR above the 75th percentile. The fences are not displayed in these plots. Observations that fall beyond the fences (outliers) are identified by the open square symbols. In the water plots (because there are a variable number of random samples per segment), the width of the box is proportional to the number of samples collected per region.

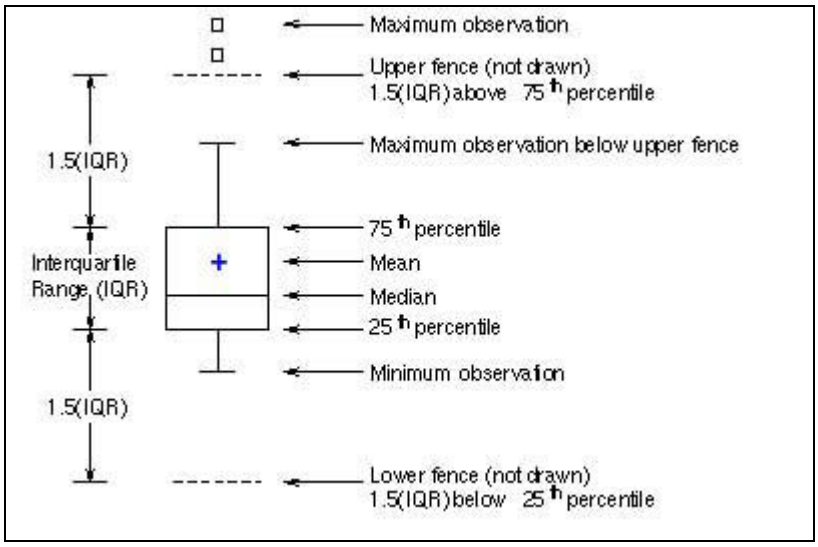

Figure 1.1. Illustration of a schematic boxplot.

Bivalve monitoring results are presented in Section 4.0. Graphics for bivalve contamination data are not presented here, however, the 2002 bivalve monitoring results are shown in tabular form. Because this is the first year of the new sampling design, there are relatively few samples for some regions (only four water samples taken from three of the five regions), no rigorous, weighted statistical evaluations will be provided in this report. Additionally, the RMP is in the middle of a three-year effort to synthesize and report results of the past 9 years of monitoring (1993-2001), so trends reporting at the historical RMP sites will be deferred to those reporting efforts.

Table 1.4 lists all parameters measured in 2002 by the Status and Trends program. While only a subset of results are presented graphically (a subset of the water and sediment

quality parameters, trace elements, and trace organics), all results for 2002 and previous years can be accessed and downloaded on-line using a new Web Query Tool: LINK.

1.3.2 Water Chemistry and Toxicity

Water sample collection occurred during the dry season in July at a total of 33 sites. Four to ten random sites were sampled per region. Two historical fixed sites and the Golden Gate reference site were also sampled. Similar analyses as in previous years were conducted for conventional water quality parameters, trace elements, and trace organics.

In 2002, new trace organics chemical methods were developed and analyses were conducted on several new contaminants that included polybrominated diphenyl ethers (PBDEs), phthalates, and p-nonylphenol. Fifteen water samples collected from all the shallow sites sampled in 2002 were tested for ambient water toxicity. Water monitoring results are discussed in Section 2.0.

1.3.3 Sediment Chemistry and Toxicity

Sediment sample collection occurred during the dry season in July/August at a total of 49 sites. Eight random sites and one historical fixed site were sampled per region. Similar analyses as in previous years were conducted for sediment quality parameters, trace elements, and trace organics. New analyses conducted in 2002 included PBDEs, phthalates, and p-nonylphenol. Twenty-eight sediment samples were tested for toxicity. Sediment monitoring results are discussed in Section 3.0.

1.3.4 Bivalve Tissue Chemistry

The bivalve bioaccumulation monitoring effort did not change significantly in 2002 and is not part of the EMAP-style monitoring design largely because of logistical mooring considerations. Fourteen sites (three fixed sites per segment) were monitored for potential bioaccumulative contaminants using transplanted and resident bivalves. Transplanted *M. californianus*, and *C. gigas* were deployed for three months and resident clams (*Corbicula fluminea*) were collected at the 2 historical River stations. Only *M. californianus* and *C. gigas* were analyzed for trace organic concentrations. New analyses conducted in 2002 bivalve samples included PBDEs, phthalates, p-nonylphenol, triphenylphosphate, and musks. Trace elements will be analyzed on a five-year cycle beginning in 2006, and tributyltins are no longer measured. For more information, refer to the bivalve tissue monitoring discussion in Section 4.0 and the recent article, *Shedding Light From Underwater: The Evolution of the RMP Bivalve Monitoring Program*, in the *RMP News: Winter/Spring 2004* (http://www.sfei.org/rmp/rmpnews.htm).

1.3.5 Episodic Toxicity

Previous monitoring by the RMP demonstrated that ambient water toxicity in the Estuary appears to be limited to episodic events, such as inflow of stormwater runoff from upstream watersheds (Ogle and Gunther, 2000). The RMP incorporated the Episodic Toxicity Monitoring Program into the Status and Trends program in 1998. As a result of ongoing seasonal monitoring, we have seen a decline in aquatic toxicity events in targeted tributaries of the Estuary over the past several sampling seasons. 2002-2003 monitoring marked the seventh year of episodic aquatic toxicity monitoring in the

tributaries. The RMP is in the midst of an adaptive redesign of this monitoring component in order to address changing patterns of pesticide usage in urban and agricultural areas.

In 2002, the episodic aquatic toxicity monitoring was conducted at five tributaries to the Estuary: Sacramento-San Joaquin Rivers (downstream of the confluence, at Mallard Island), Petaluma River, Sonoma Creek, San Lorenzo Creek, and Coyote Creek. To cover the temporal extent of potential sources of contaminant input (e.g., first flush during October-December, dormant spray runoff during December-February, row crop runoff during March-June, and urban gardening during April-June), a minimum of 5 storm events was sampled at each of the tributaries during Winter 2002 and Spring 2003. Invertebrate and fish-larvae toxicity tests were conducted, as well as Toxicity Identification Evaluation (TIEs) when significant toxicity was present. Previous reports and the 2002-2003 final report from the subcontracting laboratory are available at: TITLE OF 2002/03 REPORT @ link: http://www.sfei.org/rmp/reports. A summary of the Episodic Aquatic Toxicity Monitoring Program findings (1996-2001) can be found in the *2003 Pulse of the Estuary* (http://www.sfei.org/rmp/2003/pulse_2003.pdf).

1.4 Other RMP Studies

1.4.1 Pilot Studies

Pilot Studies may augment or improve the RMP Status and Trends monitoring effort and provide a pro-active approach in attending to management goals and needs. Pilot Studies may eventually be incorporated into the long-term program. An example of a successful RMP Pilot Study that was incorporated into the program is Episodic Aquatic Toxicity Sampling.

In 2002, three pilot studies addressed specific topics relating to contamination in the Estuary. Mercury was measured in rain samples at a sampling station in San Jose as part of the Mercury Deposition Network. Data contributed to the national database to evaluate contributions of mercury from large urban areas and long-range aerial transport from outside the region to surface waters (For more information see: *San Francisco Bay Atmospheric Deposition Pilot Study Part 1: Mercury* @ link: www.sfei.org/sfeireports). A second, five-year pilot study (begun in 2000) continued efforts to develop indicators of contaminant exposure and effects. Linking contaminant bioaccumulation and effects measurements at various levels of the food web with selected indicators can assist with the prioritization of contaminants for clean-up and prevention. In a third pilot study begun in 2002, the RMP is collaborating with the U.S. Geological Survey (USGS) to monitor suspended solid concentrations at Mallard Island. Sampling will continue through 2004 and when combined with data collected by the USGS from 1994-98, will provide a total of 10 years of nearly continuous data. These data can be used to estimate sediment loads from the Delta and when coupled with data on sediment-associated contaminants of concern, can be used to model contaminant loads entering the Estuary from the San Joaquin Valley.

1.4.2 Special Studies

Special Studies are added to the RMP to help address specific data-gaps or to address targeted management or scientific questions related to contaminants in the Estuary. Examples of successful recent Special Studies were the two "Unknown Contaminants" Surveillance Studies of RMP Status and Trends water (1993-94, 1999-2000), sediment (2000), and tissue (2001) samples that led to the addition of several new analytes to the 2002 analyte list. This effort will enable the RMP to provide data to determine if several new emerging contaminants are at high enough levels to pose a potential threat in the Estuary. Such surveillance monitoring may help regulators prevent the occurrence of new "legacy" contaminants, such as the now notorious DDTs and PCBs (For more information see: *Identification and Evaluation of Unidentified Organic Contaminants in the San Francisco Estuary* @ link: http://www.sfei.org/sfeireports.htm#Contaminants and *Identification and Evaluation of Previously Unknown Organic Contaminants in the San Francisco Estuary (1999-2000)* @ link: http://www.sfei.org/rmp/reports/unidentified_contaminants_previously_unknown_0403.pdf).

Another two-year study (begun in 2001 with non-RMP funding and moved into the RMP for 2002) analyzed the "reasonable potential" of 126 Priority Pollutants that may exceed receiving water criteria as outlined in the California Toxics Rule (CTR). The RMP evaluated which Priority Pollutants, not currently measured by the RMP, might be found at levels above their corresponding water quality criterion at three historical RMP sites (Sacramento River, Yerba Buena Island, and Dumbarton Bridge). An interim report of the first year of sampling can be found at: TITLE OF REPORT @ link: http://www.sfei.org/rmp/reports.

1.4.3 U.S. Geological Survey (USGS) Studies

As in prior monitoring years, the USGS (see link: http://ca.water.usgs.gov/currentprojects.html) continued to supplement RMP monitoring by conducting two special studies. A sediment transport study examined the role of several environmental factors controlling suspended sediments in the Estuary, such as tides, winds, storm events (runoff), and wind waves. Another study examined monthly measurements of five water quality parameters at 39 stations along a transect of the Estuary to describe the changing spatial patterns of basic water quality from the lower Sacramento River to the southern limit of the South Bay. Measurements include salinity, temperature, dissolved oxygen, suspended sediments, and phytoplankton biomass, which influence the partitioning of reactive contaminants between dissolved and particulate forms. This information is needed to better understand the seasonal changes in water quality and estuarine habitat as they influence biological communities and the distribution-reactivity of trace contaminants. A summary of these two studies (written by the principal investigators) can be found in the *2003 Pulse of the Estuary* (http://www.sfei.org/rmp/2003/pulse_2003.pdf).

1.5 References

Ogle, R. Scott and A.J. Gunther. 2000. San Francisco Bay Episodic Toxicity Report: 1999 Progress Report, October 2000 (http://www.sfei.org/sfeireports).

Stevens, Jr., D.L. 1997. Variable density grid-based sampling designs for continuous spatial populations. Environmetrics 8:167-195.

Stevens, Jr., D.L. and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics 4:415-428.

Stevens, Jr., D.L. and A.R. Olsen. 2000. Spatially-restricted random sampling designs for design-based and model-based estimation. In Accuracy 2000: Proceedings of the 4th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences. Delft University Press, The Netherlands, pp. 609-616.

Table 1.1 RMP Program Participants in 2002.

Municipal Dischargers
Central Contra Costa Sanitary District
Central Marin Sanitation Agency
City of Benicia
City of Burlingame
City of Calistoga
City of Palo Alto
City of Petaluma
City of Pinole/Hercules
City of Saint Helena
City and County of San Francisco
City of San Jose/Santa Clara
City of San Mateo
City of South San Francisco/San Bruno
City of Sunnyvale
Delta Diablo Sanitation District
East Bay Dischargers Authority
East Bay Municipal Utility District
Fairfield-Suisun Sewer District
Las Gallinas Valley Sanitation District
Marin County Sanitary District #5, Tiburon
Millbrae Waste Water Treatment Plant
Mountain View Sanitary District
Napa Sanitation District
Novato Sanitation District
Rodeo Sanitary District
San Francisco International Airport
Sausalito/Marin City Sanitation District
Sewerage Agency of Southern Marin
Sonoma County Water Agency
South Bayside System Authority
Town of Yountville
Union Sanitary District
Vallejo Sanitation and Flood Control District
West County Agency

Industrial Dischargers
C & H Sugar Company
Chevron Products Company
Dow Chemical Company
General Chemical Corporation
TOSCO – Rodeo Refinery
Rhodia, Inc.
Shell – Martinez Refining Company
Ultramar Inc - Avon Refinery
USS – POSCO Industries
Valero Refining Company

Cooling Water
Mirant of California

Stormwater
Alameda Countywide Clean Water Program
Caltrans
City and County of San Francisco
Contra Costa Clean Water Program
Fairfield-Suisun Urban Runoff Management Program
Marin County Stormwater Pollution Prevention Program
San Mateo Countywide Stormwater Pollution Prevention Program
Santa Clara Valley Urban Runoff Pollution Prevention Program
Vallejo Sanitation and Flood Control District

Dredgers
Black Point Launch Ramp
Captain Edward Payne
Chevron
CALTRANS - Golden Gate Bridge
Marin Yacht Club
Mr. Gary Scheier
Mr. R. Steven Gilley
Mr. Ron Valentine
Paradise Cay
Port of Oakland
Port of San Francisco
Sierra Point Marina
TOSCO Corporation
Valero Refining Co.
Yerba Buena Island
Vallejo Yacht Club

Table 1.2. Summary of RMP sampling stations and activities, 2002. Latitude and longitude coordinates are reported in decimal degrees. Historical and random site coordinates are reported in WGS 84 and NAD 27 datums, respectively. Conductivity, Temperature and Depth (CTD) measurements are taken at all sites. Depth measurements are taken from the Cruise Reports for water and sediment sites and from the CTD cast for bivalve sites. Resident clams are collected at BG20 and BG30.

Region/ Station Name	Site Code	Historical Site	Sample Type	Collection Date	Latitude	Longitude	Station Depth (m)	Types of Analyses			
								Trace Elements	Trace Organics	Ancillary	Toxicity
Sacramento River	BG20	x	Bivalve Tissue	8/27/02	38.060	121.790	NA		x	x	
Sacramento River	BG20	x	Sediment	7/31/02	38.059	121.813	9	x	x	x	x
Sacramento River	BG20	x	Water	7/30/02	38.060	121.810	10	x	x	x	
San Joaquin River	BG30	x	Bivalve Tissue	8/27/02	38.020	121.810	NA		x	x	
San Joaquin River	BG30	x	Sediment	7/31/02	38.023	121.807	8	x	x	x	x
San Joaquin River	BG30	x	Water	7/30/02	38.021	121.810	9	x	x	x	
Grizzly Bay	BF21	x	Sediment	7/31/02	38.067	121.934	1	x	x	x	x
Suisun	SU001S		Sediment	8/1/02	38.100	122.045	5	x	x	x	x
Suisun	SU001W		Water	7/29/02	38.103	122.050	3	x	x	x	
Suisun	SU002W		Water	7/29/02	38.056	121.980	11	x	x	x	
Suisun	SU003S		Sediment	8/1/02	38.066	122.096	6	x	x	x	x
Suisun	SU003W		Water	7/29/02	38.057	122.100	6	x	x	x	
Suisun	SU004S		Sediment	7/31/02	38.085	122.025	1	x	x	x	
Suisun	SU005S		Sediment	7/31/02	38.052	122.076	2	x	x	x	x
Suisun	SU005W		Water	7/29/02	38.078	122.060	2	x	x	x	
Suisun	SU006S		Sediment	7/31/02	38.070	121.936	1	x	x	x	
Suisun	SU007S		Sediment	8/1/02	38.084	122.064	7	x	x	x	x
Suisun	SU008S		Sediment	7/31/02	38.073	122.015	7	x	x	x	
Suisun	SU073S		Sediment	8/1/02	38.111	122.048	1		x	x	
Petaluma River	BD15	x	Bivalve Tissue	9/4/02	38.110	122.500	5		x	x	
San Pablo Bay	BD20	x	Bivalve Tissue	9/4/02	38.050	122.430	2		x	x	
Pinole Point	BD30	x	Bivalve Tissue	9/4/02	38.020	122.370	5		x	x	
Pinole Point	BD31	x	Sediment	8/1/02	38.024	122.362	5	x	x	x	x
Davis Point	BD40	x	Bivalve Tissue	9/6/02	38.050	122.260	7		x	x	
Napa River	BD50	x	Bivalve Tissue	9/6/02	38.080	122.250	8		x	x	
San Pablo Bay	SPB001S		Sediment	8/2/02	38.072	122.385	2	x	x	x	x
San Pablo Bay	SPB001W		Water	7/17/02	38.096	122.360	2	x	x	x	x
San Pablo Bay	SPB002S		Sediment	8/1/02	38.017	122.340	1	x	x	x	
San Pablo Bay	SPB002W		Water	7/17/02	38.055	122.320	7	x	x	x	
San Pablo Bay	SPB003S		Sediment	8/2/02	38.028	122.476	2	x	x	x	x
San Pablo Bay	SPB003W		Water	7/17/02	38.088	122.440	2	x	x	x	x
San Pablo Bay	SPB004S		Sediment	8/2/02	37.977	122.424	8	x	x	x	
San Pablo Bay	SPB004W		Water	7/17/02	38.017	122.380	7	x	x	x	
San Pablo Bay	SPB005S		Sediment	8/2/02	38.012	122.434	4	x	x	x	x
San Pablo Bay	SPB006S		Sediment	8/1/02	38.025	122.312	2	x	x	x	
San Pablo Bay	SPB007S		Sediment	8/2/02	38.100	122.409	1	x	x	x	x
San Pablo Bay	SPB008S		Sediment	8/2/02	38.072	122.346	2	x	x	x	
Alameda	BB71	x	Bivalve Tissue	9/3/02	37.700	122.340	8		x	x	
Yerba Buena Island	BC10	x	Bivalve Tissue	9/5/02	37.820	122.350	6		x	x	
Yerba Buena Island	BC11	x	Sediment	8/8/02	37.822	122.348	6	x	x	x	x
Golden Gate	BC20	x	Water	7/18/02	37.786	122.660	25	x	x	x	
Horseshoe Bay	BC21	x	Bivalve Tissue	9/5/02	37.830	122.480	8		x	x	
Red Rock	BC61	x	Bivalve Tissue	9/5/02	37.930	122.470	4		x	x	
Central Bay	CB001S		Sediment	8/8/02	37.876	122.360	2	x	x	x	x
Central Bay	CB001W		Water	7/18/02	37.892	122.350	2	x	x	x	x
Central Bay	CB002S		Sediment	8/7/02	37.625	122.346	4	x	x	x	
Central Bay	CB002W		Water	7/19/02	37.688	122.300	7	x	x	x	
Central Bay	CB003S		Sediment	8/8/02	37.868	122.484	2	x	x	x	x
Central Bay	CB003W		Water	7/18/02	37.852	122.470	17	x	x	x	
Central Bay	CB004W		Water	7/19/02	37.770	122.350	17	x	x	x	
Central Bay	CB005S		Sediment	8/8/02	37.853	122.325	2	x	x	x	x
Central Bay	CB006S		Sediment	8/7/02	37.713	122.248	3	x	x	x	
Central Bay	CB007S		Sediment	8/8/02	37.919	122.399	2	x	x	x	x
Central Bay	CB008S		Sediment	8/8/02	37.718	122.328	13	x	x	x	
Central Bay	CB073S		Sediment	8/8/02	37.844	122.397	12	x	x	x	

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Table 1.2 continued. Summary of RMP sampling stations and activities, 2002. Latitude and longitude coordinates are reported in decimal degrees. Historical and random site coordinates are reported in WGS 84 and NAD 27 datums, respectively. Conductivity, Temperature and Depth (CTD) measurements are taken at all sites. Depth measurements are taken from the Cruise Reports for water and sediment sites and from the CTD cast for bivalve sites. Resident clams are collected at BG20 and BG30.

Region/ Station Name	Site Code	Historical Site	Sample Type	Collection Date	Latitude	Longitude	Station Depth (m)	Types of Analyses			
								Trace Elements	Trace Organics	Ancillary	Toxicity
Dumbarton Bridge	BA30	x	Bivalve Tissue	9/3/02	37.510	122.130	2		x	x	
Redwood Creek	BA40	x	Bivalve Tissue	9/3/02	37.550	122.200	2		x	x	
Redwood Creek	BA41	x	Sediment	8/6/02	37.559	122.209	3	x	x	x	x
South Bay	SB001W		Water	7/25/02	37.590	122.290	2	x	x	x	x
South Bay	SB002S		Sediment	8/6/02	37.610	122.166	2	x	x	x	
South Bay	SB002W		Water	7/24/02	37.562	122.200	12	x	x	x	
South Bay	SB003S		Sediment	8/7/02	37.617	122.302	2	x	x	x	x
South Bay	SB003W		Water	7/26/02	37.594	122.310	3	x	x	x	x
South Bay	SB004S		Sediment	8/7/02	37.601	122.217	3	x	x	x	
South Bay	SB004W		Water	7/25/02	37.601	122.230	1	x	x	x	
South Bay	SB005S		Sediment	8/7/02	37.655	122.207	3	x	x	x	x
South Bay	SB005W		Water	7/26/02	37.608	122.240	2	x	x	x	
South Bay	SB006S		Sediment	8/6/02	37.515	122.151	2	x	x	x	
South Bay	SB006W		Water	7/23/02	37.460	121.980	3	x	x	x	
South Bay	SB007S		Sediment	8/7/02	37.682	122.230	3	x	x	x	x
South Bay	SB007W		Water	7/26/02	37.666	122.230	2	x	x	x	
South Bay	SB008S		Sediment	8/7/02	37.613	122.184	3	x	x	x	
South Bay	SB008W		Water	7/25/02	37.600	122.200	3	x	x	x	x
South Bay	SB009W		Water	7/26/02	37.670	122.220	3	x	x	x	
South Bay	SB010W		Water	7/25/02	37.563	122.230	3	x	x	x	x
South Bay	SB073S		Sediment	8/7/02	37.678	122.180	2	x	x	x	
Coyote Creek	BA10	x	Bivalve Tissue	9/3/02	37.470	122.060	3		x	x	
Coyote Creek	BA10	x	Sediment	8/5/02	37.468	122.063	4	x	x	x	x
Lower South Bay	LSB001S		Sediment	8/6/02	37.492	122.097	6	x	x	x	x
Lower South Bay	LSB001W		Water	7/24/02	37.490	122.110	3	x	x	x	x
Lower South Bay	LSB002S		Sediment	8/6/02	37.479	122.077	5	x	x	x	
Lower South Bay	LSB002W		Water	7/22/02	37.482	122.080	6	x	x	x	
Lower South Bay	LSB003S		Sediment	8/6/02	37.491	122.116	3	x	x	x	x
Lower South Bay	LSB003W		Water	7/24/02	37.502	122.110	2	x	x	x	
Lower South Bay	LSB004S		Sediment	8/5/02	37.495	122.084	1	x	x	x	
Lower South Bay	LSB004W		Water	7/24/02	37.487	122.090	5	x	x	x	x
Lower South Bay	LSB005S		Sediment	8/5/02	37.496	122.090	1	x	x	x	x
Lower South Bay	LSB005W		Water	7/23/02	37.491	122.100	7	x	x	x	
Lower South Bay	LSB006S		Sediment	8/5/02	37.470	122.064	4	x	x	x	
Lower South Bay	LSB006W		Water	7/22/02	37.472	122.060	1	x	x	x	
Lower South Bay	LSB007S		Sediment	8/6/02	37.490	122.109	2	x	x	x	x
Lower South Bay	LSB008S		Sediment	8/5/02	37.485	122.081	5	x	x	x	
Sunnyvale	C-1-3	x	Sediment	8/5/02	37.434	122.010	1	x	x	x	
Sunnyvale	C-1-3	x	Water	7/23/02	37.434	122.010	2	x		x	
San Jose	C-3-0	x	Sediment	8/5/02	37.460	121.976	2	x		x	x
San Jose	C-3-0	x	Water	7/23/02	37.491	122.100	2	x	x	x	

Table 1.3. Contractors and principal investigators for RMP 2002 Status and Trends.

Principal Contractor	Mr. Paul Salop and Dr. Andrew Gunther Applied Marine Sciences (AMS), Livermore, CA
BACWA Coordination	Mr. William Ellgas and Ms. Julia Halsne East Bay Municipal Utility District (EBMUD), Oakland, CA
Water Trace Element Chemistry	Dr. Colin Davies, Brooks-Rand Ltd. (BRL), Seattle, WA Dr. Russ Flegal and Ms. Genine Scelfo UC Santa Cruz (UCSCDET), Santa Cruz, CA
Water Trace Organic Chemistry	Ms. Laurie Phillips AXYS Analytical Services, Inc. (AXYS), Sidney, BC Dr. Dave Crane California Dept. of Fish & Game, Water Pollution Control Laboratory (CDFG-WPCL), Rancho Cordova, CA
Water Hardness	Mr. Jim Chen and Ms. Kathleen Irby, Union Sanitary District (USD), Fremont, CA
Water Toxicity Testing	Dr. Scott Ogle Pacific Eco-Risk Laboratories (PER), Martinez, CA
Sediment Trace Element Chemistry	Dr. Colin Davies, Brooks-Rand Ltd. (BRL), Seattle, WA Dr. Russ Flegal and Ms. Genine Scelfo UC Santa Cruz (UCSCDET), Santa Cruz, CA Mr. Anthony Rattonetti City and County of San Francisco (CCSF), San Francisco, CA
Sediment Trace Organics Chemistry	Mr. François Rodigari East Bay Municipal Utility District (EBMUD), Oakland, CA
Sediment Toxicity Testing	Mr. John Hunt, Mr. Brian Anderson, and Mr. Bryn Phillips Marine Pollution Studies Lab (MPSL), Granite Canyon, CA
Bivalve Trace Element Chemistry	Mr. Lonnie Butler City and County of San Francisco (CCSF), San Francisco, CA Dr. Colin Davies, Brooks-Rand Ltd. (BRL), Seattle, WA
Bivalve Trace Organics	Dr. Dave Crane California Dept. of Fish & Game, Water Pollution Control Laboratory (CDFG-WPCL), Rancho Cordova, CA
Bivalve Condition and Survival	Mr. Paul Salop Applied Marine Sciences (AMS), Livermore, CA
USGS Water Quality	Dr. James Cloern, USGS, Menlo Park, CA
USGS Sediment Transport	Dr. David Schoellhamer, USGS, Sacramento, CA

Table 1.4. Parameters analyzed in water, sediment, and bivalve tissue (RMP 2002).
Refer to Table 1.3 for laboratory names.

Conventional Water Quality Parameters	**Lab(s)**	**Reporting Units**
Conductivity	AMS/UCSCDET	µmho
Dissolved Ammonia	UCSCDET	mg/L (N)
Dissolved Nitrate	UCSCDET	mg/L (N)
Dissolved Nitrite	UCSCDET	mg/L (N)
Dissolved Organic Carbon	UCSCDET	µg/L
Dissolved Oxygen	UCSCDET	mg/L
Dissolved Phosphates	UCSCDET	mg/L
Dissolved Silicates	UCSCDET	mg/L
Hardness (when salinity is < 5 ‰)	USD	mg/L ($CaCO_3$)
pH	AMS/UCSCDET	pH
Phaeophytin	UCSCDET	mg/m^3
Salinity (by salinometer)	UCSCDET	psu
Salinity (by SCT)	AMS/UCSCDET	‰
Temperature	AMS/UCSCDET	°C
Total Chlorophyll-*a*	UCSCDET	mg/m^3
Total Suspended Solids	UCSCDET	mg/L
Sediment Quality Parameters	**Lab(s)**	**Reporting Units**
% clay (< 4 µm)	UCSCDET	% dry weight
% silt (4 µm–63 µm)	UCSCDET	% dry weight
% sand (63 µm – 2 mm)	UCSCDET	% dry weight
% gravel + shell (> 2 mm)	UCSCDET	% dry weight
% solids	BRL/CCSF/EBMUD	% dry weight
Depth	AMS	m
Hydrogen Sulfide *(QAQC measurement)*	MPSL	µg/kg
pH (porewater, interstitial sediment)	AMS	pH
Total Ammonia *(QAQC measurement)*	MPSL	µg/kg
Total Organic Carbon	UCSCDET	%
Total Sulfide *(QAQC measurements)*	MPSL	µg/kg
Total Nitrogen	UCSCDET	%
Bivalve Tissue Parameters	**Lab(s)**	**Reporting Units**
% Lipid	CDFG-WPCL	%
% Moisture	CDFG-WPCL	%
Bivalve Percent Survival	AMS	%
Growth - Change in Internal Shell Volume	AMS	mL
Dry Flesh Weight	AMS	g
Toxicity Tests—Water and Sediment	**Lab(s)**	**Reporting Units**
Aquatic Toxicity –*Americamysis* (shrimp) % Survival	PERL	%
Episodic Aquatic Toxicity – (*Ceriodaphnia, Menidia, Americamysis*) % Survival	PERL	%
Sediment Toxicity – (Amphipod) % Survival	MPSL	%
Sediment Toxicity – (Bivalve) % Normal Development	MPSL	%

Table 1.4 continued. Parameters analyzed in water, sediment, and bivalve tissue (RMP 2002).

Trace elements analyzed in water and sediment samples[1] (RMP 2002): Target Method Detection Limits (MDLs) are in parentheses following the reporting units.		
	Water (Dissolved and Total)	**Sediment** (dry weight)
Lab(s)	BRL/UCSCDET	BRL/CCSF/ UCSCDET
Aluminum (Al)*	-	mg/kg (200)
Arsenic (As)	µg/L (0.1)	mg/kg (0.2)
Cadmium (Cd)*	µg/L (0.001)	mg/kg (0.001)
Cobalt (Co)	µg/L	-
Copper (Cu)*	µg/L (0.01)	mg/kg (2)
Iron (Fe)*	µg/L (10)	mg/kg (200)
Lead (Pb)*	µg/L (0.001)	mg/kg (0.5)
Manganese (Mn)*	µg/L (0.01)	mg/kg (20)
Mercury (Hg)	µg/L (.0001)	mg/kg (0.00001)
Methylmercury (MeHg)	ng/L (0.005)	µg/kg (0.005)
Nickel (Ni)*	µg/L (0.01)	mg/kg (5)
Selenium (Se)	µg/L (0.02)	mg/kg (0.01)
Silver (Ag)*	µg/L (0.0001)	mg/kg (0.001)
Zinc (Zn)*	µg/L (0.005)	mg/kg (5)

- Parameter is not sampled for the matrix.

* Near-total instead of total concentrations are reported for water. Near-total metals are extracted with a weak acid (pH < 2) for a minimum of one month, resulting in measurements that approximate bioavailability of these metals to Estuary organisms.

[1] Beginning in 2002, trace elements in bivalve tissue will be analyzed on a five-year cycle.

Table 1.4 continued. Parameters analyzed in water, sediment, and bivalve tissue (RMP 2002).

Trace organic parameters (lab; reporting units) –
in water (AXYS; pg/L), sediment (EBMUD; µg/kg), and bivalve tissue (CDFG-WPCL; µg/kg) samples:
Organochlorines analyzed by GC-ECD will be determined using two columns of differing polarity.

PAHS
(Target MDLs: water – 200 pg/L, sediment and tissue – 5 µg/kg; water PAHs reported in ng/L)

1-Methylnaphthalene
2,3,5-Trimethylnaphthalene
2,6-Dimethylnaphthalene
2-Methylnaphthalene
Biphenyl
Naphthalene
1-Methylphenanthrene
Acenaphthene
Acenaphthylene
Anthracene
Fluorene
Phenanthrene
Benz(a)anthracene
Chrysene
Fluoranthene
Pyrene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(e)pyrene
Benzo(k)fluoranthene
Dibenz(a,h)anthracene
Perylene
Benzo(ghi)perylene
Indeno(1,2,3-cd)pyrene
Dibenzothiophene

Alkylated PAHs
C1-Chrysenes
C2-Chrysenes
C3-Chrysenes
C4-Chrysenes
C1-Dibenzothiophenes
C2-Dibenzothiophenes
C3-Dibenzothiophenes
C1-Fluoranthene/Pyrenes
C1-Fluorenes
C2-Fluorenes
C3-Fluorenes
C1-Naphthalenes
C2-Naphthalenes
C3-Naphthalenes
C4-Naphthalenes
C1-Phenanthrene/Anthracenes
C2-Phenanthrene/Anthracenes
C3-Phenanthrene/Anthracenes
C4-Phenanthrene/Anthracenes

SYNTHETIC BIOCIDES
(Target MDLs: water – 2 pg/L, sediment and tissue – 1 µg/kg)

Cyclopentadienes
Aldrin
Dieldrin
Endrin

Chlordanes
alpha-Chlordane
cis-Nonachlor
gamma-Chlordane
Heptachlor
Heptachlor Epoxide
Oxychlordane
trans-Nonachlor

DDTs
o,p'-DDD
o,p'-DDE
o,p'-DDT
p,p'-DDD
p,p'-DDE
p,p'-DDT

HCH
alpha-HCH
beta-HCH
delta-HCH
gamma-HCH

Other Synthetic Biocides
Chlorpyrifos (water only; CDFG-WPCL)
Dacthal (water only)
Diazinon (water only; CDFG-WPCL)
Endosulfan I (water only)
Endosulfan II (water only)
Endosulfan Sulfate (water only)
Hexachlorobenzene
Mirex
Oxadiazon (water only)

Other Synthetic Compounds[1]
(Target MDLs: water – 50 pg/L, sediment and tissue – 5 µg/kg)
p-Nonylphenol
Triphenylphosphate (tissue only)

OTHER SYNTHETIC COMPOUNDS
[1]New analytes added in 2002.
[2]Constitute Octa-BDEs.
[3]Constitute Nona-BDEs.

PCB congeners (IUPAC numbers)
(Target MDLs: water – 2 pg/L, sediment and tissue – 1 µg/kg)
8, 18, 28, 31, 33, 44, 49, 52, 56, 60, 66, 70, 74, 87, 95, 97, 99, 101, 105, 110, 118, 128, 132, 138, 141, 149, 151, 153, 156, 158, 170, 174, 177, 180, 183, 187, 194, 195, 201, 203

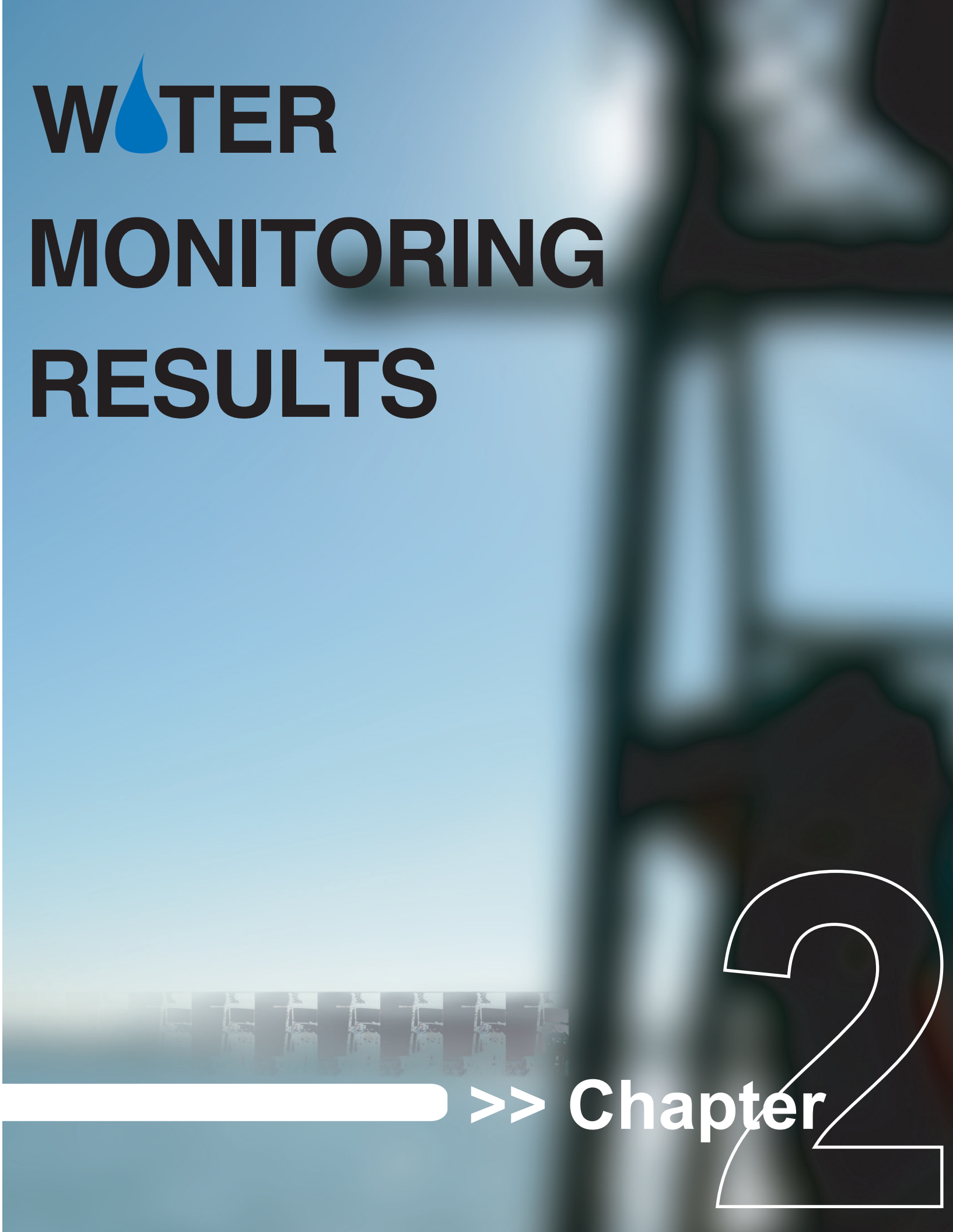
Polybrominated Diphenyl Ethers[1]
(BDE-IUPAC No., Compound Name)
(Target MDLs: water – 1 pg/L, sediment and tissue – 1 µg/kg).
BDE 17 [2,2',4-triBDE]
BDE 28 [2,4,4'-triBDE]
BDE 47 [2,2',4,4'-tetraBDE]
BDE 66 [2,3',4,4'-tetraBDE]
BDE 82 [2,2',3,3',4-pentaBDE]
BDE 85 [2,2',3,4,4'-pentaBDE]
BDE 99 [2,2',4,4'5-pentaBDE]
BDE 100 [2,2',4,4',6-pentaBDE]
BDE 128 [2,2',3,3',4,4'-hexaBDE]
BDE 138 [2,2',3,4,4',5'-hexaBDE]
BDE 153 [2,2',4,4',5,5'-hexaBDE]
BDE 154 [2,2',4,4',5,6'-hexaBDE]
BDE 183 [2,2',3,4,4',5',6-heptaBDE]
BDE 190 [2,3,3',4,4',5,6-heptaBDE]
BDE 203[2]
BDE 204[2]
BDE 205[2]
BDE 206[3]
BDE 207[3]
BDE 208[3]
BDE 209 [2,2',3,3',4,4',5,5',6,6'-decaBDE]

Nitro Musks[1] (tissue only)
Musk ambrette Musk xylene
Musk ketone

Polycyclic Musks[1] (tissue only)
Celestolide Tonalide
Galazolide Versalide

Phthalates[1]
(Target MDLs: water – 50 pg/L, sediment and tissue – 5 µg/kg)
Bis(2-ethylhexyl)phthalate
Butylbenzylphthalate
Di-n-Butylphthalate
Diethylphthalate
Dimethylphthalate

WATER MONITORING RESULTS



>> Chapter 2

2.0 WATER MONITORING

Jon Leatherbarrow, Sarah Lowe, and Nicole David

2.1 Background

Trace contaminants are introduced to the water column of the San Francisco Estuary through several major transport pathways, such as runoff from rivers and creeks, atmospheric deposition, municipal and industrial wastewater effluent discharge, and remobilization of contaminants from surface sediments to the overlying water column. Contaminants of current environmental concern in the Estuary primarily originate in areas of the watershed that have been altered or disturbed by human activities through urbanization, industrial development, and agriculture. Historic mining activities have also contributed contaminants to the Estuary (e.g., mercury). The transport of contaminants from these various sources and pathways, coupled with the dynamic nature of water and sediment movement, creates complex and constantly varying conditions of contamination throughout the Estuary. For over a decade, the San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) has monitored waters of the Estuary for trace elements, organic contaminants, and conventional water quality parameters to develop a better understanding of the cycling and distribution of contaminants in the Estuary and the management actions necessary to reduce their potential exposure to wildlife and humans. Information gained from contaminant monitoring in Estuary water assists the RMP in addressing program objectives listed in the Introduction.

2.2 Approach

2.2.1 Methods

In 2002, RMP Status and Trends implemented a new monitoring design that incorporated a stratified, random sampling approach developed through the RMP Redesign Workgroup (see Introduction). Thirty-three total stations were monitored for contaminants in water in 2002. Twenty-eight stations were randomly selected and monitored within five major hydrographic regions of the Estuary: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay (Figure 2.1). The random allocation provided greater spatial coverage than the previous monitoring design and included both shallow areas and deep channels. In addition, five fixed "historic" sites that were monitored in previous years were revisited to provide data for analyses of long-term temporal trends. These sites included two stations in the Delta formed by the confluence of the Sacramento (BG20) and San Joaquin (BG30) Rivers and two stations in sloughs of the Lower South Bay monitored in cooperation with the cities of San Jose (C-3-0) and Sunnyvale (C-1-3). A reference site was also maintained outside of the Golden Gate (BC20). Station names, codes, location, and sampling dates are listed in Table 1.2 in the Introduction and shown in Figure 2.1. Status and Trends monitoring in 2002 was conducted during the dry season (July) only, as opposed to seasonal sampling conducted in previous years, to characterize water quality and contamination when Estuary conditions are most consistent between years.

The RMP measured 13 trace elements and a variety of organic contaminants, including polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides (Table 1.4 in Introduction). In addition, several new contaminants were added to the RMP for monitoring in 2002 water samples that included polybrominated diphenyl ethers (PBDEs), phthalates, and p-nonylphenol. Monitoring results for these contaminants in water and sediment are discussed in Section 5. The RMP measures trace elements in water as dissolved (0.45 µm filtered) and total (or near-total) concentrations. Trace organic contaminant concentrations were measured in water and reported as dissolved (operationally defined as water fraction that is filtered through a wound glass fiber filter with a nominal pore size of 1 µm) and total (dissolved + particulate) concentrations.

The RMP also measured conventional water quality parameters in 2002 to relate contaminant concentrations to general water quality conditions at the time of sampling, (Table 1.4). In addition, the U.S. Geological Survey (USGS) collected water quality data (salinity, temperature, dissolved oxygen, suspended sediments, and phytoplankton biomass) on a monthly basis along a transect of the deep water channels from the Lower South Bay to the confluence of the Sacramento and San Joaquin Rivers. Water quality data from USGS is available on their website at http://sfbay.wr.usgs.gov/access/wqdata/.

Field and analytical methods are described in Section 6 – *Description of Methods*. The referred section also provides information on additional RMP sampling and analysis reference documentation. Data are available for downloading via the RMP website using the Web Query Tool @ http://www.sfei.org/rmp/data.htm.

2.2.2 Water Quality Guidelines

To evaluate potential ecological effects, contaminant concentrations were compared to various water quality guidelines. The Regional Board uses RMP water contaminant data (and other information) in making recommendations for changes to the state's 303 (d) list of impaired water bodies, and for evaluating "background" concentrations of regulated contaminants in their 'reasonable potential' analyses (see section 2.2.4 below).

Concentrations of dissolved and total trace elements and organic contaminants were compared to the lower of the aquatic life and/or human health (consumption of organisms only) water quality effects thresholds listed in the U.S. Environmental Protection Agency's California Toxics Rule (CTR, U.S. EPA, 2000), the San Francisco Bay Water Quality Control Plan (Basin Plan, SFBRWQCB, 1995), or other sources. Table 2.1 lists the various guidelines used.

The CTR lists several effects thresholds aimed at protecting aquatic life or human health. RMP trace element data were compared to the lowest threshold reported for each contaminant (generally the four-day average aquatic life criteria). Trace organic contaminant concentrations were compared to the human health criteria for the consumption of aquatic organisms only, since RMP stations are all downstream of drinking water intakes in the Delta.

Proposed Basin Plan revisions in 2004 clarify the definition of freshwater, marine, and estuarine waters for the Estuary to align with the CTR. These definitions are used to categorize dischargers and determine which set of water quality objectives form the basis of effluent limitations. The CTR defines freshwater as less than 1 part per thousand (‰) at least 95% of the time and marine water as greater than 10 ‰ at least 95% of the time. Anything in between is defined as estuarine water, for which the lower of the marine or freshwater objectives apply. Where applicable, estuarine RMP samples were compared to the lower freshwater or saltwater effects threshold for trace elements (see *Defining "Estuarine" Regions in the Estuary* section below). Concentrations of six trace elements (cadmium, copper, nickel, lead, silver, and zinc) were compared to the lower of the freshwater or saltwater criteria at sites considered "Estuarine" (see below). Freshwater effects thresholds were calculated for each sample using hardness data that were measured on site or (if data were not available) a hardness factor of 100 mg/L (the default value in the CTR, US EPA, 2000). A hardness cap of 400 mg/L was used for calculating freshwater thresholds (per recommendation of the Regional Board staff, 2003).

Regulatory Effects Thresholds

Only a subset of effects threshold comparisons in this report has regulatory implications. This subset consists of nine trace elements and twenty-six trace organic contaminants (Table 2.1). Arsenic, cadmium, copper, lead, silver, nickel, and zinc were compared to the dissolved water quality criteria (WQC) listed in the CTR. The Lower South Bay (south of the Dumbarton Bridge) has site-specific objectives approved for that region for copper, nickel, and mercury (see *Site-specific Objectives for the Lower South Bay* section below). Total mercury concentrations were compared to the aquatic life objective for total recoverable mercury listed in the Basin Plan (0.025 µg/L), except for the Lower South Bay where the CTR criterion of 0.051 µg/L applies (which is the human health criterion (for the consumption of organisms only)). The CTR lists a selenium criterion of 5 µg/L for total recoverable selenium that was promulgated for all waters in San Francisco Bay and upstream, including the Delta, in the National Toxics Rule (NTR, U.S. EPA, 1992). Total (dissolved plus particulate fractions) organic contaminants were compared to the CTR human health criterion (for the consumption of organisms only). Additionally, total PAHs were compared to the Basin Plan objective of 15.0 µg/L.

Non-Statutory/Regulatory Effects Thresholds

Effects threshold comparisons of total trace element concentrations for the seven metals mentioned above (arsenic, cadmium, copper, lead, silver, nickel, and zinc), and total organic concentrations for diazinon, chlorpyrifos, and mirex are strictly for informational purposes and do not have regulatory implications. The total metals effects thresholds used in this report were calculated using the default CTR conversion factors to convert dissolved metals thresholds to total metals thresholds, except for the Lower South Bay where site-specific translators are available for copper and nickel (see below).

Some organic contaminants analyzed by the RMP are not listed in the CTR or Basin Plan, but effects thresholds do exist. The following contaminants were compared to effects thresholds from other sources (Table 2.1). Total diazinon concentrations were compared to an effects threshold concentration of 40 ng/L, developed by the California Department

of Fish and Game (Menconi and Cox, 1994). Chlorpyrifos and mirex were compared to the EPA recommended thresholds for these contaminants (U.S. EPA, 1999).

Site-specific Objectives for the Lower South Bay

There are new site-specific aquatic life water quality objectives for *dissolved* copper and nickel adopted by the State of California in 2003 and approved by the U.S. EPA for Lower South San Francisco Bay (south of the Dumbarton Bridge). The dissolved copper objective changed from 4.8 µg/L to 10.8 µg/L acute (exposure for one hour) and from 3.1 µg/L to 6.9 µg/L chronic (exposure for four days). The dissolved nickel objectives changed from 74 µg/L to 62.4 µg/L acute and from 8.2 µg/L to 11.9 µg/L chronic. Additionally there are site-specific translators to convert the objective from dissolved to total. The translators for copper and nickel are 0.53 and 0.44 respectively (dissolved objective / translator value = site-specific total objective).

Defining "Estuarine" Regions in the Estuary

In order to evaluate which regions should be considered estuarine by the new definition, SFEI staff queried the USGS long-term database for salinity data sampled between 1993 and 2002 (http://sfbay.wr.usgs.gov/access/wqdata). This program provides monthly CTD (conductivity, temperature, and depth) and discrete water quality measurements at varying depths for 39 sites located along the "spine" of the Estuary (monitoring begin in 1969). For a summary of the program (which is partially funded through the RMP) see the 2003 Pulse of the Estuary article by Cloern *et al.,* (2003) at http://www.sfei.org/rmp/pulse/pulse2003.pdf.

Monthly salinity data were compiled for two depths: 1) near surface (at 1 meter below the surface), and 2) near bottom (1 meter above sediment surface). Between 86 and 484 salinity samples were evaluated at each depth for each site. Near surface and bottom data were evaluated to determine the percentage of samples that were below 1 ‰ and above 10 ‰, respectively (Table 2.2). Results showed that none of the RMP sampling sites are located within a freshwater region and that the Rivers, Suisun Bay, San Pablo Bay, and the Lower South Bay regions are estuarine as defined by the proposed Basin Plan and the CTR (Figures 2.0 and 2.1).

2.2.3 Aquatic Toxicity Testing

Ambient Water Toxicity

Since 1993, the RMP has conducted ambient water toxicity testing on seasonal to annual time scales. In recent years, there has been a reduction in observed toxicity to aquatic organisms in RMP water samples, especially in the dry season. For this reason, the new RMP monitoring plan called for scaling back the frequency of ambient water toxicity testing. In 2002, the RMP collected water samples from nine shallow water stations to ensure that toxicity was not observed in shallow areas close to the Estuary margins. Toxicity was evaluated using a short-term chronic test by exposing *Americamysis bahia* to water samples for seven days with survival as the test endpoint. Significant toxicity was determined by statistical comparison (t-tests) of field samples with controls. Tests were conducted following U.S. EPA guidelines (U.S. EPA, 1994a).

Episodic Water Toxicity

Episodic toxicity testing was conducted on water samples collected following storm events between November 2002 and April 2003 at five shallow water sites in the Estuary: downstream of the confluence of the Sacramento and San Joaquin Rivers (at Mallard Island), Petaluma River, Sonoma Creek, San Lorenzo Creek, and Coyote Creek (see Ogle and Gunther, 2004). Water samples were collected for episodic toxicity testing from November 2002 to April 2003. Toxicity was evaluated using a short-term chronic test by exposing *A. bahia* and *Menidia beryllina* for seven days with survival as the test endpoint. Toxicity of samples with conductivity below 2,000 µmho was also evaluated using a short-term chronic test by exposing *Ceriodaphnia dubia* for six to eight days with survival and reproduction as the test endpoints. Significant toxicity was determined by statistical comparison (t-tests) of field samples with controls. Tests were conducted following U.S. EPA guidelines (U.S. EPA 1994a; U.S. EPA 1994b).

2.2.4 Summary of Background Concentrations for Total-water-column Contaminants at Historical RMP Sites

The State Board adopted the *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* (SIP) effective as of May 22, 2000 (www.swrcb.ca.gov/iswp/final.pdf). Among other things, the SIP establishes implementation provisions for priority pollutant criteria promulgated by the U.S. EPA through the National and the California Toxics Rules, and for priority pollutant water quality objectives (WQO's) established by the Regional Boards in their Basin Plans. The SIP specifies how toxic water quality objectives are translated into effluent limitations.

The Regional Board uses RMP total-water-column data (dissolved plus particulate for organic and total-recoverable for trace element concentrations) to determine "background" contaminant levels in the Estuary. This information serves as a reference for the Regional Board in their Reasonable Potential analyses, part of their National Pollutant Discharge Elimination System (NPDES) permitting program. "Reasonable Potential" is defined as the likelihood that the concentration of a pollutant in a discharge would cause or contribute to an exceedance of a water quality guideline. If the Regional Board determines that the pollutant has 'reasonable potential', the SIP requires the discharger to have an effluent limit for that pollutant in its NPDES permit (i.e., a limit is "triggered").

Overall, there are three triggers for effluent limits: (1) if the maximum effluent concentration exceeds the WQO, (2) if the maximum background concentration exceeds the WQO, or (3) if there is other information that would require the need for an effluent limit (e.g., 303(d) listing).

The Regional Board uses RMP data from fixed historical sites to estimate background contaminant concentrations in the water-column when determining NPDES effluent limits (trigger 2 above). Following format guidance provided by the permit staff at the Regional Board a summary of that data (1994-2002) is provided in *Appendix A* (and is also available in csv format). For each historical RMP site and reported contaminant that

has a WQO, we reported the minimum, maximum (or the lowest reported detection limit if all samples were non-detects), average, median, sample size, and number of samples reported as not detected. The raw total-water-column data are also available for downloading on the RMP website: http://www.sfei.org/sfeidata.htm.

2.3 Results and Discussion

Results from 2002 RMP Status and Trends water monitoring are presented in a series of maps that display the distribution and concentration ranges of salinity (Figure 2.2), total suspended solids (TSS; Figure 2.3), dissolved organic carbon (DOC; Figure 2.4), trace elements (Figures 2.5 – 2.22), and organic contaminants (Figures 2.24 – 2.39). Furthermore, box plots with interquartile ranges of contaminant concentrations summarize results from randomly allocated stations grouped into the five major hydrographic regions of the Bay: Suisun Bay, San Pablo Bay, Central Bay, South Bay, and Lower South Bay. As only one year of data is available using the new RMP monitoring design, detailed analyses of spatial and temporal trends were not covered within the scope of this data summary report. Therefore, highlights of monitoring results are discussed below. As previously noted, monitoring results for the new analytes PBDEs, musks, and phthalates are summarized in Section 5.

2.3.1 Spatial Distribution

Trace Elements

The highest dissolved concentrations of all trace element contaminants were measured in stations in the southern segments of the South Bay and Lower South Bay, as well as the slough stations at San Jose (C-3-0) and Sunnyvale (C-1-3) (Figures 2.5 – 2.13). Dissolved methyl mercury was not detected in any samples collected in 2002. In the five major segments, dissolved concentrations of arsenic, copper, mercury, nickel, lead, selenium, and zinc were generally higher in Lower South Bay compared to other segments of the Bay. Dissolved concentrations of cadmium and silver were higher in South Bay. Dissolved concentrations of trace elements were operationally defined as the fraction of sample that passes through a 0.45-µm filter, which also allows smaller particles and colloids to pass through. Thus, dissolved trace element concentrations measured in RMP water samples may have been influenced by concentrations of DOC (Kuwabara *et al.,* 1989) and colloids (Sañudo-Wilhelmy *et al.,* 1996).

The cycling and distribution of many trace elements measured by the RMP in Estuary water are greatly influenced by the transport of suspended particles (Schoellhamer, 1996a, Conaway *et al.,* 2003, Schoellhamer *et al.,* 2003). Maximum total concentrations of mercury (0.075 µg/L), silver (0.014 µg/L), nickel (6.2 µg/L), lead (0.21 µg/L), selenium (1.0 µg/L), and zinc (9.9 µg/L) were measured at San Jose (C-3-0) (Figures 2.17 – 2.22), which also had the highest concentration of TSS (330 mg/L). Furthermore, the highest concentrations of total cadmium (0.16 µg/L, Figure 2.15) and total copper (4.0 µg/L; Figure 2.16) were measured in San Pablo Bay (SPB003W), which had the second highest TSS concentration (270 mg/L) measured in 2002. Among the five major Bay regions, relatively high concentrations of silver, cadmium, copper, mercury, nickel, lead, and zinc were measured in San Pablo Bay and were likely influenced by TSS concentrations greater than 240 mg/L at two of the four stations sampled in that region.

The close relationship between suspended sediment and particle reactive trace elements has important implications in understanding how they (and sediment-associated organic contaminants) are transported throughout the Estuary and the extent to which water samples exceed water quality guidelines. For example, Figure 2.23 shows a strong correlation between mercury and TSS and indicates that concentrations of mercury were greater than the Basin Plan saltwater guideline of 25 ng/L at only the five stations with TSS greater than 240 mg/L. It is worth noting that these five samples were collected in relatively shallow locations with water depths of 2 meters or less. Sediments in shallow regions of the Estuary are highly susceptible to resuspension from wind, tides, and freshwater flows and subsequent advection to deeper channels of the Bay (Schoellhamer, 1996b). As a result, concentrations that exceed water quality guidelines are not necessarily a result of close proximity to contaminant sources, but are also influenced by water quality conditions at the time of sampling. For a more detailed discussion of the influence of suspended sediment on contaminant dynamics in the San Francisco Estuary, see Schoellhamer *et al*., (2003) in the 2003 Pulse of the Estuary available online at http://www.sfei.org/rmp/pulse/pulse2003.pdf.

Total methyl mercury was detected only in the southern reaches of the Bay at Sunnyvale (C-1-3; 1.1 ng/L), San Jose (C-3-0; 0.39 ng/L), and LSB006 (0.20 ng/L), which is the station in closest proximity to major tributaries of Lower South Bay. Elevated concentrations at these stations in the summer are consistent with findings from Conaway *et al.,* (2003), which suggest that production of methylmercury is greater in the southern reaches of the Bay during the summer, and that greater production may be associated with conditions of low dissolved oxygen, high DOC, high nutrient concentrations, and low salinity.

Organic Contaminants

Similar to past years of RMP monitoring, concentrations of PCBs and PAHs, which are primarily associated with sources in urban areas, were typically highest in southern regions of the Bay in 2002 (Figures 2.30, 2.31, 2.37, 2.38). Maximum concentrations of total and dissolved ΣPCBs were measured at San Jose (C-3-0), while maximum concentrations of total and dissolved ΣPAHs were measured at Sunnyvale (C-1-3). The influence of TSS on these contaminants was also evident at San Pablo Bay sites SPB001W and SPB003W where total ΣPAH and ΣPCB concentrations exceeded 100,000 pg/L and 1,000 pg/L, respectively.

Concentrations of organochlorine (OC) pesticides, which were used for both agricultural and urban applications, were also highest in the southern regions of the Bay. Maximum concentrations of total and dissolved ΣDDTs and hexachlorocyclohexanes (ΣHCHs) were measured at San Jose (C-3-0) (Figures 2.28, 2.29, 2.35, 2.36), while maximum concentrations of total and dissolved ΣChlordanes were measured at Sunnyvale (C-1-3) (Figures 2.24, 2.32).

The organophosphorous (OP) pesticides, chlorpyrifos and diazinon, were detected only in the dissolved fraction (Figures 2.25 and 2.26). Chlorpyrifos was detected only in the

Sacramento (BG20; 660 pg/L) and San Joaquin (BG30; 490 pg/L) Rivers and at San Jose (C-3-0; 720 pg/L), which are in close proximity to areas of pesticide usage in adjacent watersheds. Seaward gradients of decreasing diazinon concentrations were observed through Suisun and San Pablo Bays in the northern regions of the Estuary and through the Lower South Bay and South Bay segments. The highest concentration of diazinon (8,500 pg/L) was measured at San Jose (C-3-0).

Concentrations of most trace elements and organic contaminants were highest in southern segments of the Estuary. These findings are consistent with results from the RMP Estuary Interface Pilot Study, which showed higher concentrations of several contaminants of concern in the tidal regions of Coyote Creek and Guadalupe River draining into Lower South Bay (Leatherbarrow et al., 2002). Much of the South Bay and Lower South Bay lie adjacent to watersheds with regions of urbanization, agriculture, and historic mercury mining. Tributaries that drain local watersheds carry surface runoff with high concentrations of sediment and associated contaminants, including trace metals, PCBs and OC pesticides from urban and agricultural sources, as well as mercury from historic mining (McKee *et al.,* 2004; Thomas *et al.*, 2002). The southern reach also receives treated wastewater effluent from three municipal treatment facilities. In addition, many trace contaminants of concern are persistent in sediment of the South Bay, which receives limited seasonal hydraulic flushing of freshwater from local tributaries compared to the northern reaches of the Estuary. Thus, high concentrations of trace elements and organic contaminants may reflect combined influences of watershed and the treatment plant inputs, as well as the tidal resuspension of persistent contaminants from the sediment of the South and Lower South Bays.

2.3.2 Temporal Trends

An objective of the RMP is to determine patterns and trends in contaminant concentrations and distribution in the San Francisco Estuary. Trend evaluation was not in the scope of this data summary and was deferred to the RMP's upcoming synthesis of information from the past ten years (1993-2002) of water monitoring in the Estuary.

Temporal trends have previously been evaluated in studies of dissolved lead and silver in the San Francisco Estuary and these trends are summarized by Flegal *et al.,* (2004) in this year's edition of the Pulse of the Estuary, 2004. Briefly, Steding *et al.,* (2000) used isotopic compositions of lead to determine that no significant decrease in dissolved lead concentrations had occurred in San Francisco Bay waters between 1989 and 1998. This was attributed to benthic remobilization from sediments in the Bay and lengthy retention times of lead in the watersheds adjacent to the Bay and in the Central Valley. Squire *et al.,* (2002) used time series models to provide further evidence of relatively constant concentrations of lead in the Estuary, while showing that dissolved silver concentrations have significantly decreased in the South Bay over the last decade. A key finding from Squire *et al.,* (2002) is that decreasing dissolved silver concentrations may have been attributed to reductions in contaminant loading from wastewater treatment plants and a concomitant decline in concentrations in surface sediment in the South Bay.

2.3.3 Comparison to Water Quality Guidelines

Numerous water samples collected in 2002 had contaminant concentrations that were above the water effects thresholds (some of which have regulatory implications, see Table 2.3). None of the regulatory criteria were exceeded for dissolved metals. The water quality objective was exceeded for total mercury (5 samples), and sum of PCB's (28 of 33 samples).

Calculated CTR effects threshold for total metals were compared to total metals concentrations. Total metal concentrations were above the non-regulatory total effects thresholds for copper (7 samples), nickel (6 samples), and lead (5 samples).

Besides the Golden Gate reference site (BC20), only a few sites in the northern Estuary (San Pablo Bay, Suisun Bay, and the Rivers regions) were below the total PAHs and PCBs criteria (Figures 2.37a&b and 2.38a&b). The San Jose (C-3-0), Sunnyvale (C-1-3), and Lower South Bay station (LSB006W), were above the effects thresholds for total lead, mercury, PAHs, and PCBs. Two San Pablo Bay sites (SPB001W and SPB003W) were above the effects thresholds for total lead, mercury, copper, nickel, PAHs, and PCBs. As previously noted, these were the only sites with TSS greater than 240 mg/L, which could have partially influenced the high concentrations of the trace metal contaminants.

2.3.4 Toxicity of Water to Organisms

Ambient Water Toxicity

The RMP evaluated ambient water toxicity in samples collected from nine shallow stations in 2002 (Figure 2.40). Toxicity tests using *Americamysis bahia* indicated that no significant water toxicity occurred in July 2002. Because the RMP has not typically observed aquatic toxicity in Estuary samples collected during the dry season, the frequency of aquatic toxicity testing in subsequent monitoring years will be reduced.

Episodic Water Toxicity

Episodic toxicity monitoring in 2002 was conducted following periods of potential episodic inputs of toxic contaminants (e.g., storm events, dormant spray runoff, row crop runoff, and urban gardening). In 22 samples from five tributaries during five storm water runoff events, significant toxicity of *A. bahia* and *C. dubia* occurred only during the first sampling event (November 7, 2002) at San Lorenzo Creek (0% survival). Toxicity Identification Evaluation (TIE) procedures indicated that toxicity of *C. dubia* was probably caused by the presence of high concentrations of the organophosphorous (OP) pesticide diazinon and chlorpyrifos. Since episodic toxicity testing began in 1996, there has been an apparent reduction in aquatic toxicity in Estuary waters that has been attributed to reductions in the concentrations of OP pesticides in the watershed (Ogle and Gunther, 2004). For more information on the results of the 2002/03 Episodic Aquatic Toxicity monitoring effort see the report entitled "Episodic ambient water toxicity in the San Francisco Estuary" at http://www.sfei.org/sfeireports.htm. In addition, an overview of toxicity testing in water and sediment over the past ten years of RMP monitoring was summarized by Anderson *et al.* (2003) in the 2003 Pulse of the Estuary. http://www.sfei.org/rmp/pulse/pulse2003.pdf

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Table 2.1. Water quality guidelines. California Toxics Rule (CTR) water quality criteria (USEPA, 2000) are listed except where noted. Dissolved trace element criteria are listed (except for mercury and selenium). Total trace element criteria (not shown) were calculated using procedures specified in the CTR. Criteria for organic compounds are listed on a total basis (dissolved + particulate). Bold and italicized concentrations are hardness dependent criteria and were calculated using a hardness concentration of 100 mg/L. Units are µg/L for all concentrations.

Parameter	Aquatic Life				Human Health (10^{-6} risk for carcinogens)	
	Fresh Water		Salt Water		Fresh Water	Salt & Fresh Water
	1-hour	4-day	1-hour	4-day	Water & Organisms	Organisms only
Ag	***3.4***	.	1.9	.	.	.
As	340	150	69.0	36.0	.	.
Cd	***4.3***	***2.2***	43.0	9.3	.	.
Cr VI	16.0	11.0	1100	50.0	.	.
Cu	***13.4***	***9.0***	4.8	3.1	1300	.
Cu (lower South Bay only)			10.8	6.9		
Hg [A]	2.4	0.025	2.1	0.025	0.05	0.051
Ni	***470***	***52.0***	74.0	8.2	610	4600
Ni (lower South Bay only)			62.4	11.9		
Pb	***64.6***	***2.5***	220	8.1	.	.
Se [B]		5.0	290	71.0	.	.
Zn	***120***	***120***	90.0	81.0	.	.
Alpha-HCH	.	.	.	.	0.0039	0.013
Acenaphthene	.	.	.	.	1200	2700
Anthracene	.	.	.	.	9600	110000
Benz(a)anthracene	.	.	.	.	0.0044	0.049
Benzo(a)pyrene	.	.	.	.	0.0044	0.049
Benzo(b)fluoranthene	.	.	.	.	0.0044	0.049
Benzo(k)fluoranthene	.	.	.	.	0.0044	0.049
Beta-HCH	.	.	.	.	0.014	0.046
Chlordane	2.4	0.0043	0.09	0.004	0.00057	0.00059
Chlorpyrifos [C]	0.083	0.041	0.011	0.0056	.	.
Chrysene	.	.	.	.	0.0044	0.049
Diazinon[D]	.	.	.	.	.	0.04
Dibenz(a,h)anthracene	.	.	.	.	0.0044	0.049
Dieldrin	0.24	0.056	0.71	0.0019	0.00014	0.00014
Endrin	0.086	0.036	0.037	0.0023	0.76	0.81
Fluoranthene	.	.	.	.	300	370
Fluorene	.	.	.	.	1300	14000
Gamma-HCH	0.095	0.08	0.16	.	0.019	0.063
Heptachlor	0.52	0.0038	0.053	0.0036	0.00021	0.00021
Heptachlor Epoxide	0.52	0.0038	0.053	0.0036	0.0001	0.00011
Hexachlorobenzene	.	.	.	.	0.00075	0.00077
Indeno(1,2,3-cd)pyrene	.	.	.	.	0.0044	0.049
p,p'-DDD	.	.	.	.	0.00083	0.00084
p,p'-DDE	.	.	.	.	0.00059	0.00059
p,p'-DDT	1.1	0.001	0.13	0.001	0.00059	0.00059
Pyrene	.	.	.	.	960	11000
Mirex [C]	.	0.001	.	0.001	.	.
Total PAHs[E]	.	.	.	.	0.031	0.031
Total PCBs	.	0.014	.	0.03	0.00017	0.00017

[A] Mercury guidelines are from the Basin Plan (SFBRWQB, 1995) and are for total recoverable mercury. The Lower South Bay region is compared to the Human Health (organisms only) mercury guideline of 0.051 µg/L.

[B] Selenium values are region-specific criteria as outlined in the National Toxics Rule (USEPA, 1992) and are for total recoverable selenium.

[C] Chlorpyrifos and mirex criteria from USEPA (1999).

[D] Diazinon guideline is from California Department of Fish and Game (Menconi and Fox, 1994).

[E] Total PAH guideline is from the footnote in the Basin Plan, 1995 (SFBRWQB, 1995). However the current objective is 15 µg/L.

Table 2.2. Salinity patterns in San Francisco Estuary based on water quality monitoring by the USGS. Percentage of time when salinity was less than 1 ppt or greatter than 10 ppt at two depths per station: 1 meter below the surface and 1 meter above the bottom (max-depth minus 1 meter).

Station Number	Station Name	Latitude	Longitude	Depth (m) 1 meter and max depth -1m	Salinity	Region	Designation
649	Sacramento River	38°3.7'	121°48.0'	1	74% of time < 1 ppt	Rivers	estuarine
				9	70% of time < 1 ppt	Rivers	estuarine
2	Chain Island	38°3.8'	121°51.3'	1	63% of time < 1 ppt	Rivers	estuarine
				10	59% of time < 1 ppt	Rivers	estuarine
6	Roe Island	38°3.9'	122°2.1'	1	11.4% of time > 10 ppt	Suisun Bay	estuarine
				9	25% of time > 10 ppt	Suisun Bay	estuarine
9	Benicia	38°3.0'	122°10.4'	1	52.5% of time > 10 ppt	Suisun Bay	estuarine
				33	75% of time > 10 ppt	Suisun Bay	estuarine
12	Pinole Shoal	38°3.1'	122°18.7'	1	74% of time > 10 ppt	San Pablo Bay	estuarine
				8	93.6% of time > 10 ppt	San Pablo Bay	estuarine
15	Point San Pablo	37°58.8'	122°26.2'	1	81% of time > 10 ppt	San Pablo Bay	estuarine
				22	100% of time > 10 ppt	San Pablo Bay	marine
17	Raccoon Strait	37°52.9'	122°25.6'	1	88% of time > 10 ppt	Central Bay	estuarine
				31	100% of time > 10 ppt	Central Bay	marine
18	Point Blunt	37°50.8'	122°25.3'	1	98% of time > 10 ppt	Central Bay	marine
				42	100% of time > 10 ppt	Central Bay	marine
21	Bay Bridge	37°47.3'	122°21.5'	1	96.8% of time > 10 ppt	Central Bay	marine
				16	99.5% of time > 10 ppt	Central Bay	marine
22	Potrero Point	37°45.9'	122°21.5'	1	97.4% of time > 10 ppt	Central Bay	marine
				17	100% of time > 10 ppt	Central Bay	marine
23	Hunter's Point	37°43.7'	122°20.2'	1	97% of time > 10 ppt	Central Bay	marine
				19	100% of time > 10 ppt	Central Bay	marine
24	Candlestick Point	37°41.9'	122°20.3'	1	97% of time > 10 ppt	Central Bay	marine
				10	100% of time > 10 ppt	Central Bay	marine
25	Oyster Point	37°40.2'	122°19.5'	1	98% of time > 10 ppt	Central Bay	marine
				7	100% of time > 10 ppt	Central Bay	marine
27	SF Airport	37°37.1'	122°17.5'	1	99% of time > 10 ppt	South Bay	marine
				12	100% of time > 10 ppt	South Bay	marine
28	North of San Mateo Bridge	37°36.1'	122°16.2'	1	99% of time > 10 ppt	South Bay	marine
				15	100% of time > 10 ppt	South Bay	marine
29	South of San Mateo Bridge	37°34.8'	122°14.7'	1	99% of time > 10 ppt	South Bay	marine
				13	100% of time > 10 ppt	South Bay	marine
29.5	Steinberger Slough	37°34.1'	122°13.1'	1	99% of time > 10 ppt	South Bay	marine
				13	99% of time > 10 ppt	South Bay	marine
30	Redwood Creek	37°33.3'	122°11.4'	1	98% of time > 10 ppt	South Bay	marine
				11	99% of time > 10 ppt	South Bay	marine
32	Ravenswood Point	37°31.1'	122°8.0'	1	93.5% of time > 10 ppt	South Bay	estuarine
				12	95.5% of time > 10 ppt	Lower South Bay	marine
33	Dumbarton Bridge	37°30.5'	122°7.3'	1	94.7% of time > 10 ppt	Lower South Bay	estuarine
				10	96.3% of time > 10 ppt	Lower South Bay	marine
34	Newark Slough	37°29.7'	122°5.6'	1	92.9% of time > 10 ppt	Lower South Bay	estuarine
				8	94.5% of time > 10 ppt	Lower South Bay	estuarine
35	Mowry Slough	37°28.8'	122°4.8'	1	94.6% of time > 10 ppt	Lower South Bay	estuarine
				8	95.1% of time > 10 ppt	Lower South Bay	marine
36	Calaveras Point	37°28.3'	122°3.9'	1	44% of time < 1 ppt	Lower South Bay	estuarine
				7	48% of time < 1 ppt	Lower South Bay	estuarine

Table 2.3. Summary of total trace organic and total trace element contaminants that were above water quality guidelines. Only compounds that were above guidelines are listed.
Note: none of the dissolved trace elements were above guidelines.
dot = above guideline. Units are µg/L.

	Code	Station Name or Region	Σ PCBs	Mercury	Copper	Nickel	Lead
			0.00017	**A**	**A**	**A**	**A**
Rivers	BG20	Sacramento River					
	BG30	San Joaquin River	●				
Suisun Bay	SU001W	Suisun Bay			●	●	
	SU002W	Suisun Bay			●		
	SU003W	Suisun Bay	●		●		
	SU005W	Suisun Bay	●		●		
San Pablo Bay	SPB001W	San Pablo Bay	●	●	●	●	●
	SPB002W	San Pablo Bay					
	SPB003W	San Pablo Bay	●	●	●	●	●
	SPB004W	San Pablo Bay	●				
Golden Gate	BC20	Golden Gate					
Central Bay	CB001W	Central Bay	●				
	CB002W	Central Bay	●				
	CB003W	Central Bay	●				
	CB004W	Central Bay	●				
South Bay	SB001W	South Bay	●				
	SB002W	South Bay	●				
	SB003W	South Bay	●				
	SB004W	South Bay	●				
	SB005W	South Bay	●				
	SB006W	South Bay	●		●		
	SB007W	South Bay	●				
	SB008W	South Bay	●				
	SB009W	South Bay	●				
	SB010W	South Bay	●				
Lower South Ba	LSB001W	Lower South Bay	●				
	LSB002W	Lower South Bay	●				
	LSB003W	Lower South Bay	●				
	LSB004W	Lower South Bay	●				
	LSB005W	Lower South Bay	●				
	LSB006W	Lower South Bay	●	●			●
Southern Sloughs	C-3-0	San Jose	●	●			●
	C-1-3	Sunnyvale	●	●			●

A. The guidelines used for these comparisons varied by site. The sites within estuarine regions were compared to the lower of the hardness dependent fresh or salt water gudieline and/or the Lower South Bay has a different objective.

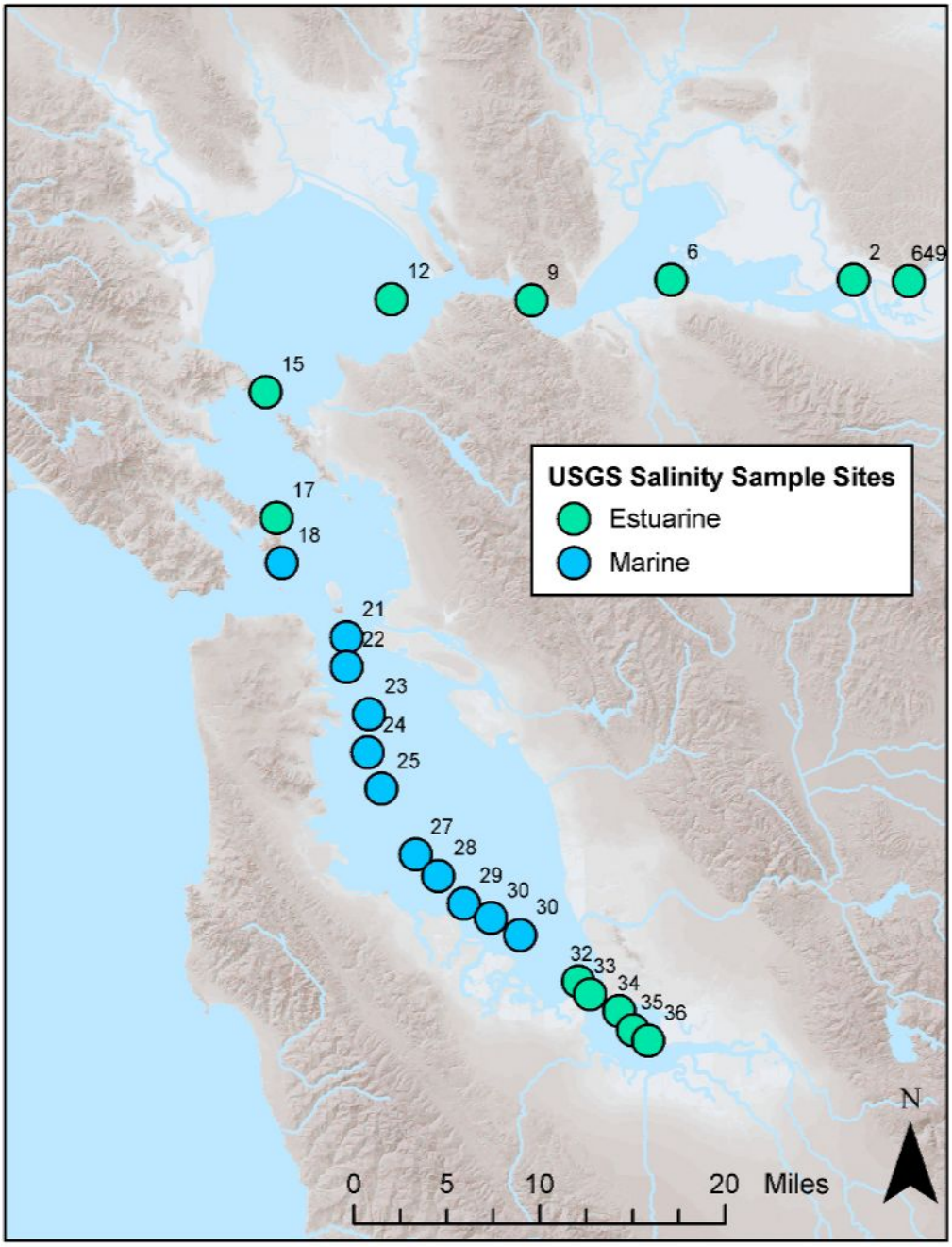


Figure 2.0. USGS monthly water quality sampling sites evaluated showing which sites are estuarine (at 1 meter from the surface) according to the new proposed Basin Plan definition. Between 86 and 484 salinity samples were evaluated for each site from samples collected since 1993.

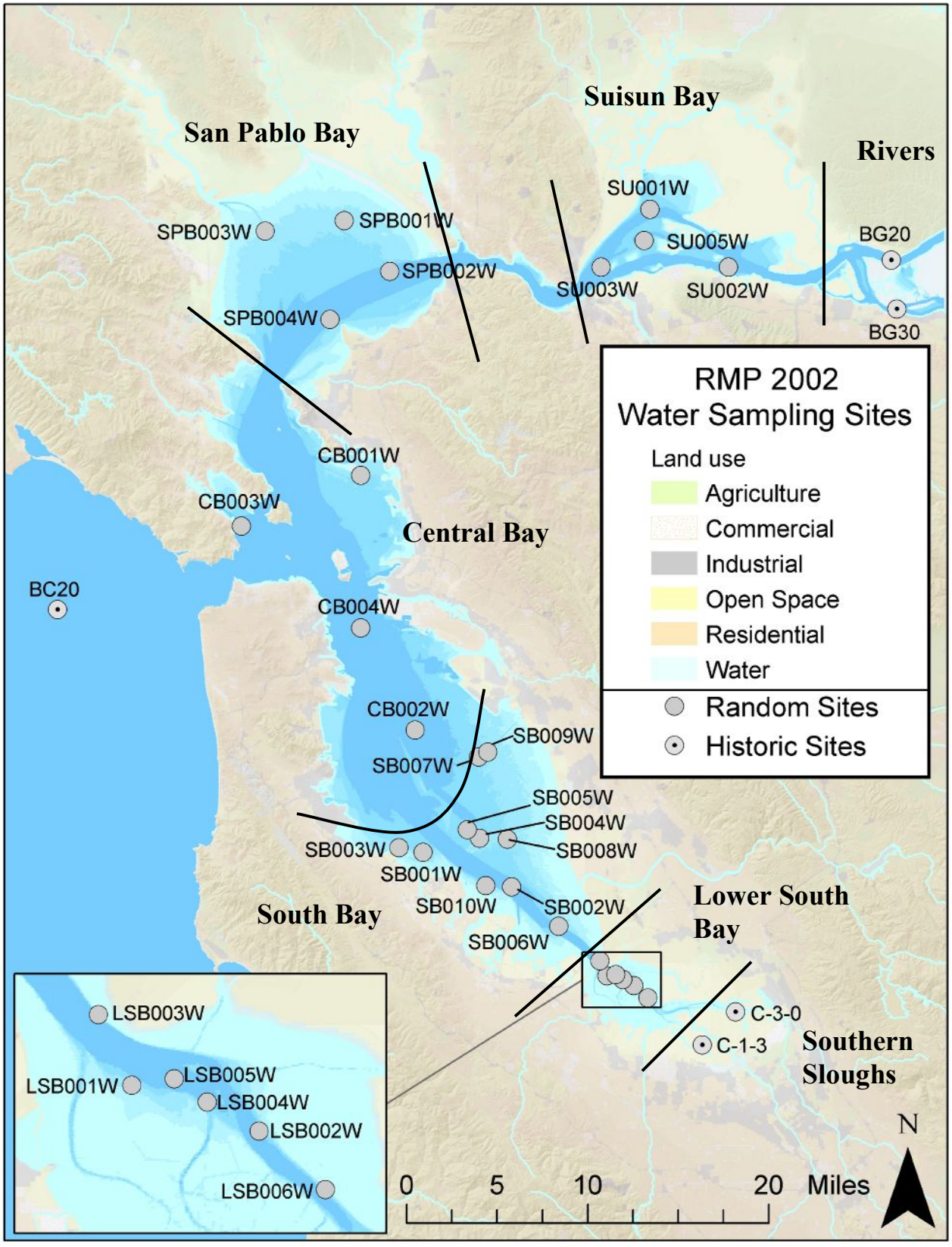


Figure 2.1. Map of the 2002 RMP Status and Trends water monitoring effort at both randomly selected and historic fixed sampling sites. 33 stations were sampled in the San Francisco Estuary for analyses of water quality, and trace contaminants.

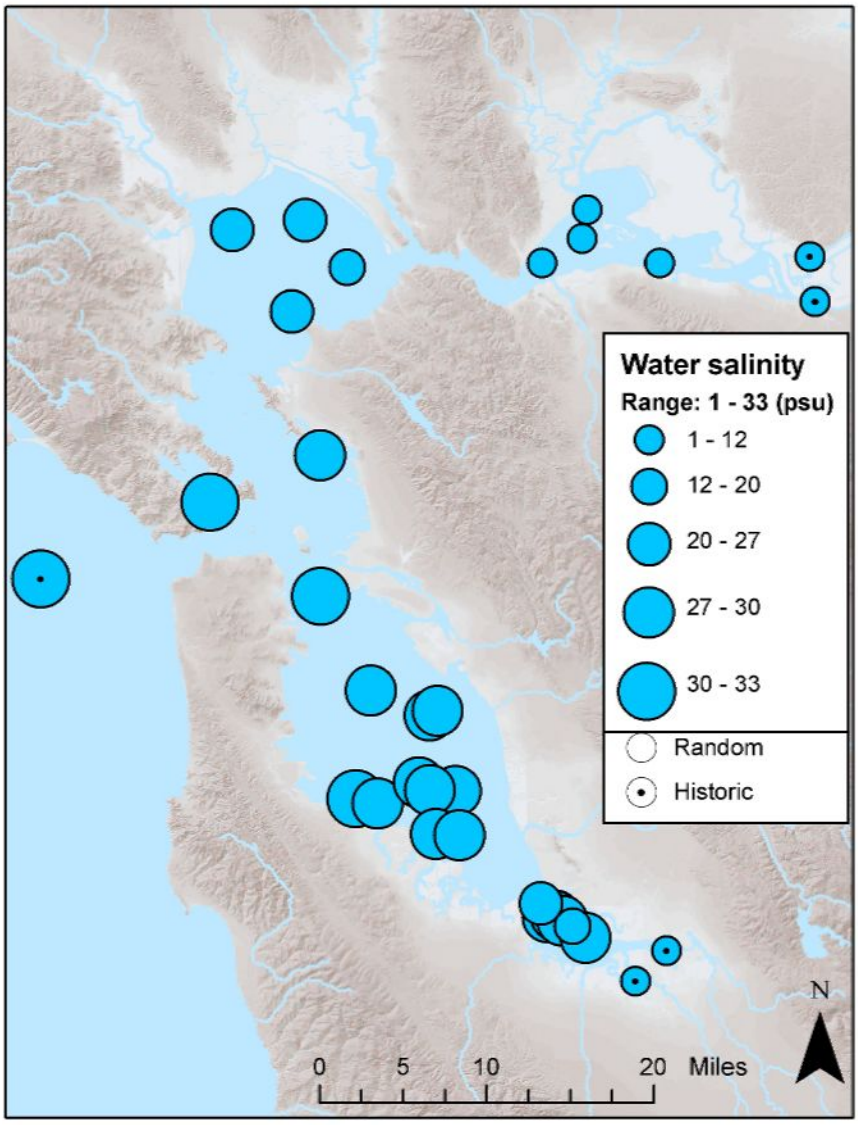


Figure 2.2. Salinity in practical salinity units (psu) in water sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002.

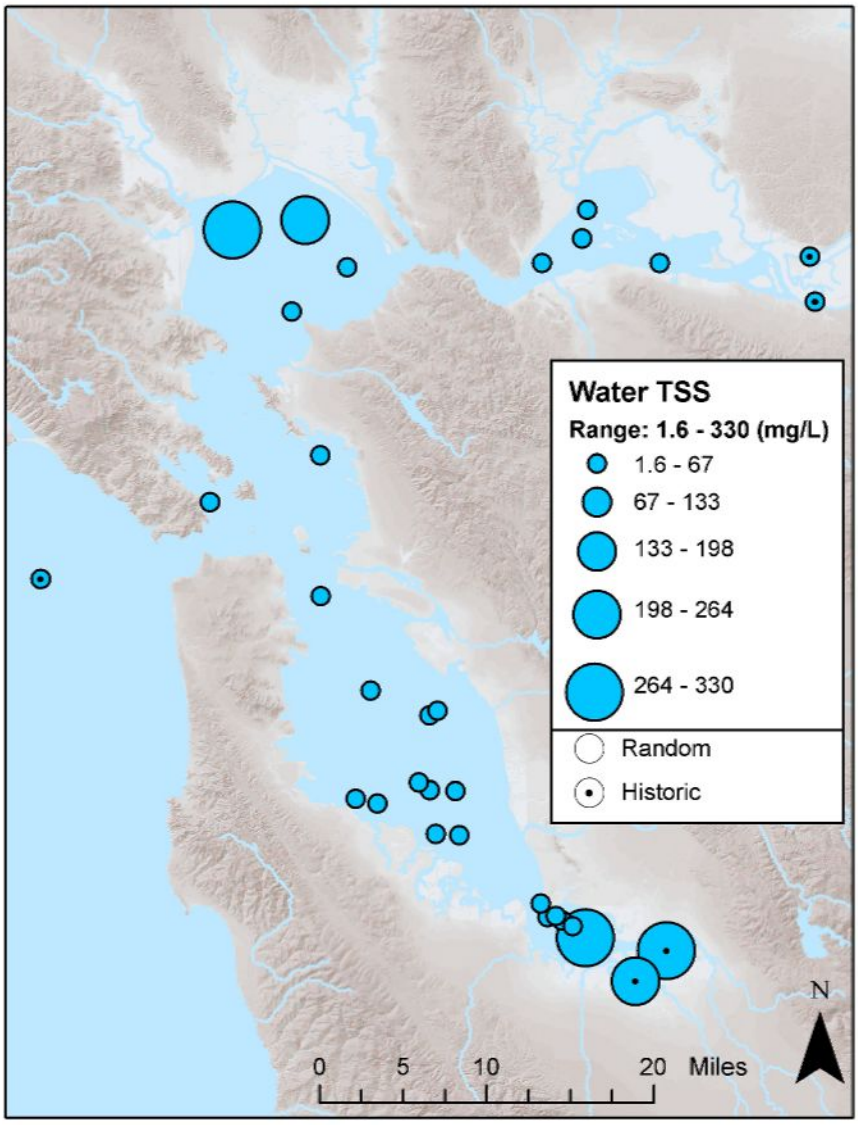


Figure 2.3. Total suspended solids (TSS, mg/L) in water sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002.

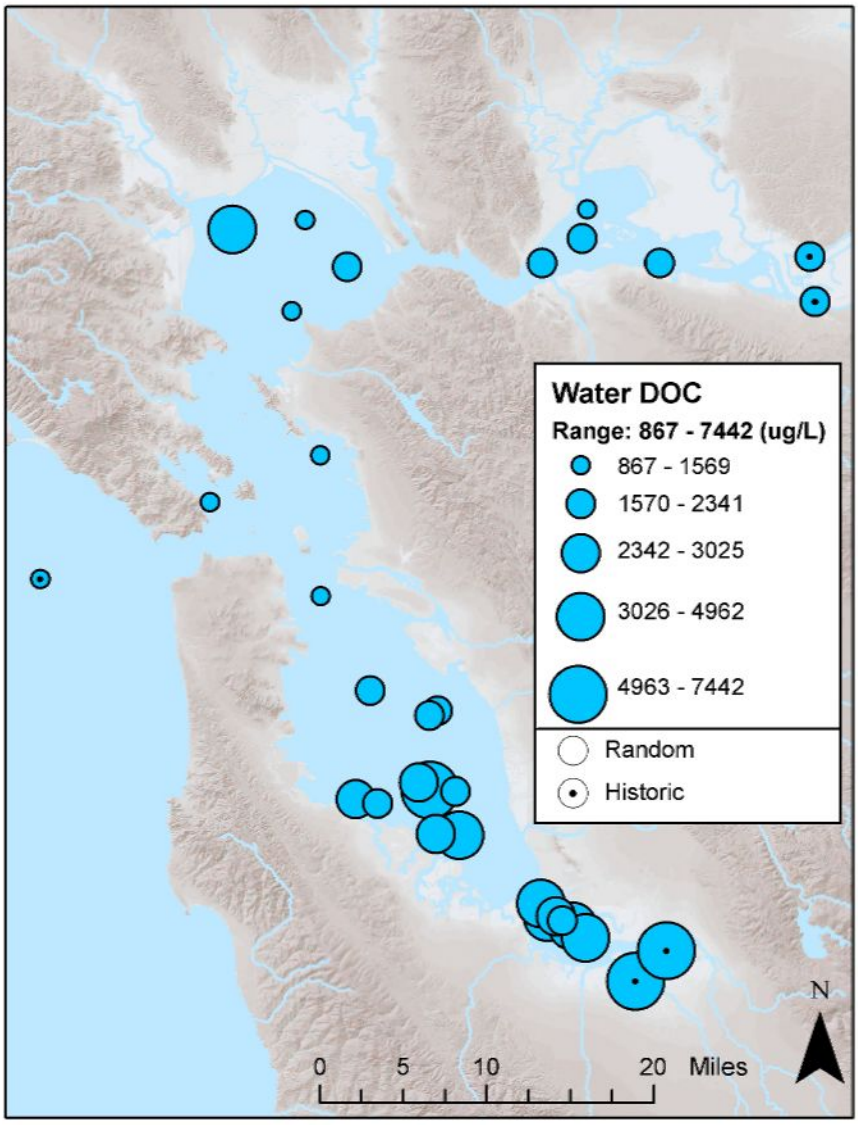


Figure 2.4. Dissolved organic carbon (DOC, µg/L) in water sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002.

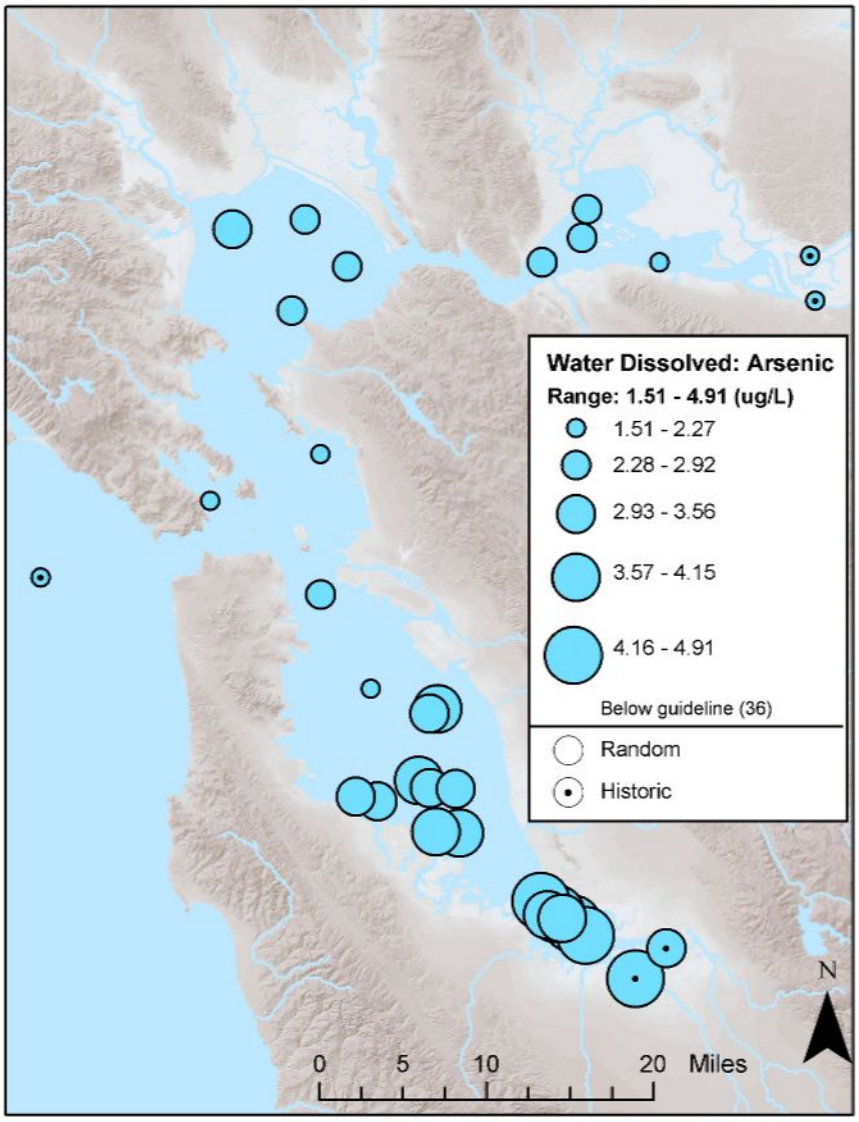


Figure 2.5a. Dissolved arsenic concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. All samples were below the CTR 4-day Aquatic Life saltwater criterion of 36 µg/L.

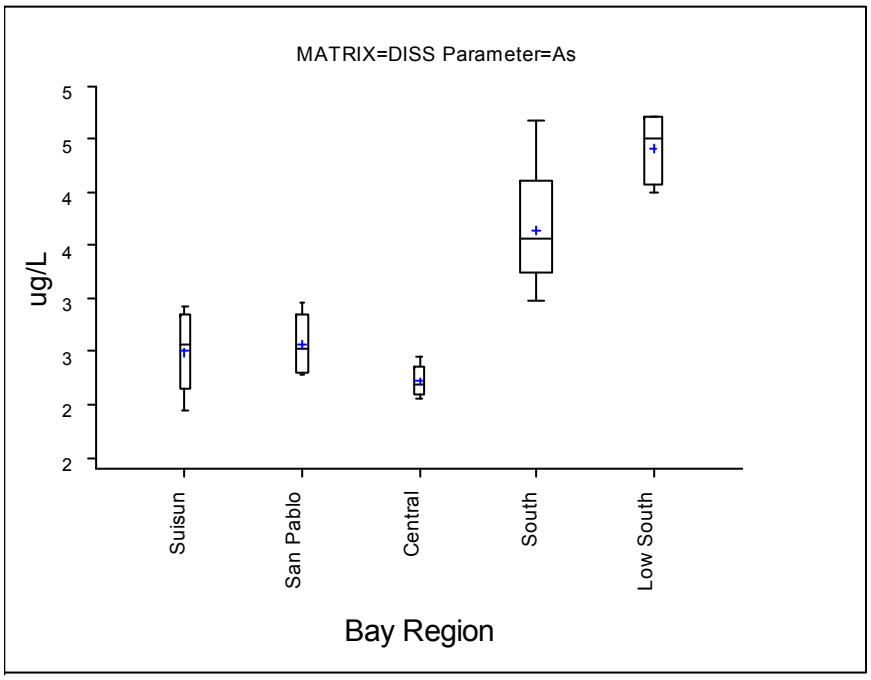


Figure 2.5b. Boxplot of dissolved arsenic concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

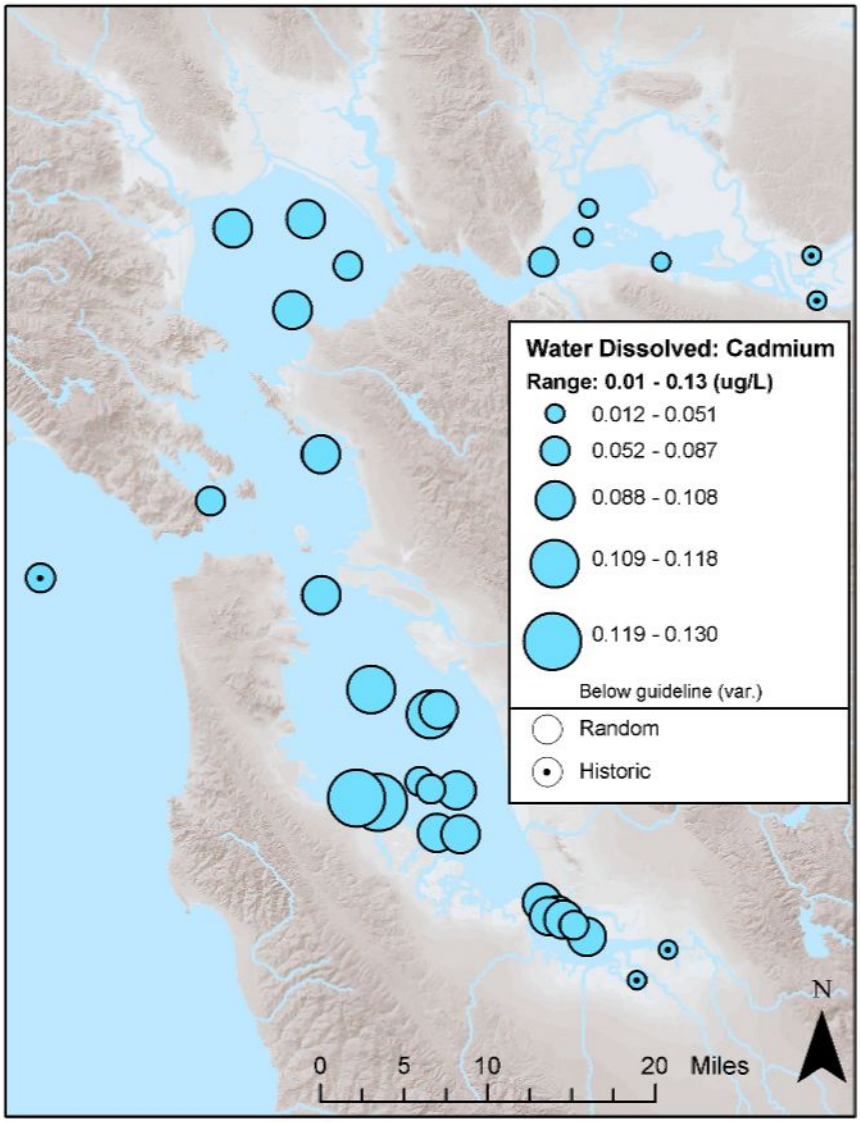


Figure 2.6a. Dissolved cadmium concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The cadmium freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below calculated CTR criterion.

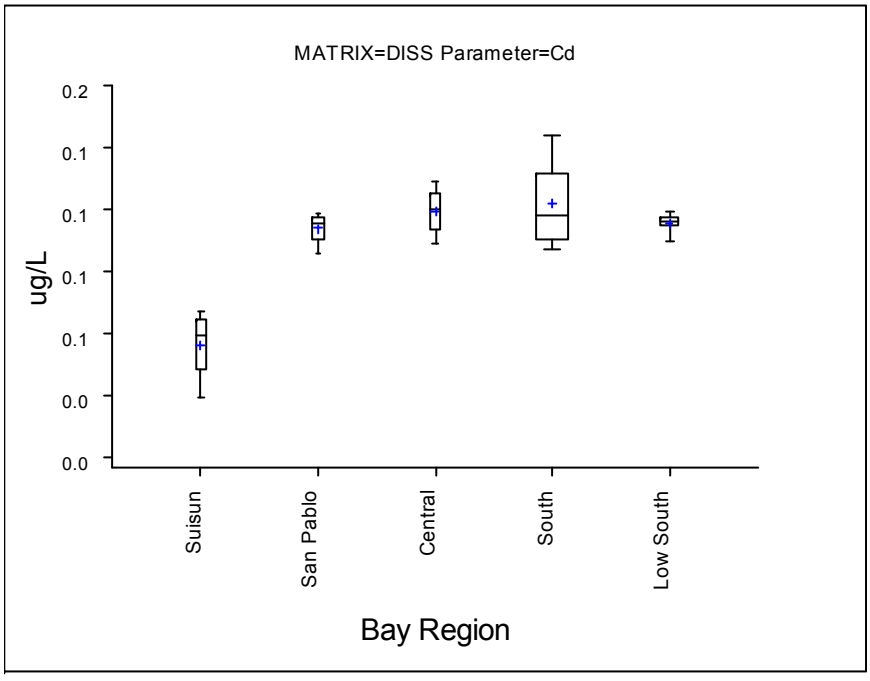


Figure 2.6b. Boxplot of dissolved cadmium concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

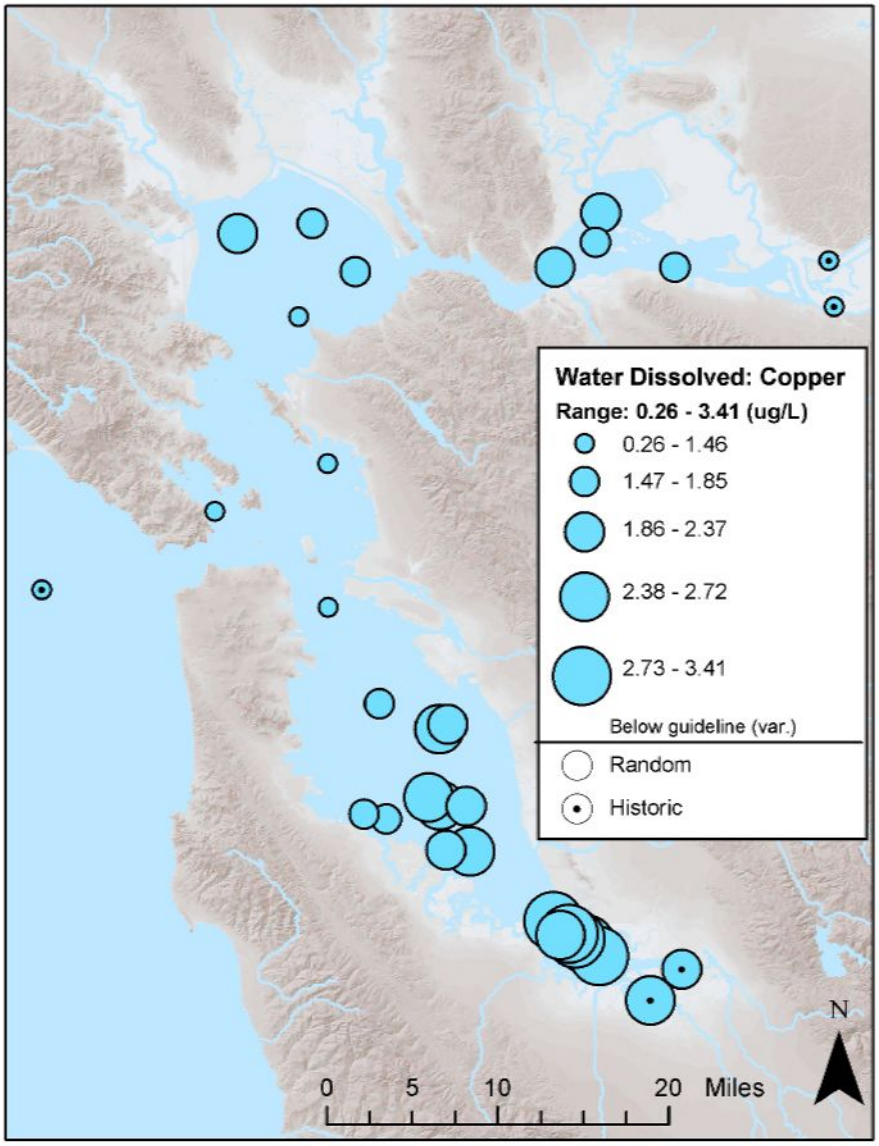


Figure 2.7a. Dissolved copper concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The copper freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). The Lower South Bay has a site-specific objective of 6.9 µg/L that was used in this evaluation. All samples were below the regulatory guidelines.

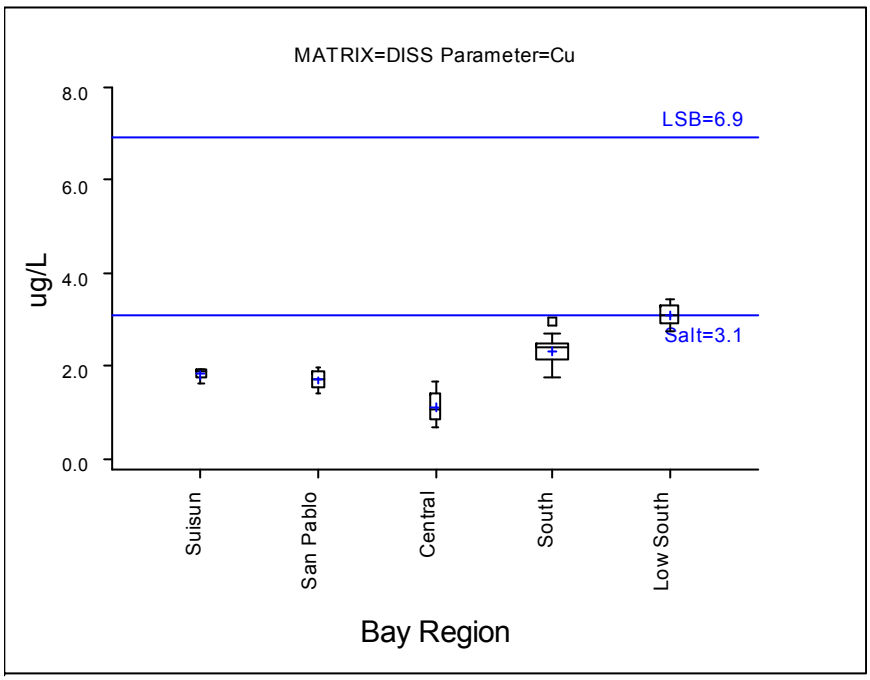


Figure 2.7b. Boxplot of dissolved copper concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. LSB is the new site specific water quality objective for the Lower South Bay. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

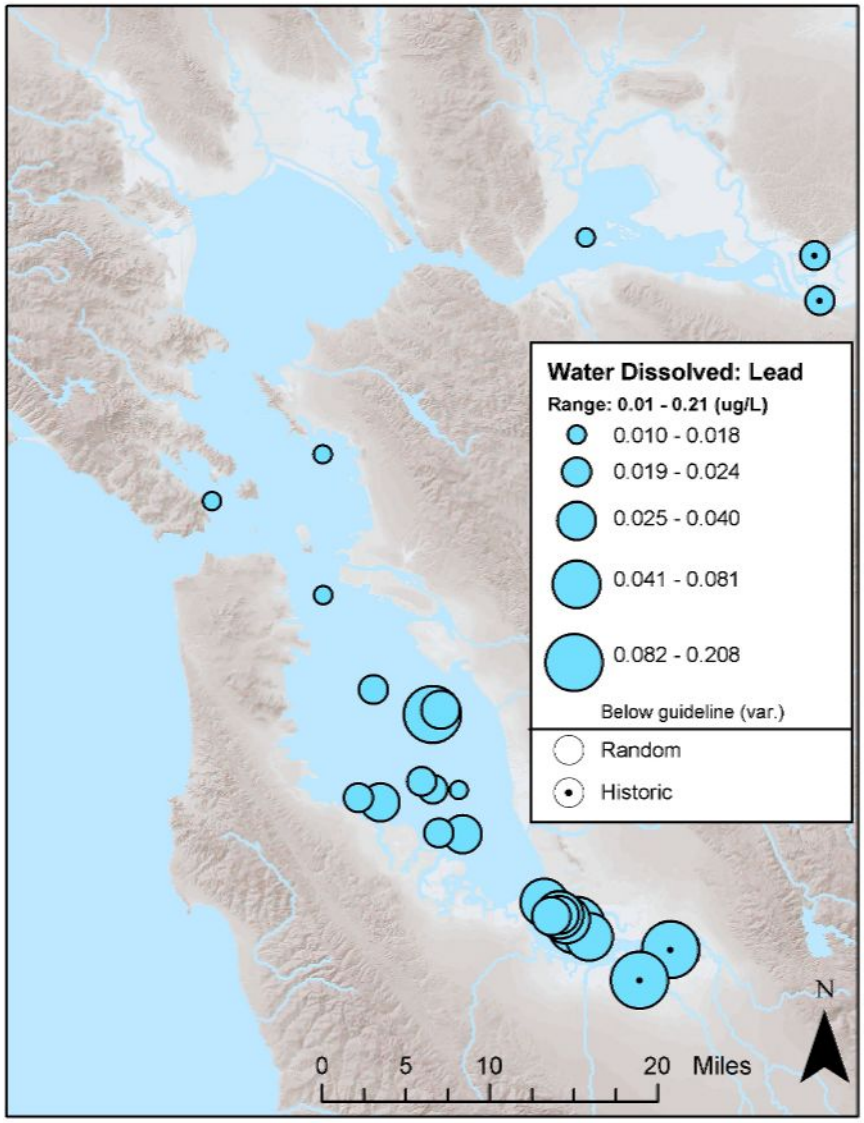


Figure 2.8a. Dissolved lead concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Most data from San Pablo and Suisun Bays did not pass QA/QC and therefore are not reported here. The lead freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below calculated CTR criterion.

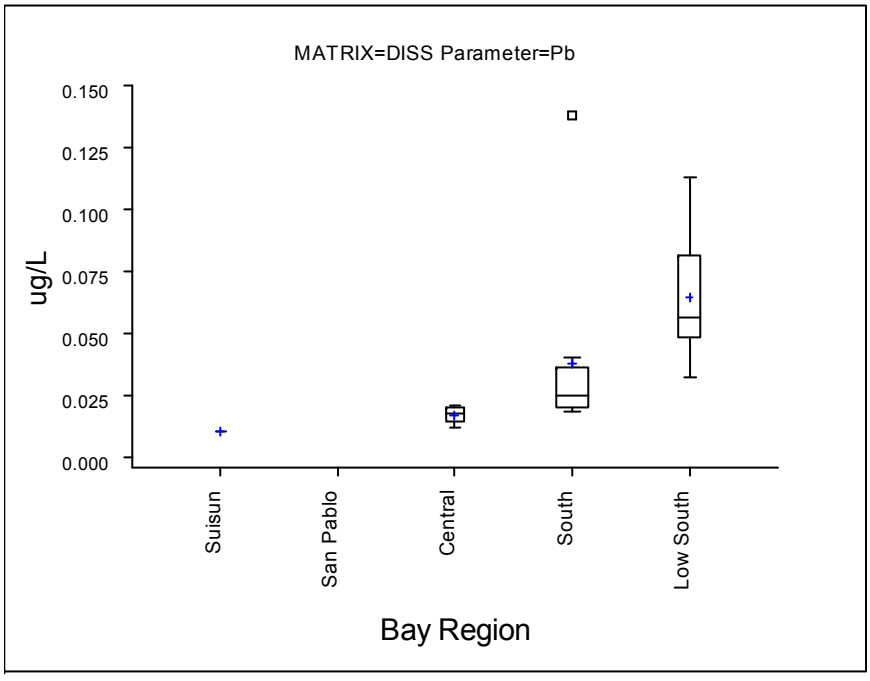


Figure 2.8b. Boxplot of dissolved lead concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

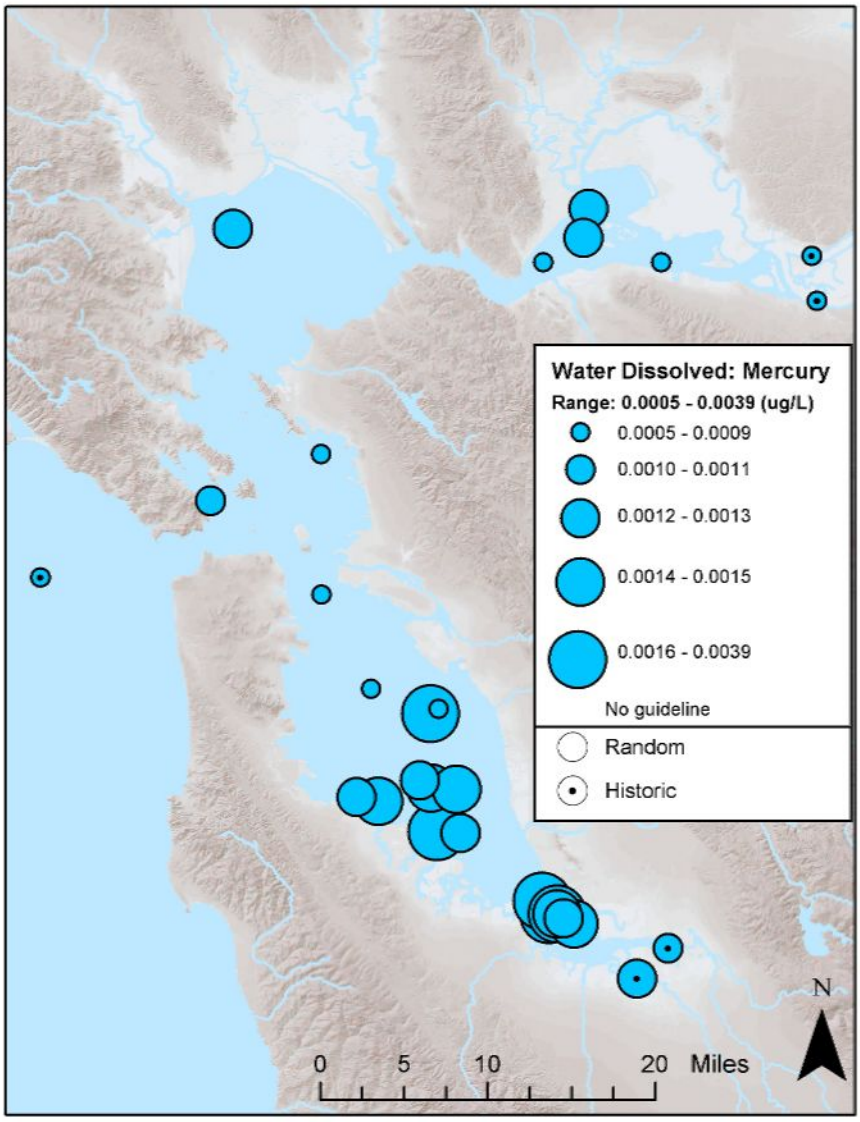


Figure 2.9a. Dissolved mercury concentrations in water (µg/L) in sampled at both randomly selected and historic fixed RMP sites the San Francisco Estuary in 2002. Mercury is evaluated against guidelines on a total basis (see Figure 2.18a).

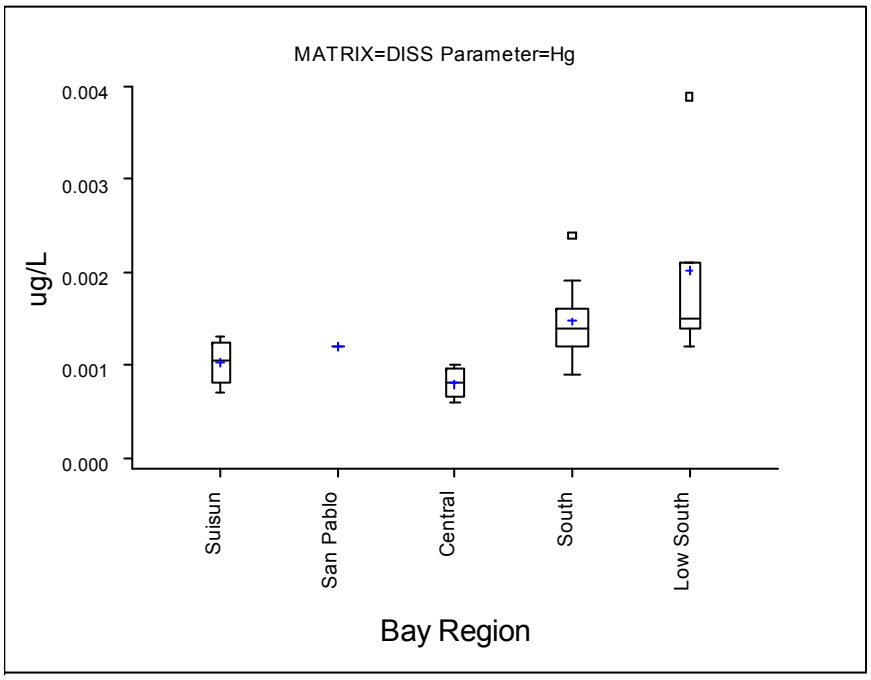


Figure 2.9b. Boxplot of dissolved mercury concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

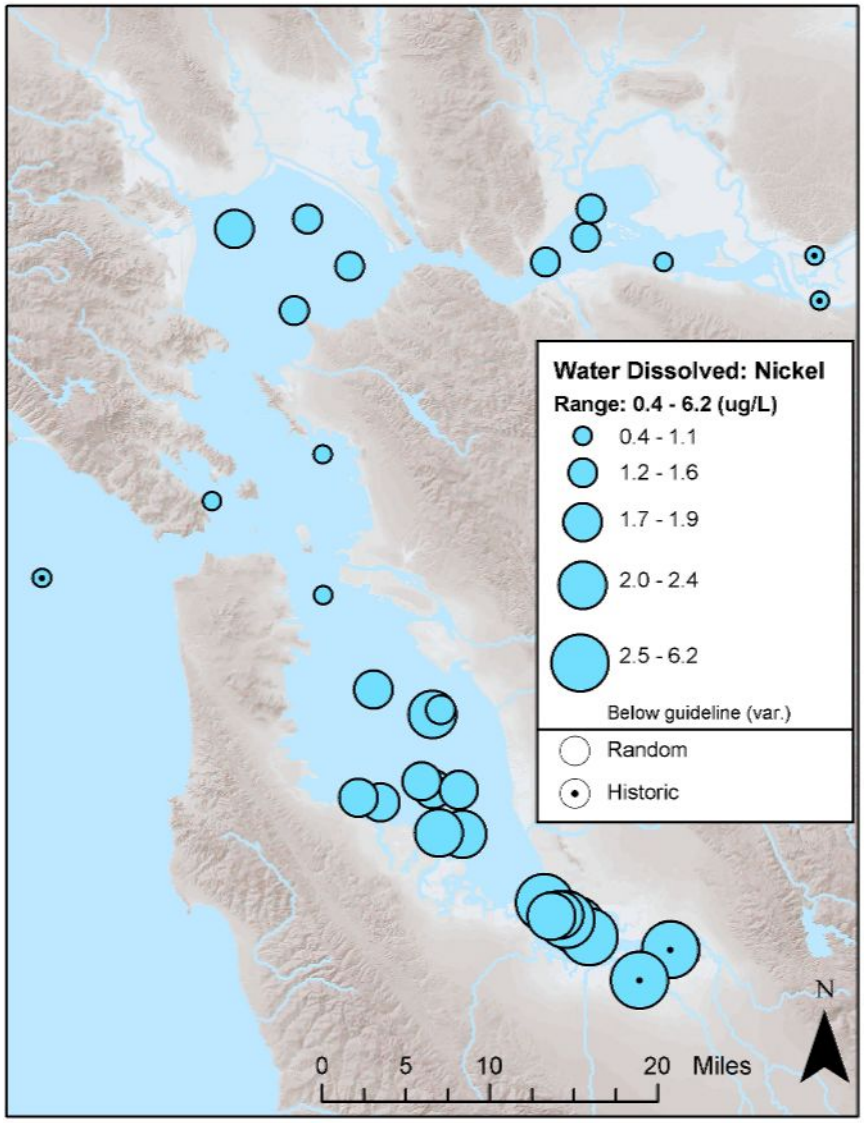


Figure 2.10a. Dissolved nickel concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The nickel freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). The Lower South Bay has a site-specific objective of 11.9 µg/L that was used in this evaluation. All samples were below the regulatory guidelines.

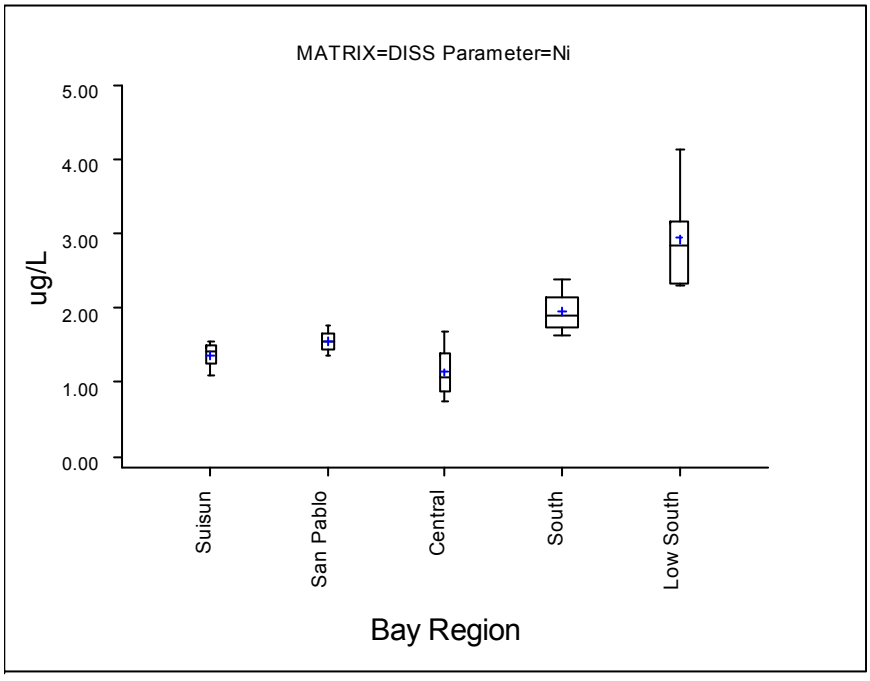


Figure 2.10b. Boxplot of dissolved nickel concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

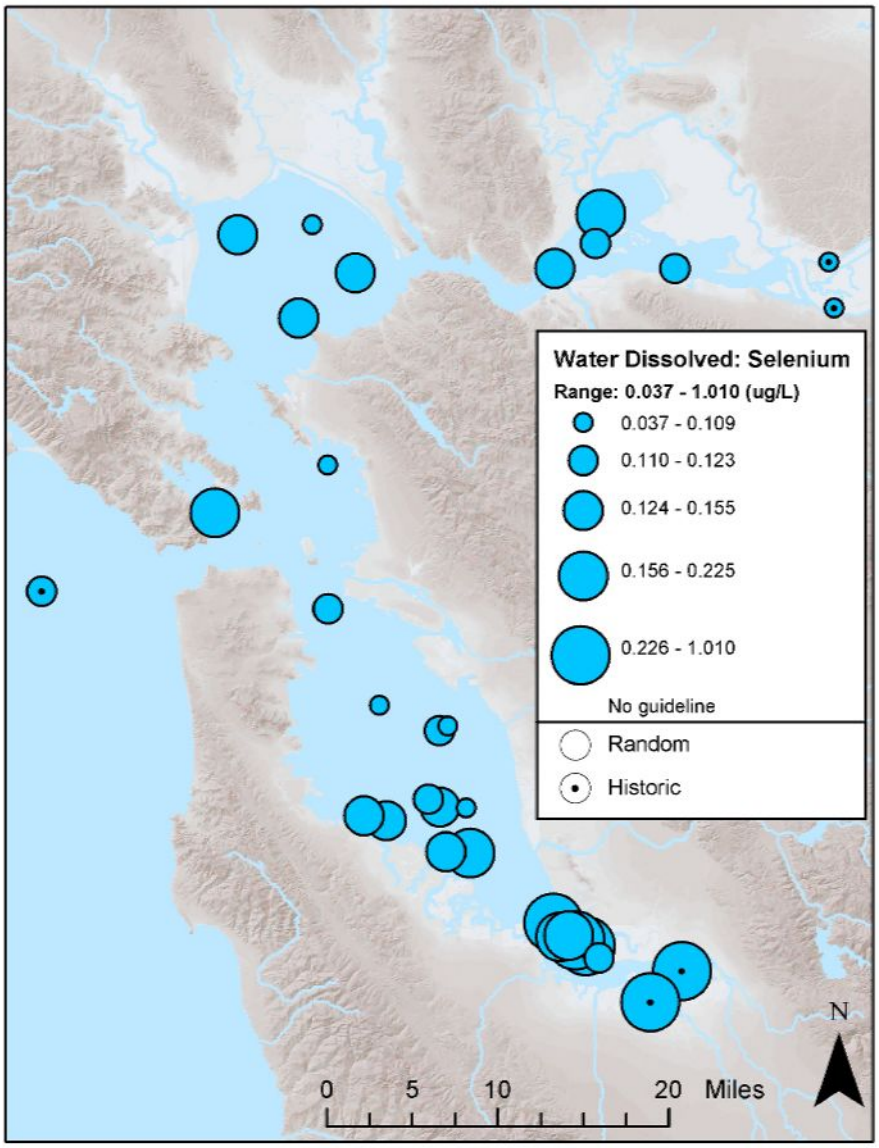


Figure 2.11a. Dissolved selenium concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Selenium is evaluated against guidelines on a total basis (see Figure 2.20a).

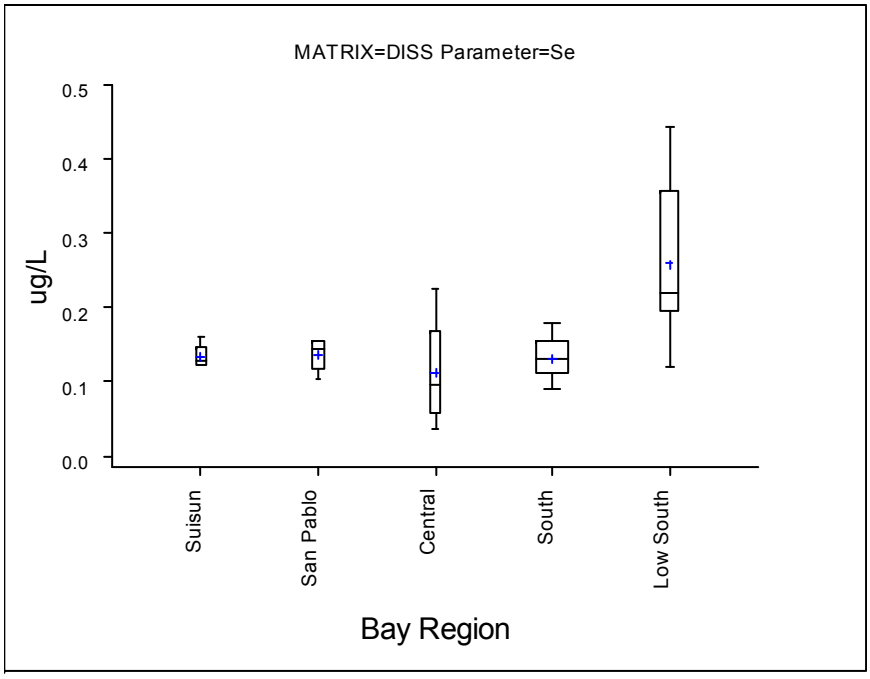


Figure 2.11b. Boxplot of dissolved selenium concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

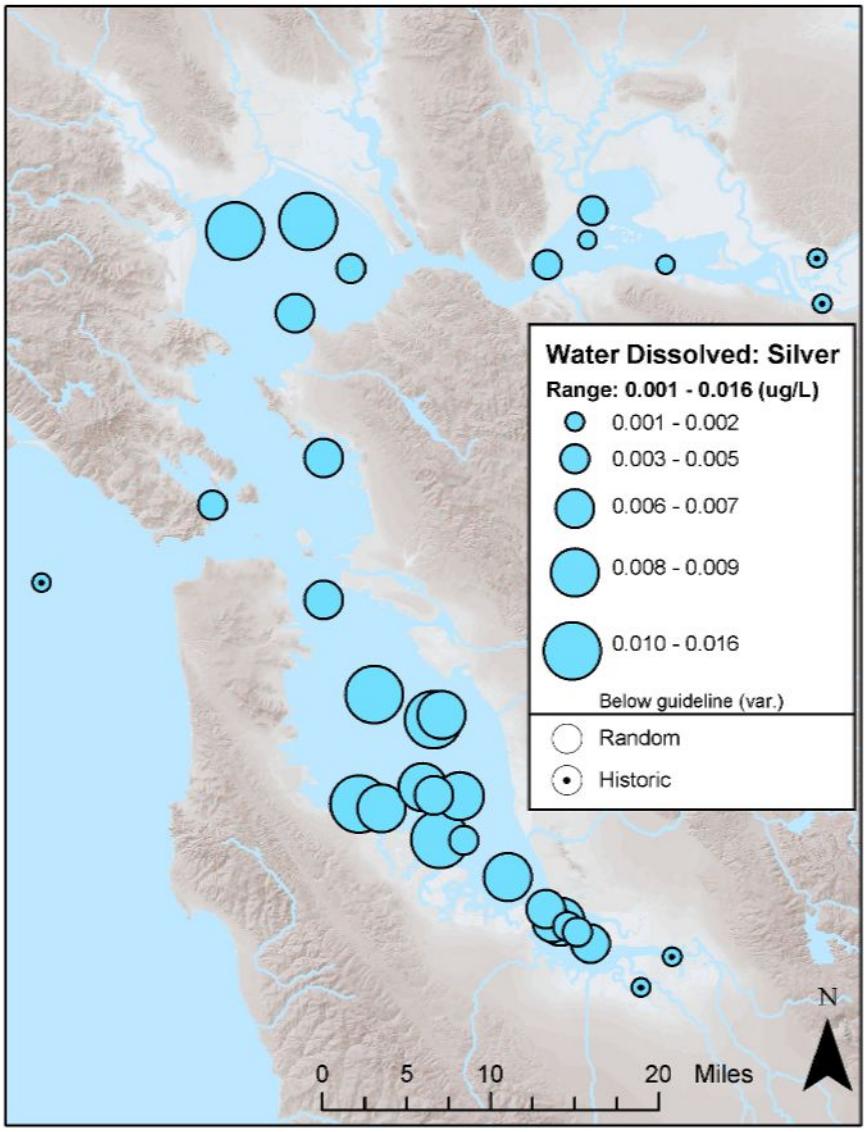


Figure 2.12a. Dissolved silver concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The silver freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below the regulatory guidelines.

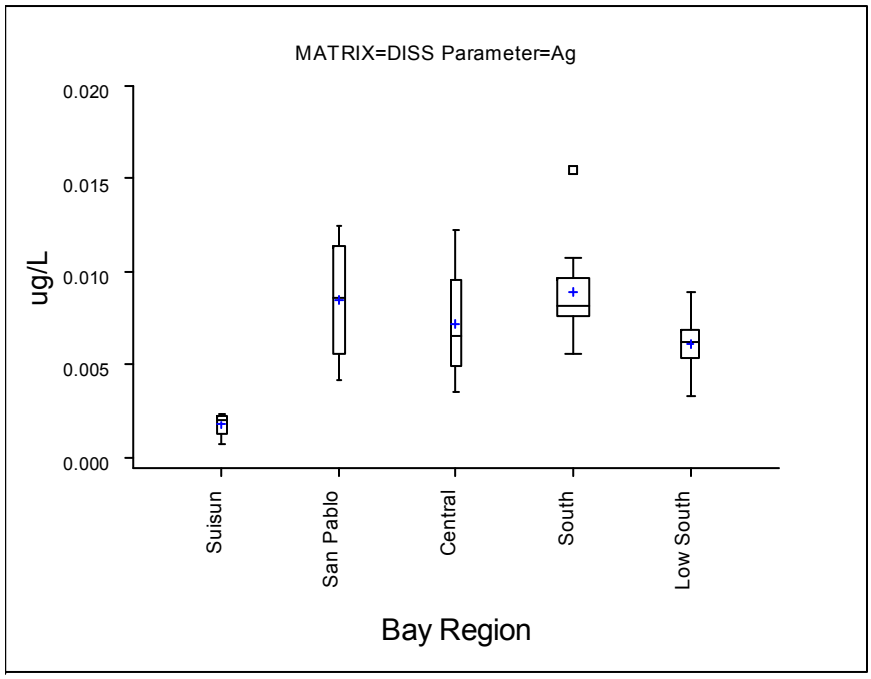


Figure 2.12b. Boxplot of dissolved silver concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

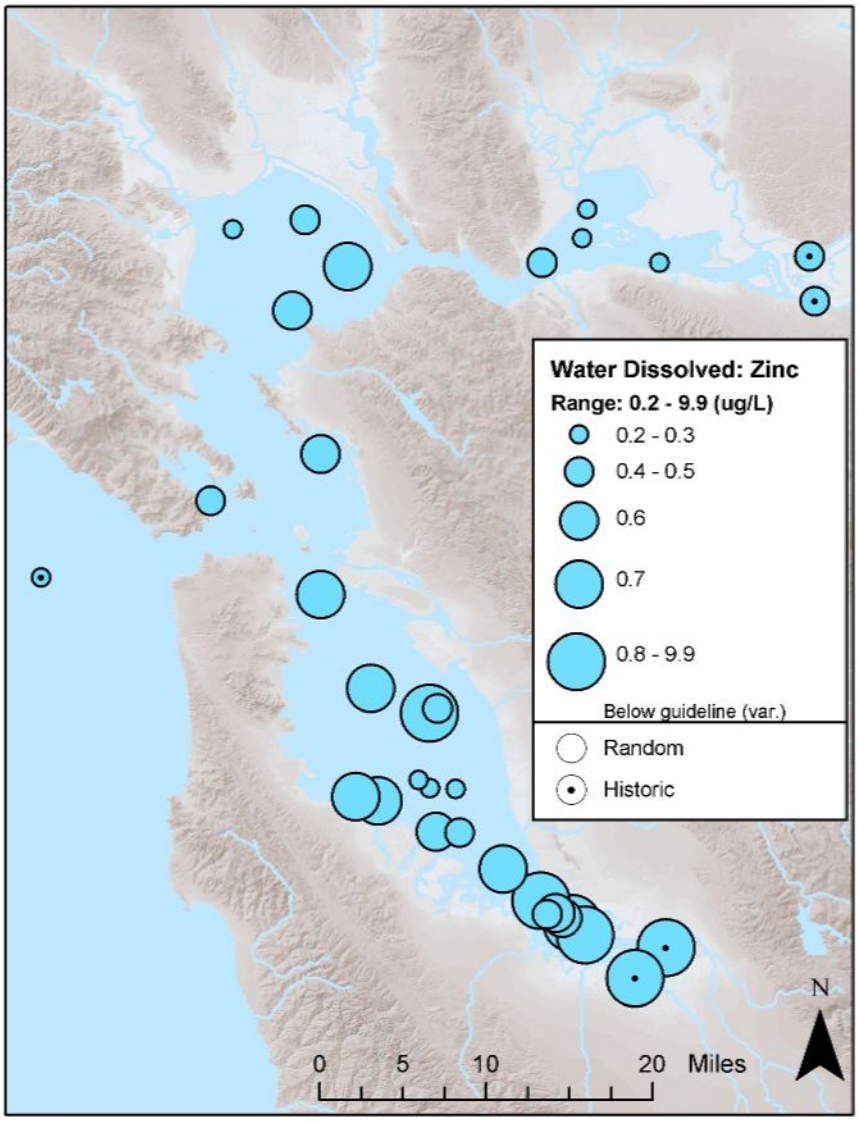


Figure 2.13a. Dissolved zinc concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The zinc freshwater criterion is hardness dependent and therefore salt and freshwater criteria were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below the regulatory guidelines.

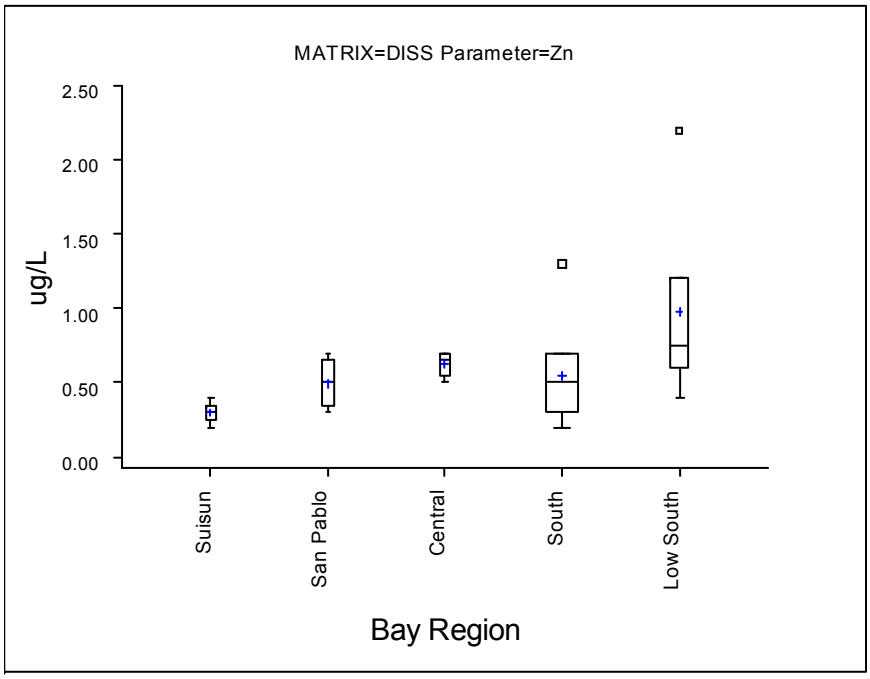


Figure 2.13b. Boxplot of dissolved zinc concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

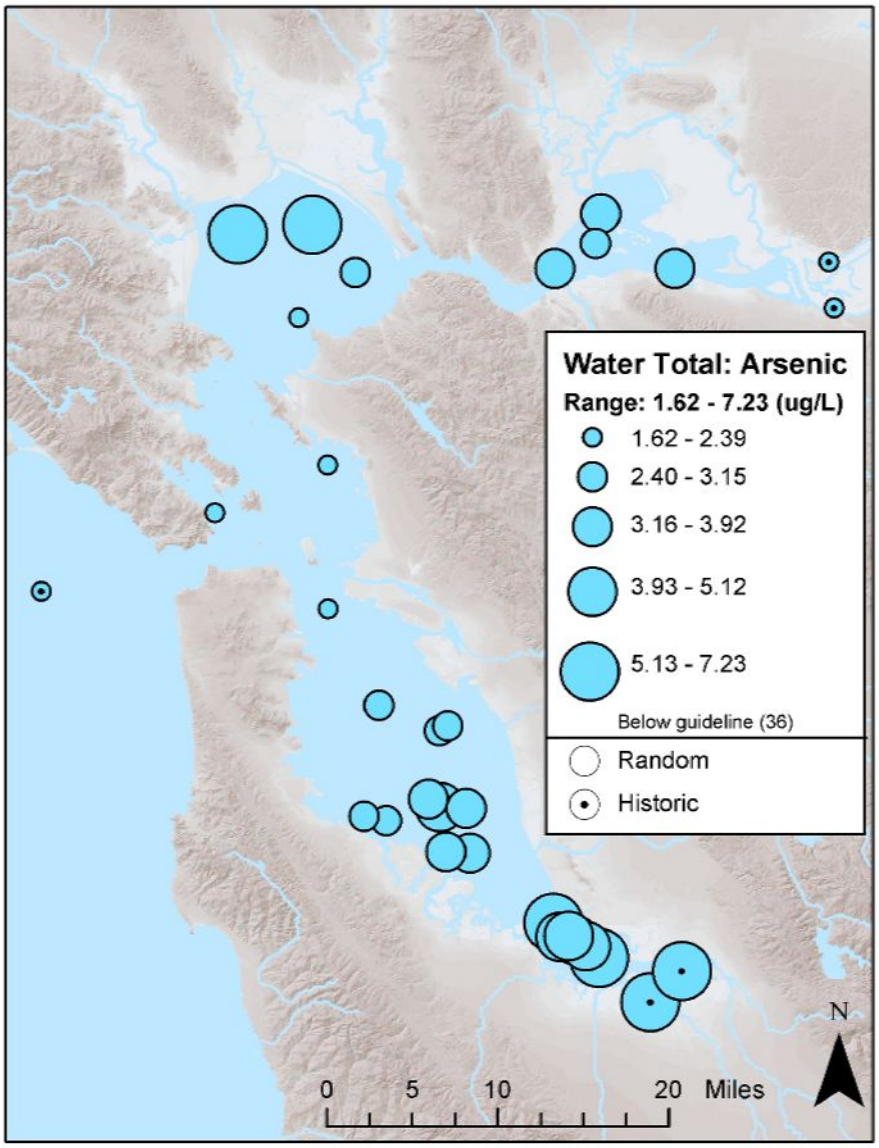


Figure 2.14a. Total arsenic concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold value. All samples were below the non-regulatory effects threshold of 36 µg/L.

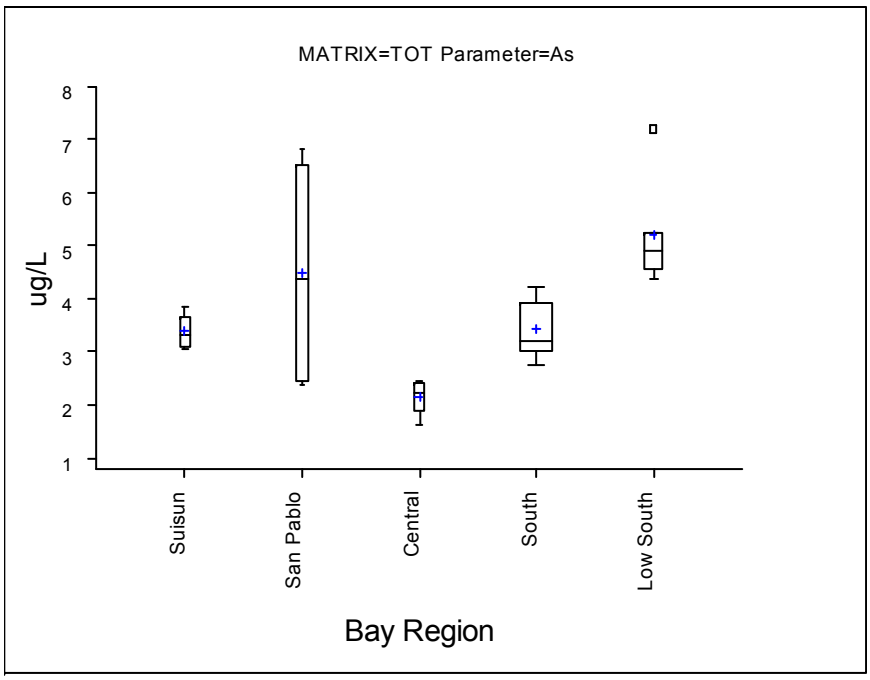


Figure 2.14b. Boxplot of total arsenic concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

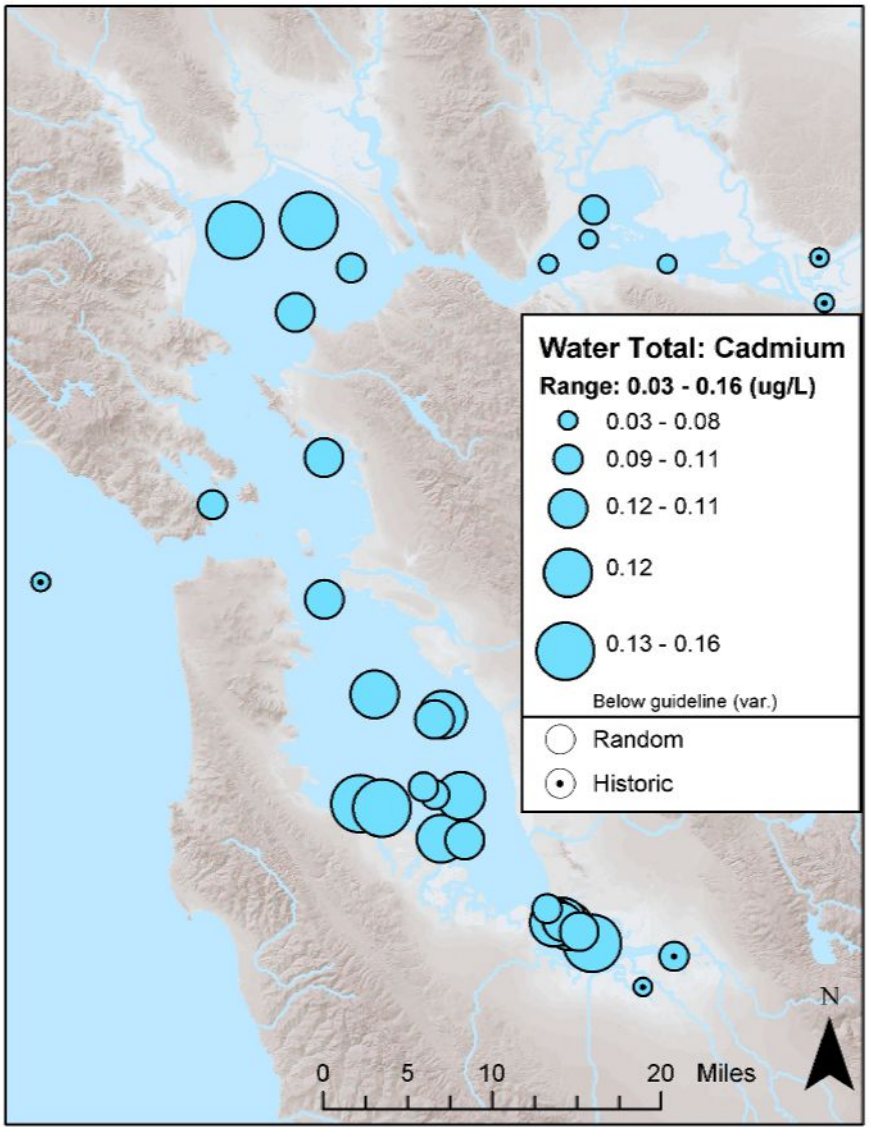


Figure 2.15a. Total cadmium concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values. The cadmium freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below the calculated effects thresholds.

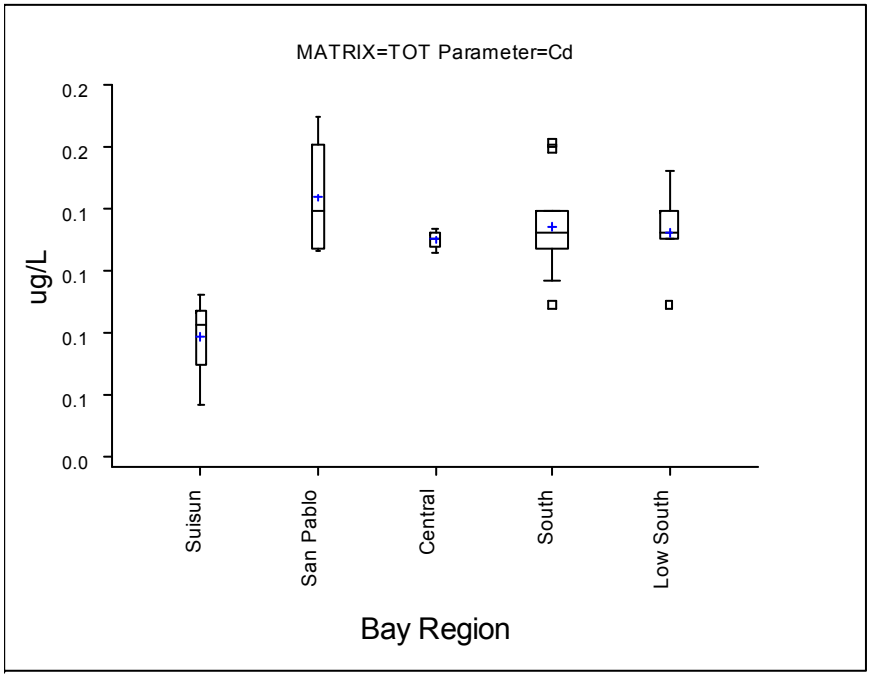


Figure 2.15b. Boxplot of total cadmium concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. Salt LSB is the new site specific water quality objective for the Lower South Bay. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

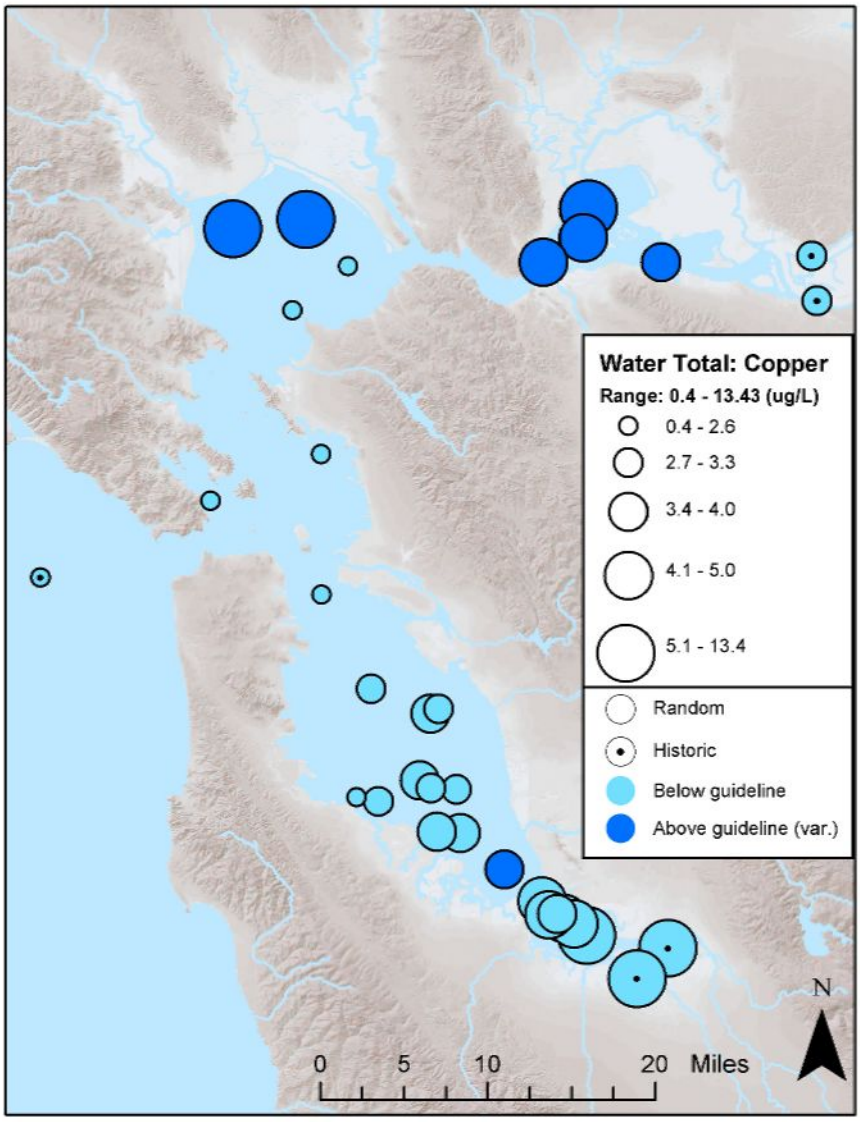


Figure 2.16a. Total copper concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values for all regions except the Lower South Bay where site-specific translators were used resulting in a site-specific objective of 13.02 µg/L for that region. The copper freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). Seven samples were above the calculated effects thresholds.

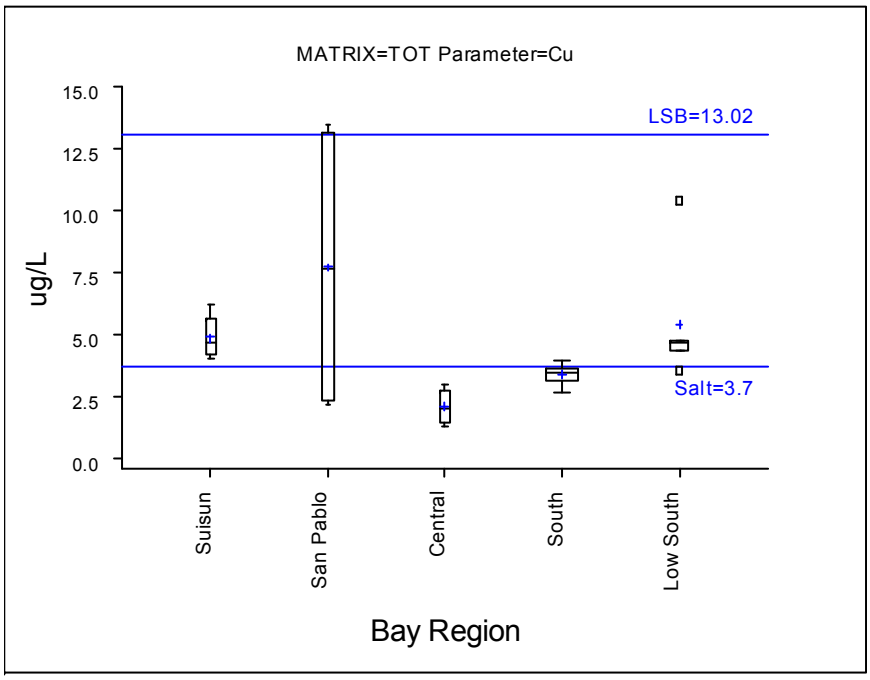


Figure 2.16b. Boxplot of total copper concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

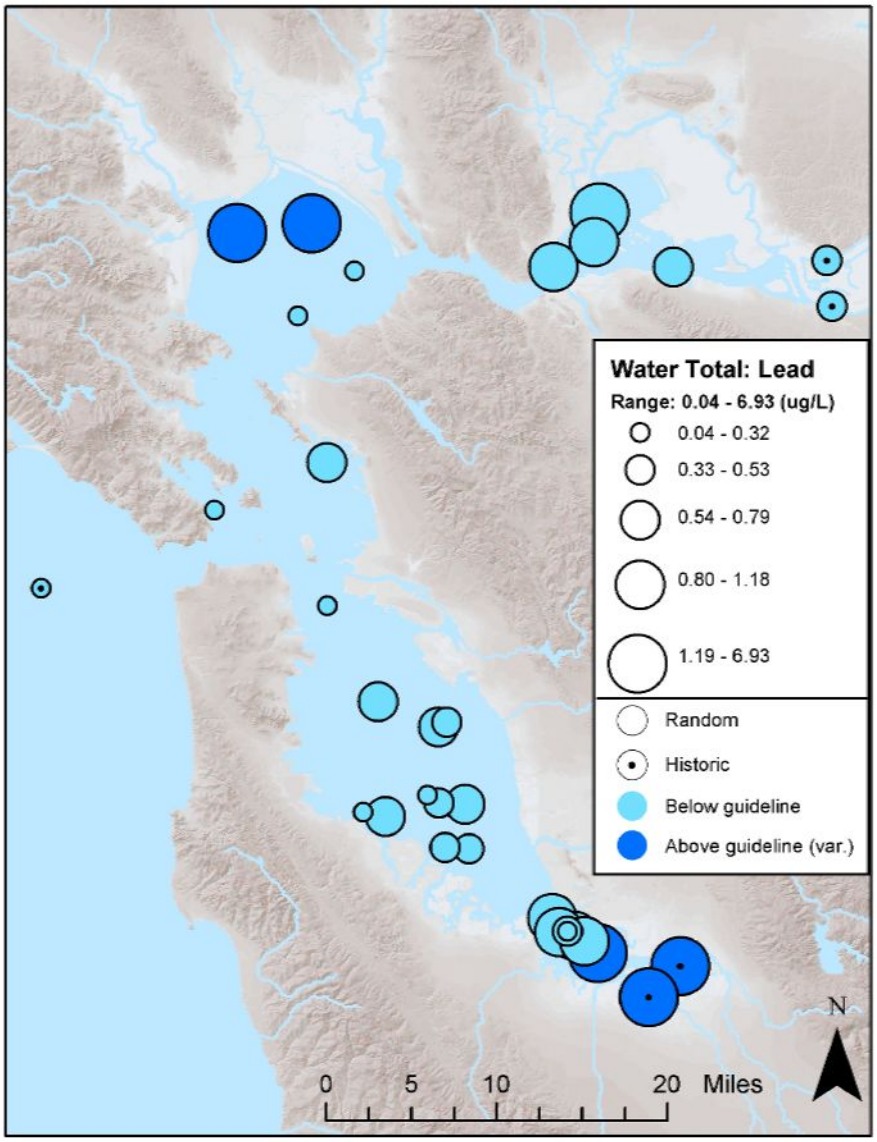


Figure 2.17a. Total lead concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values. The lead freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). Five samples were above the calculated effects thresholds.

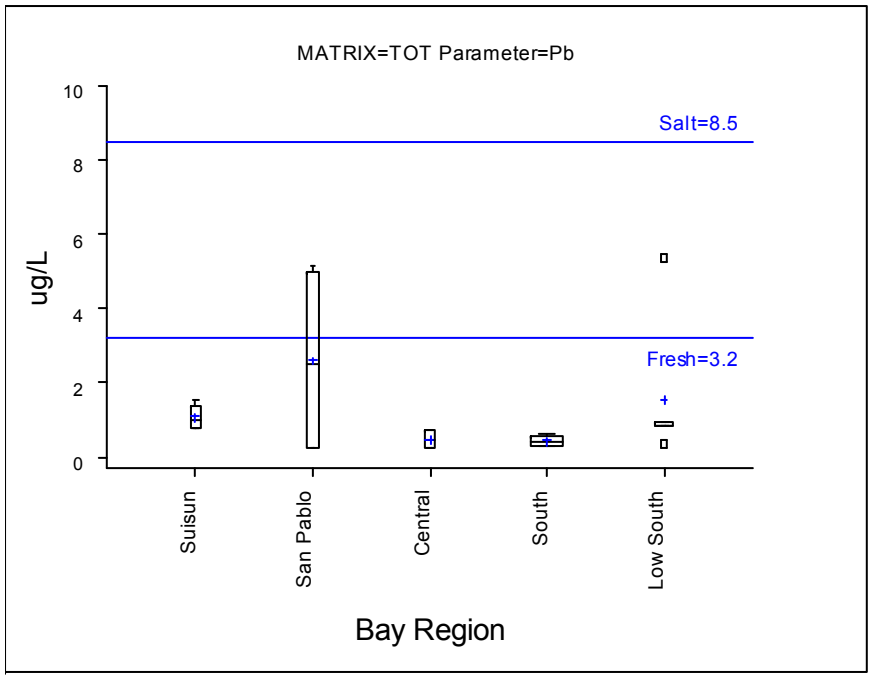


Figure 2.17b. Boxplot of total lead concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

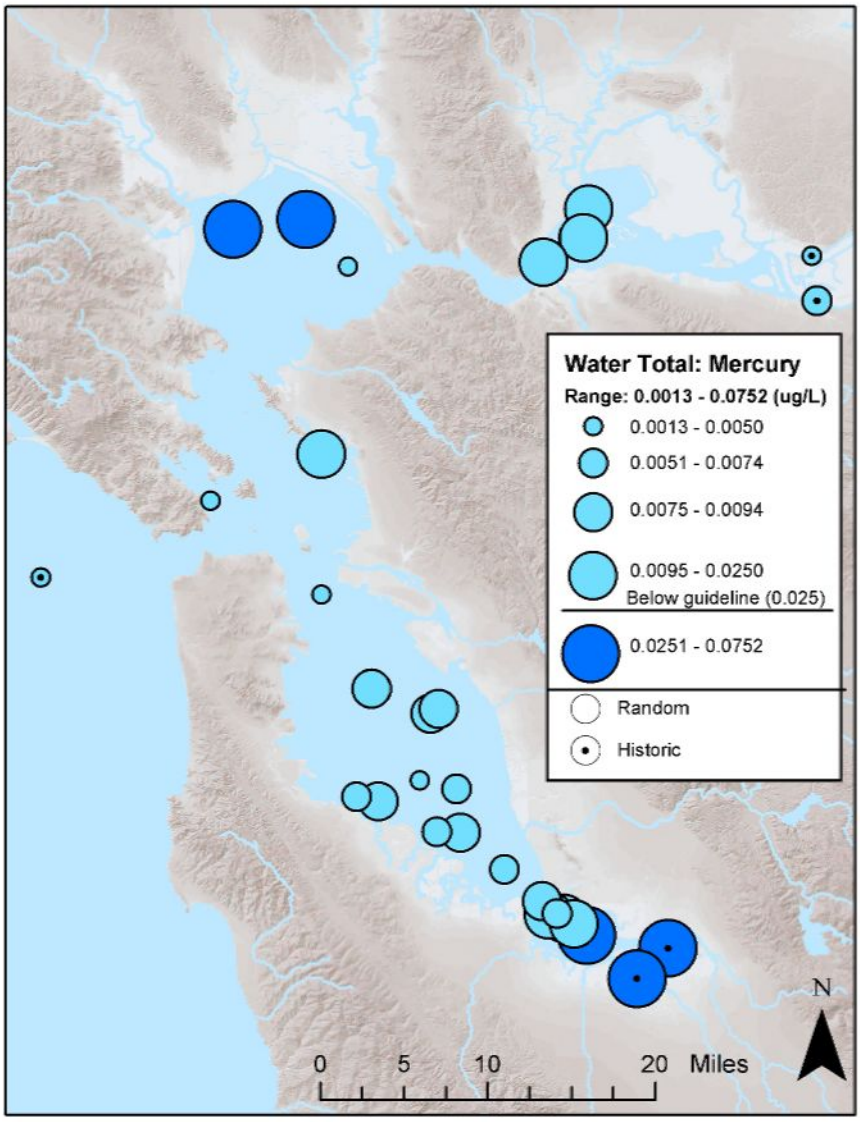


Figure 2.18a. Total mercury concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The Aquatic Life Basin Plan objective of 0.025 µg/L applies to samples north of the Dumbarton Bridge while the CTR Human Health criterion of 0.051 µg/L applies to the Lower South Bay region. Five samples were above these regulatory guidelines.

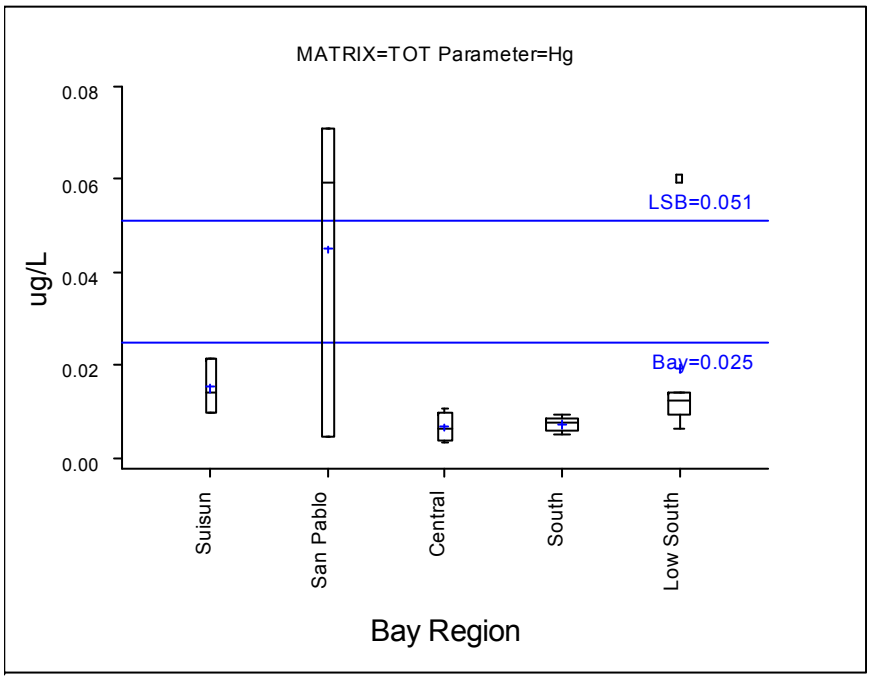


Figure 2.18b. Boxplot of total mercury concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

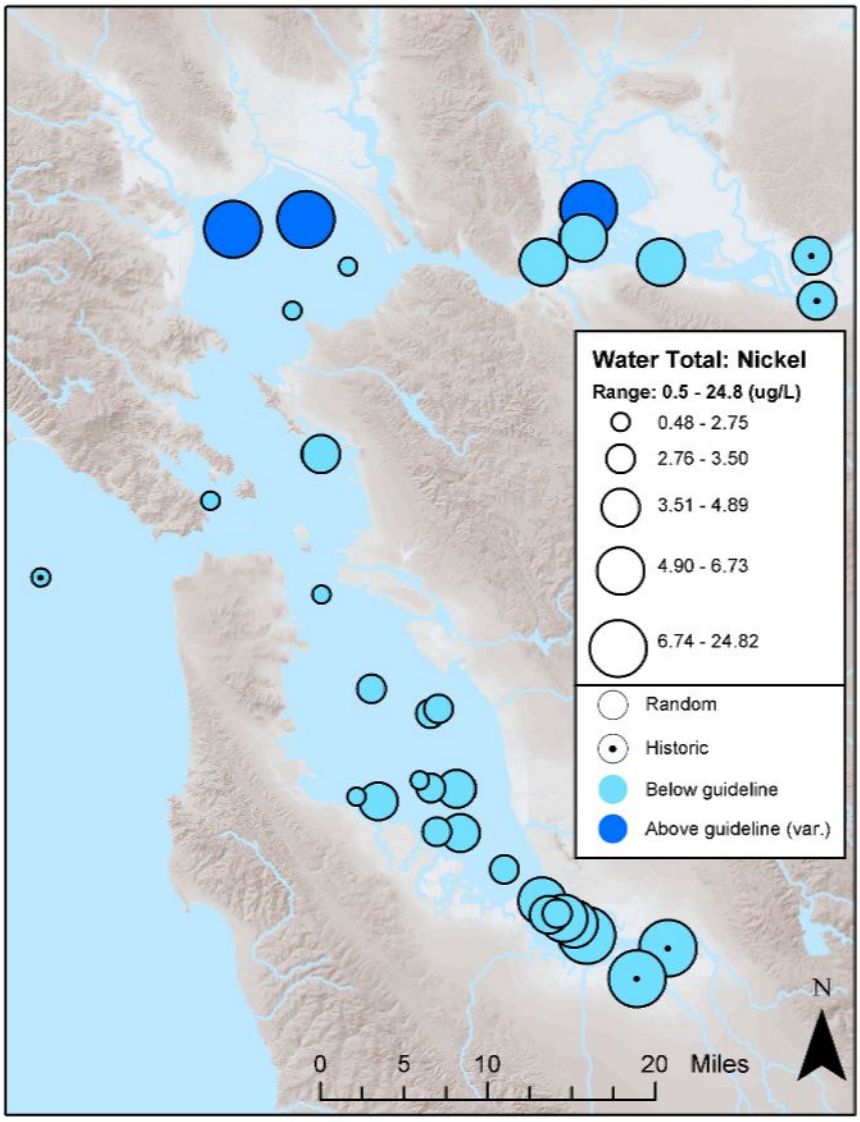


Figure 2.19a. Total nickel concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values. The nickel freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). Three samples were above the calculated effects thresholds.

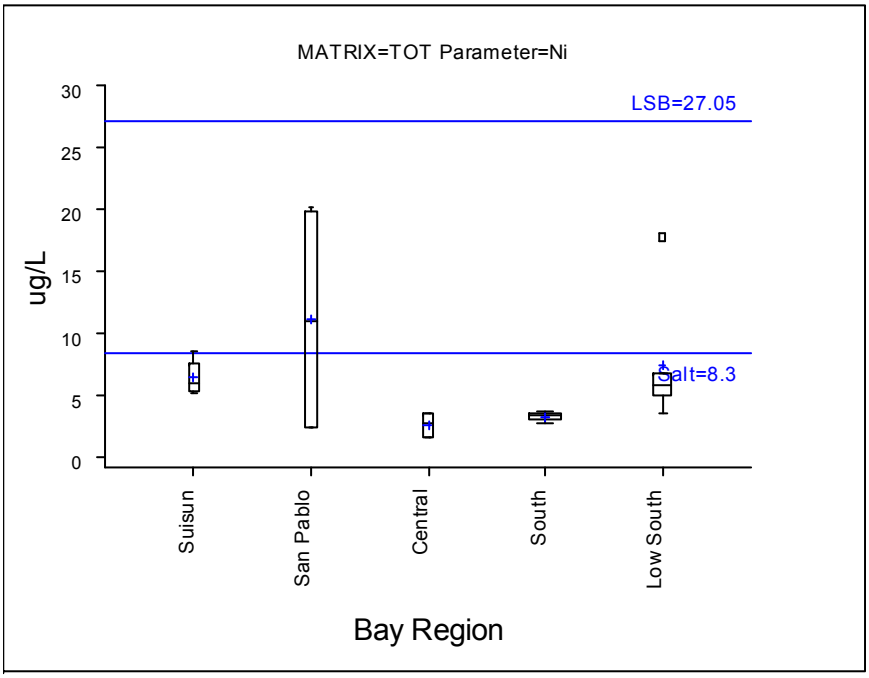


Figure 2.19b. Boxplot of total nickel concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

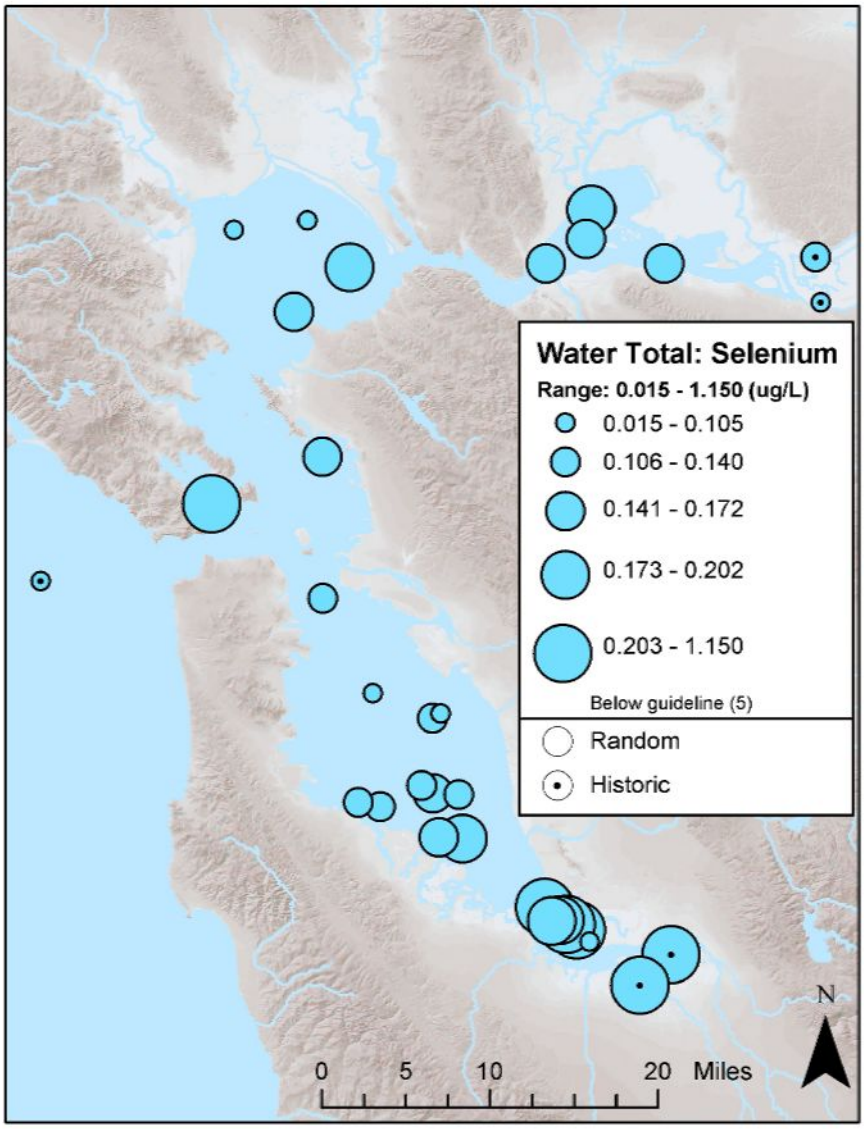


Figure 2.20a. Total selenium concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The CTR freshwater aquatic life chronic criterion of 5 µg/L applies to the whole Estuary. All samples were below this regulatory criterion.

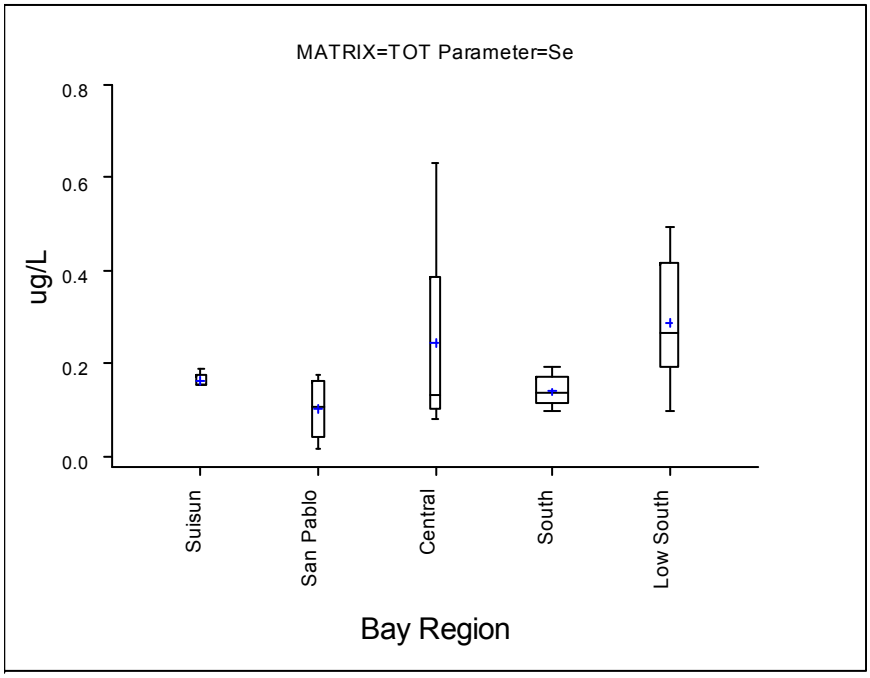


Figure 2.20b. Boxplot of total selenium concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

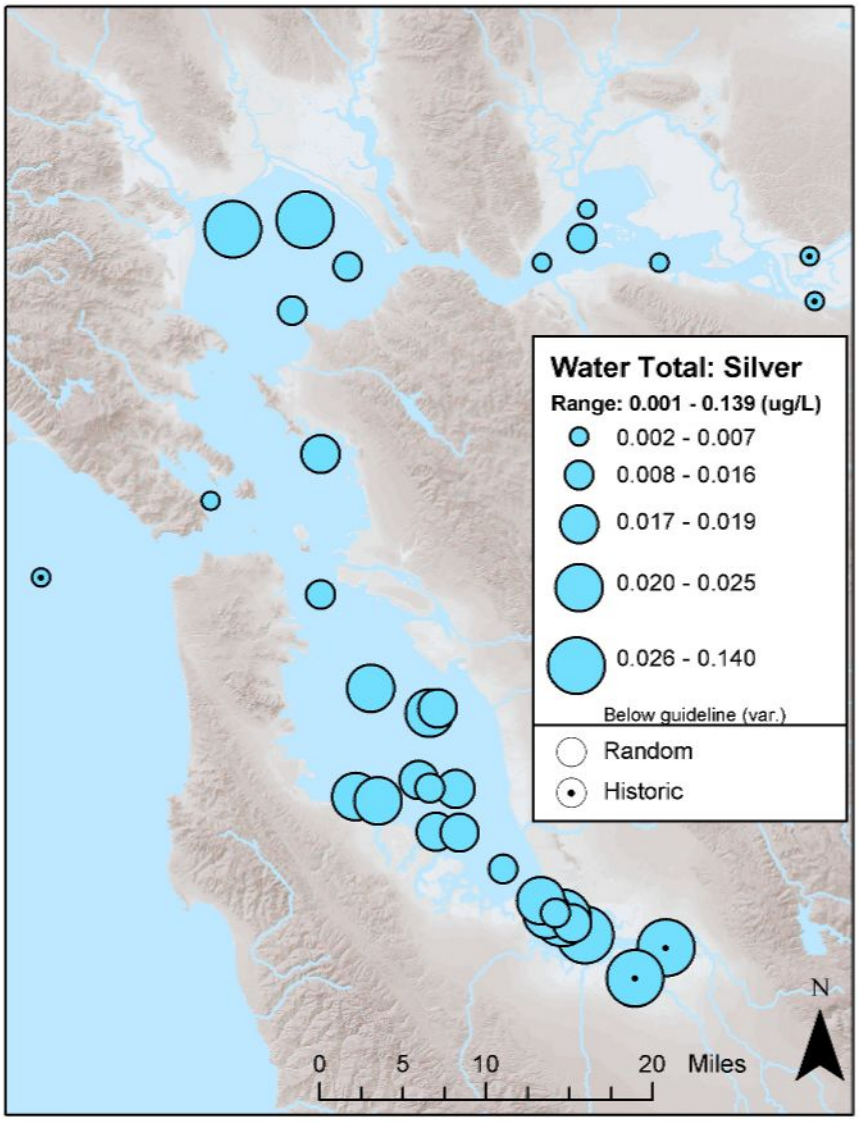


Figure 2.21a. Total silver concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values. The silver freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below the calculated effects thresholds.

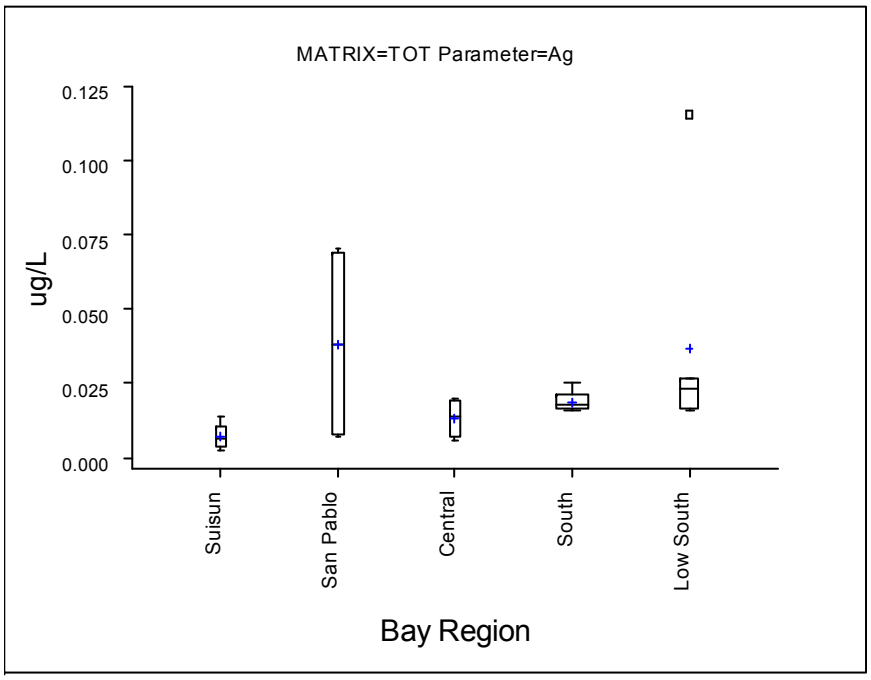


Figure 2.21b. Boxplot of total silver concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

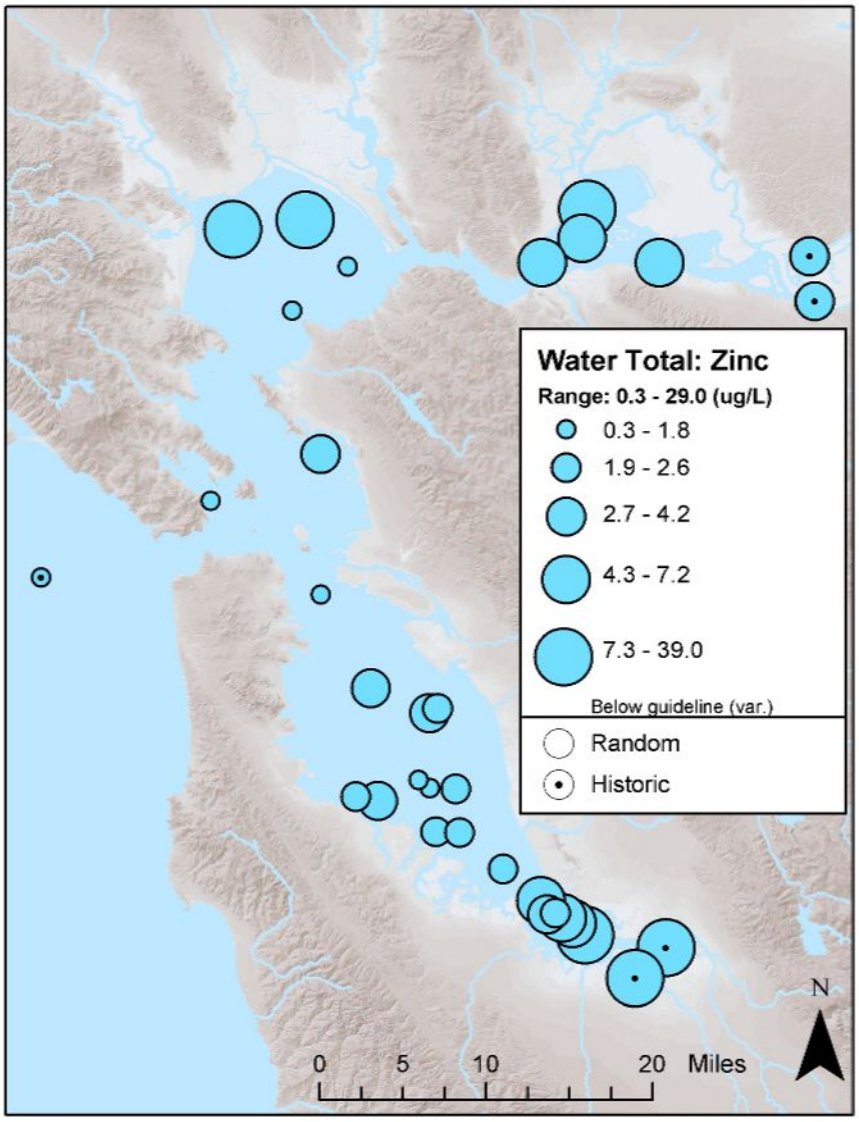


Figure 2.22a. Total zinc concentrations in water (µg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Default CTR conversion factors were used to calculate the total effects threshold values. The zinc freshwater threshold values are hardness dependent and therefore salt and freshwater values were calculated and compared separately for each estuarine sample (the guidelines were site-specific and varied (var.) throughout the Estuary). All samples were below the calculated effects thresholds.

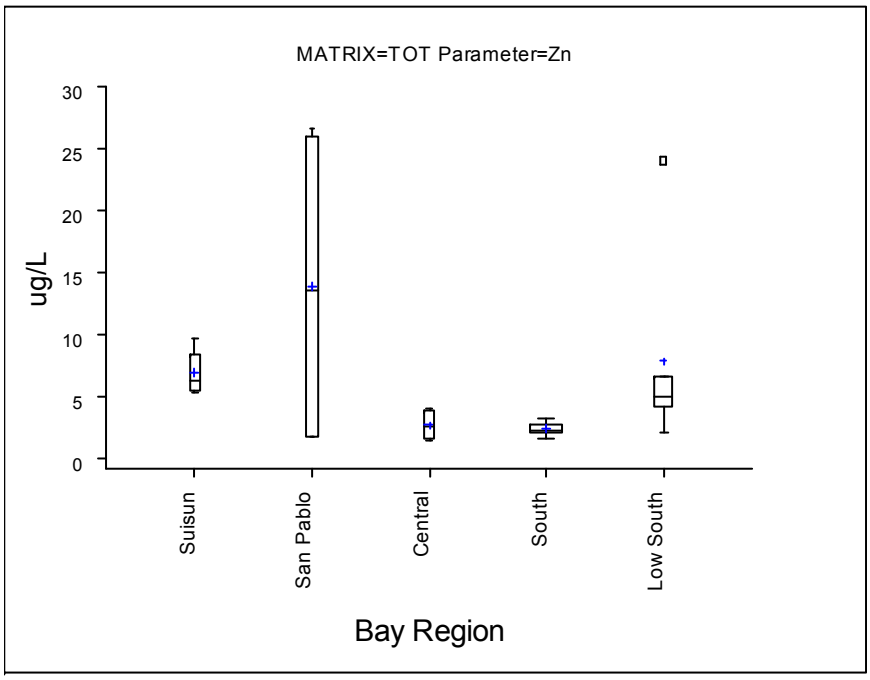


Figure 2.22b. Boxplot of total zinc concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

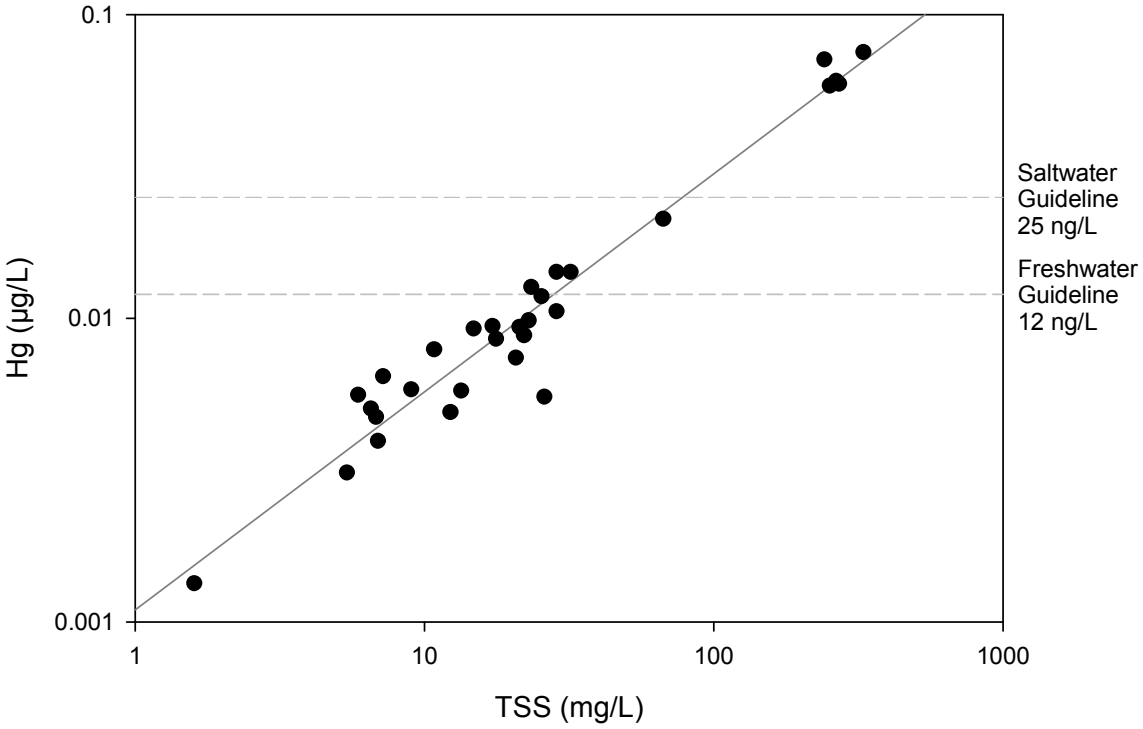


Figure 2.23. Relationship of total mercury concentrations and total suspended solids (TSS) in RMP water samples collected in July 2002.

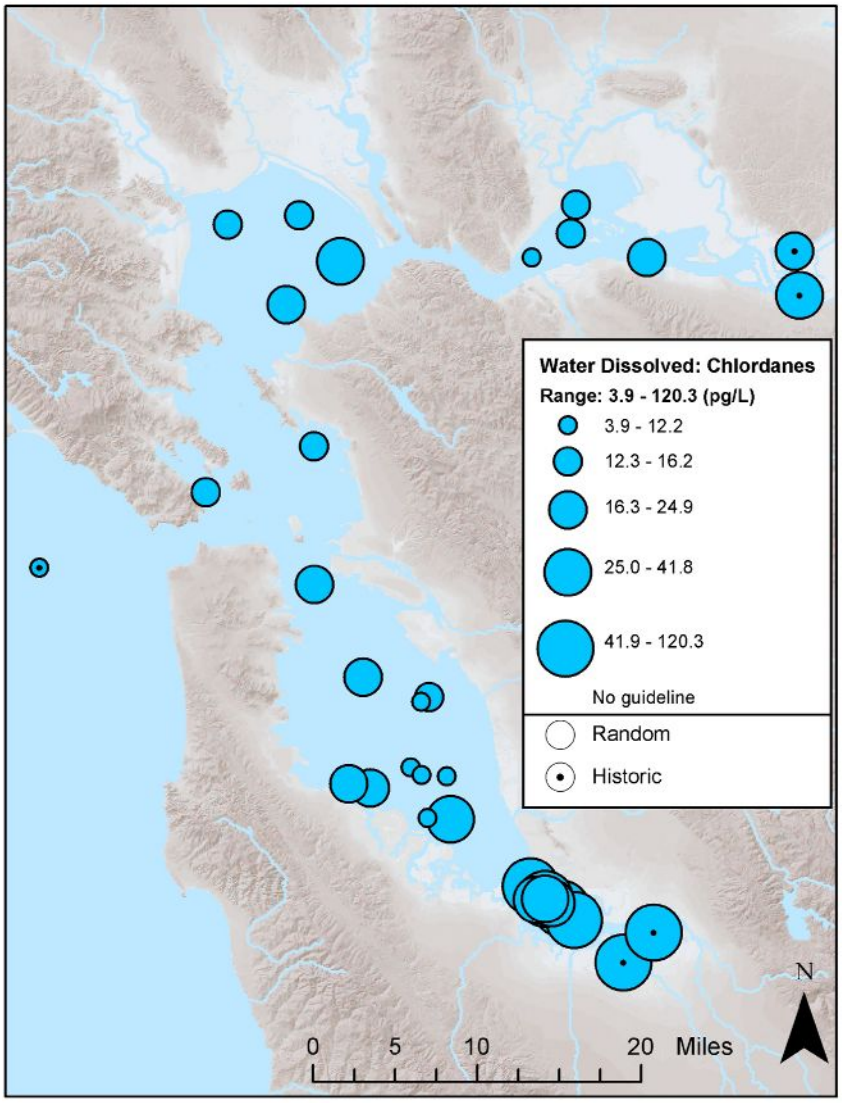


Figure 2.24a. Dissolved ΣChlordane concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

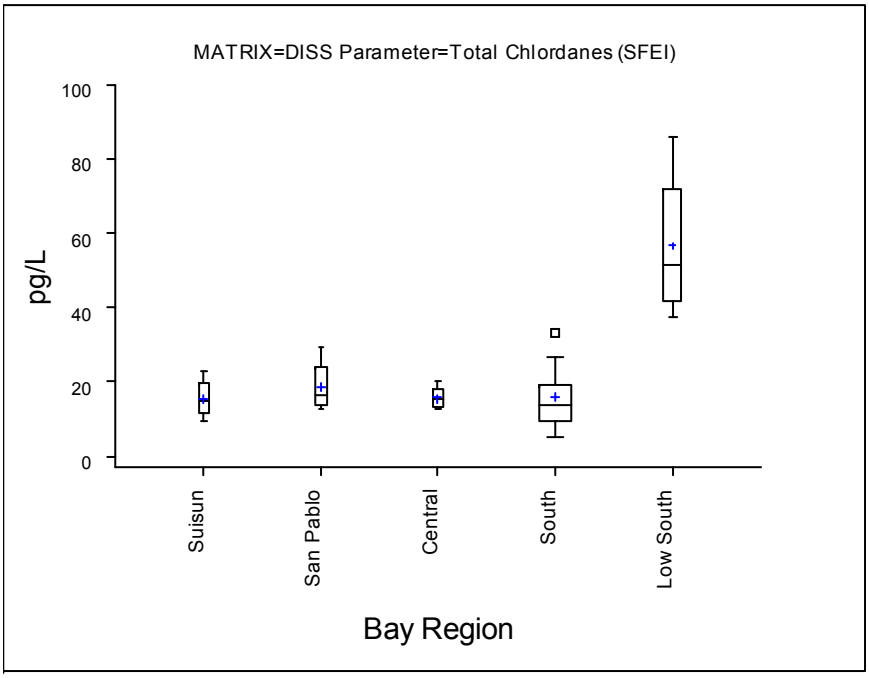


Figure 2.24b. Boxplot of dissolved ΣChlordane concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

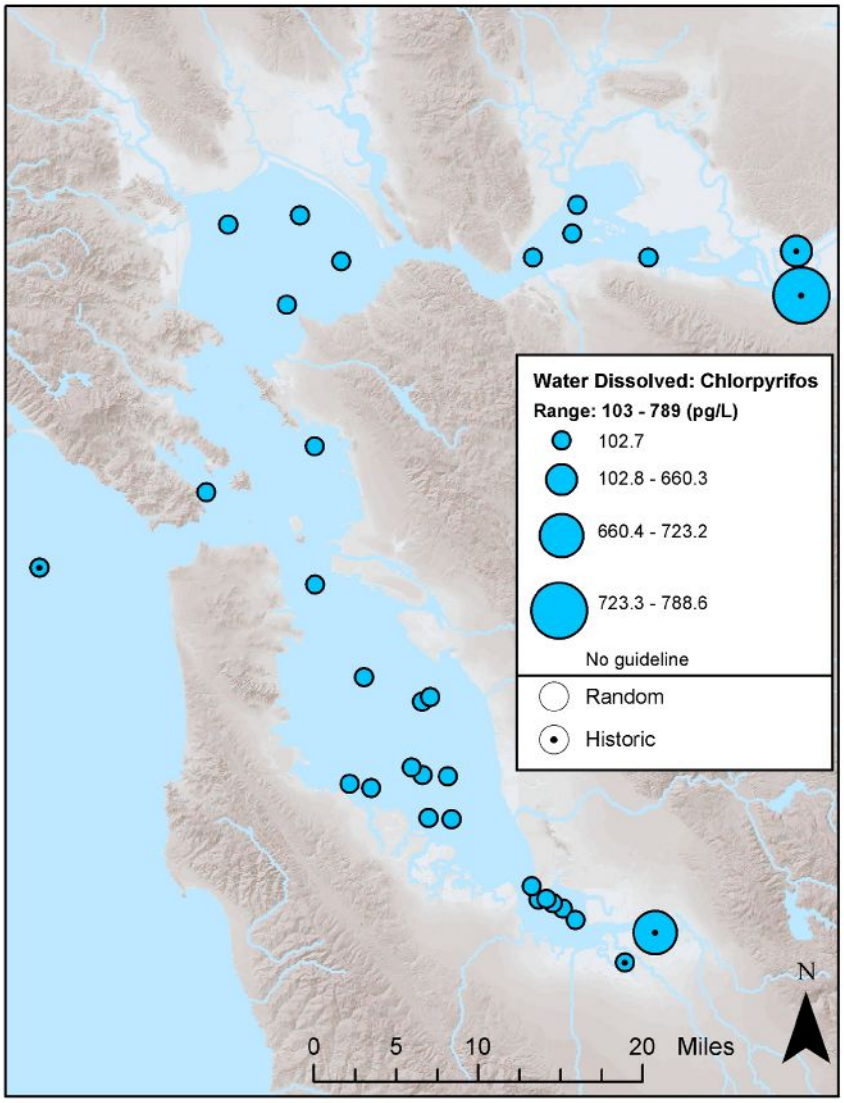


Figure 2.25a. Dissolved chlorpyrifos concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis. All but three samples were below the method detection limit of 205 pg/L (1/2 the MDL is reported here for samples qualified as not detected (ND)).

No Boxplot available as all but three sites were ND.

Figure 2.25b. Boxplot of dissolved chlorpyrifos concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

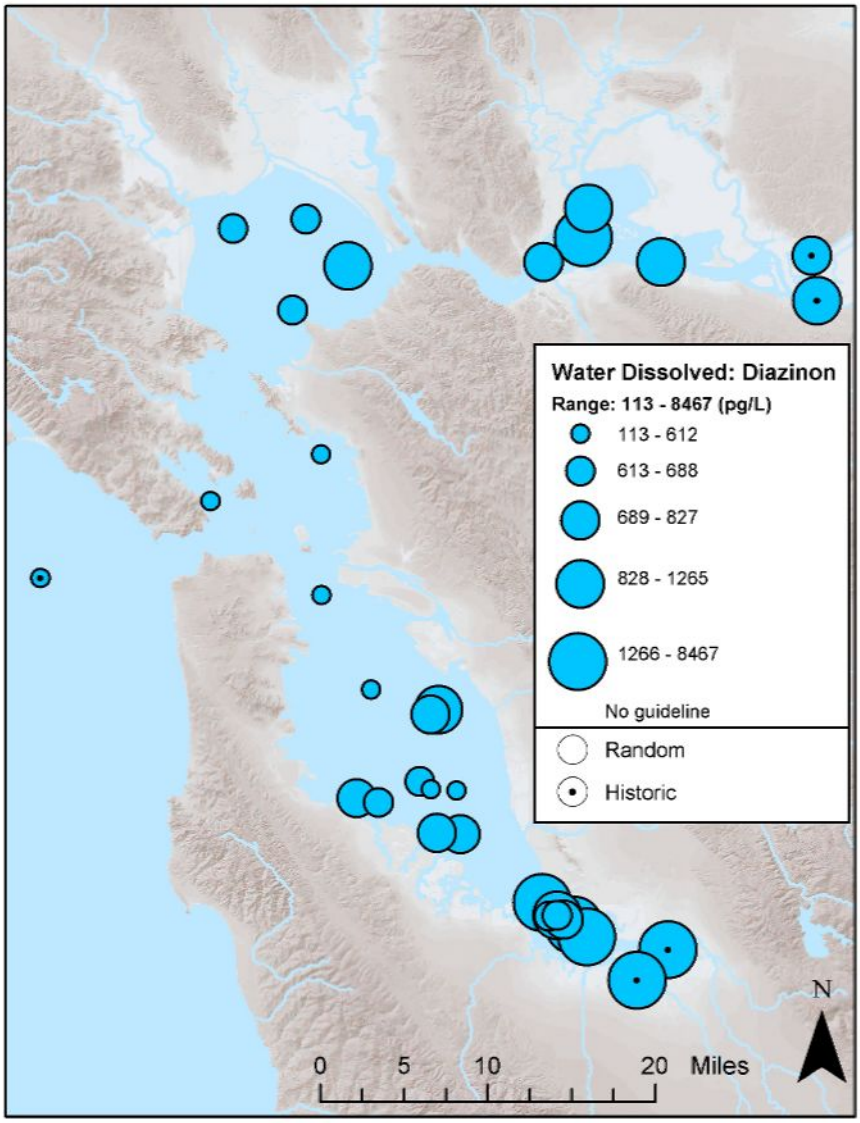


Figure 2.26a. Dissolved diazinon concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

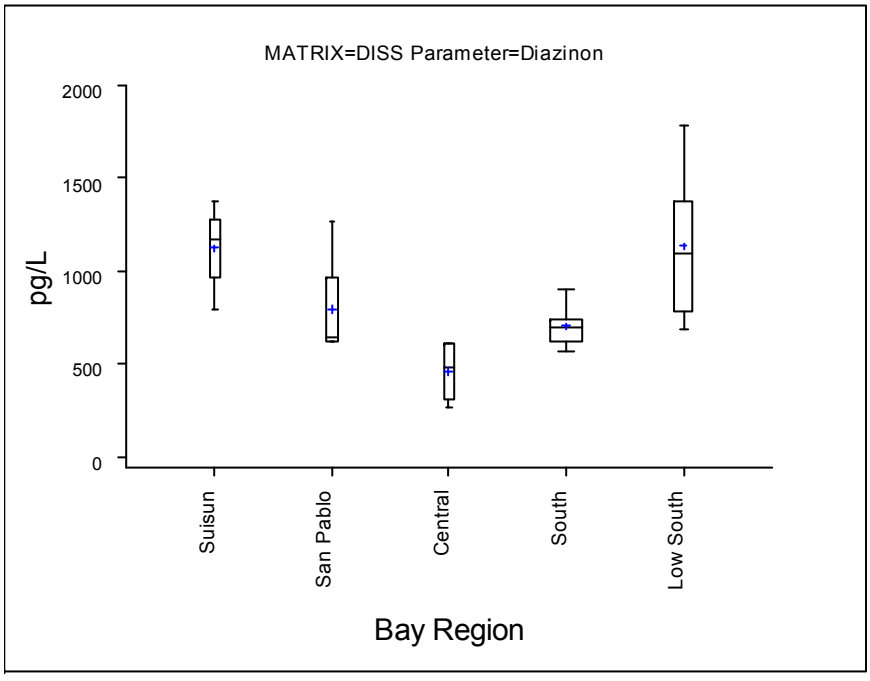


Figure 2.26b. Boxplot of dissolved diazinon concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002.
Salt LSB is the new site specific water quality objective for the Lower South Bay. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

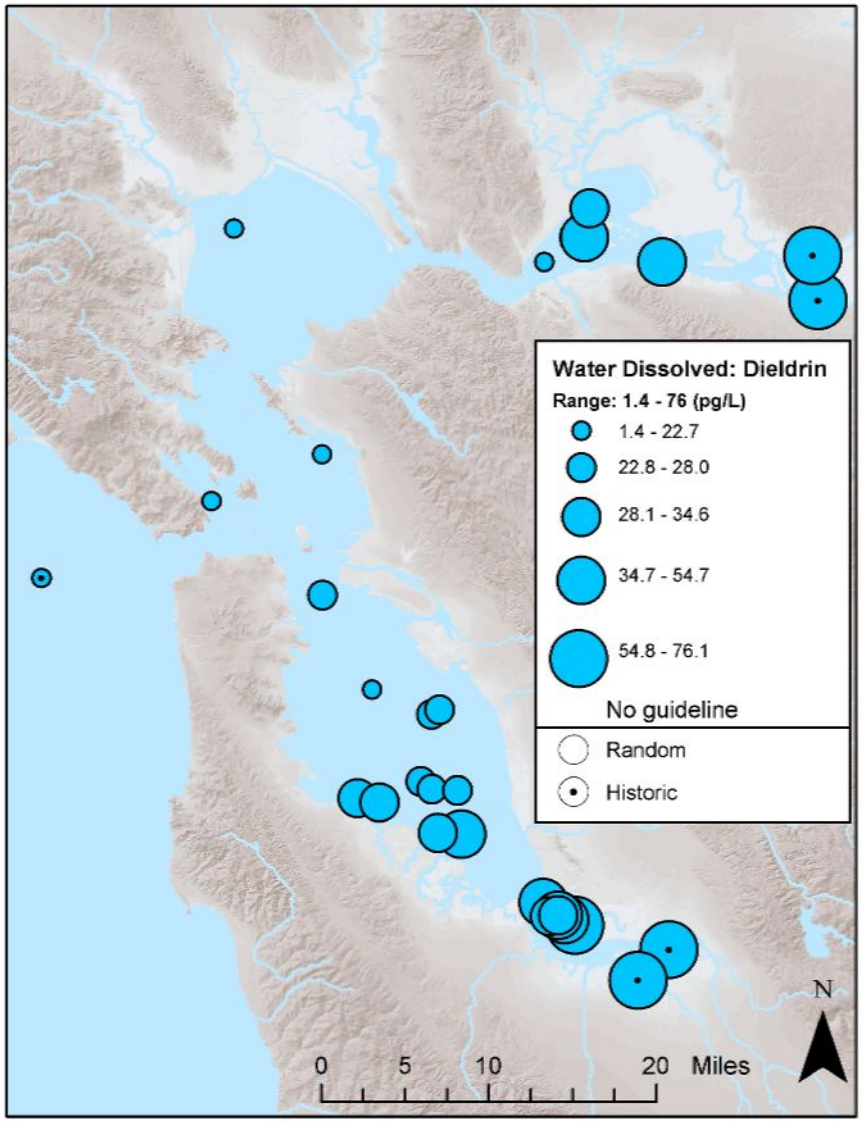


Figure 2.27a. Dissolved dieldrin concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

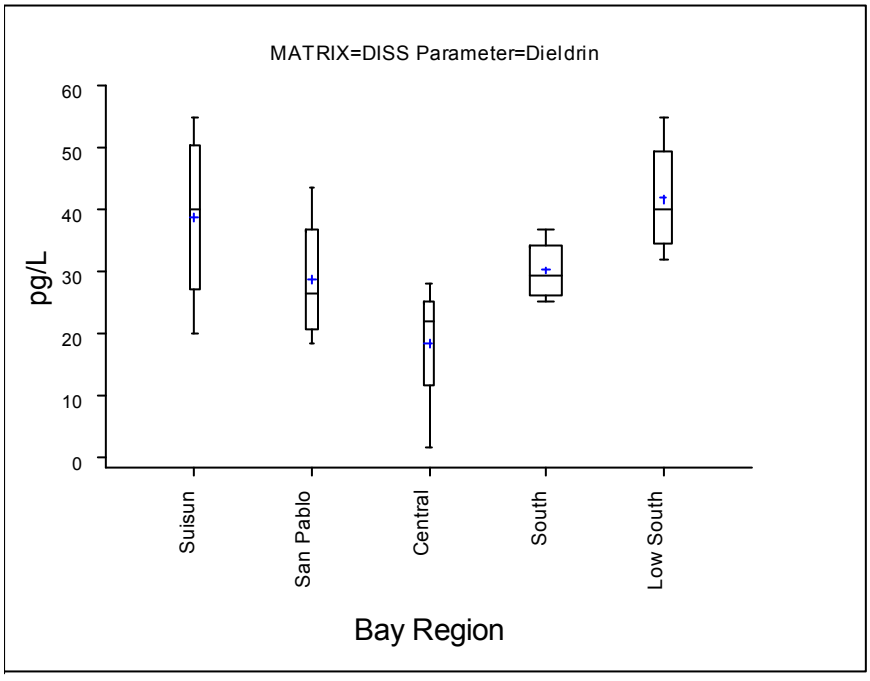


Figure 2.27b. Boxplot of dissolved dieldrin concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

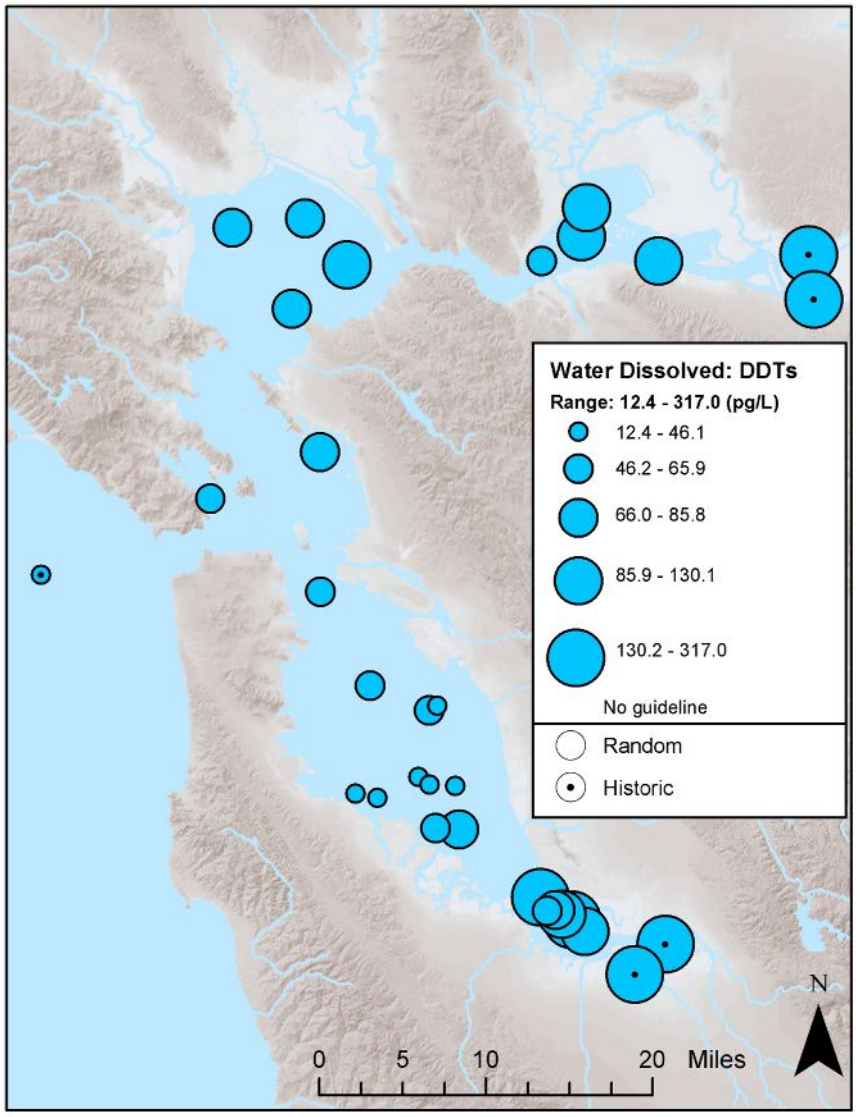


Figure 2.28a. Dissolved ΣDDT concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

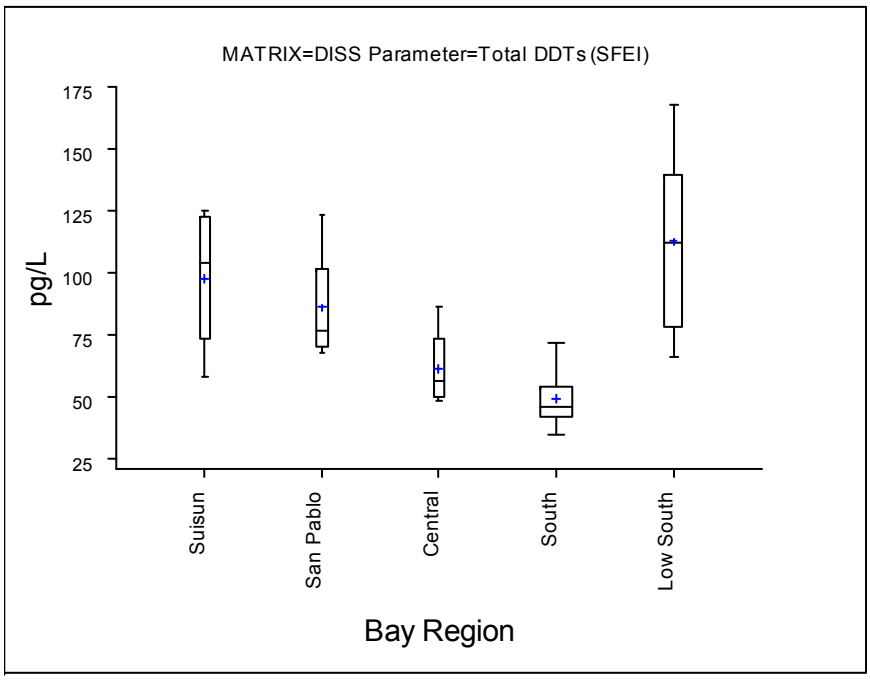


Figure 2.28b. Boxplot of dissolved ΣDDT concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

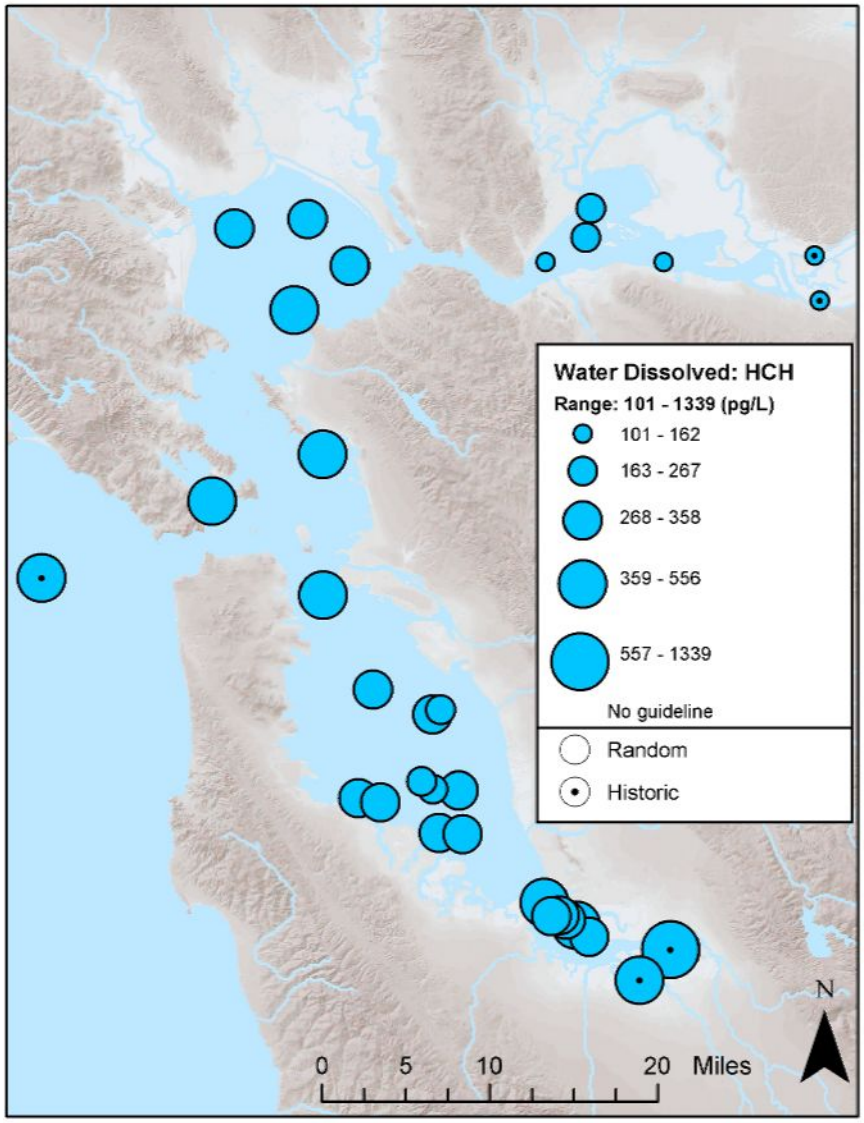


Figure 2.29a. Dissolved ΣHCH concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

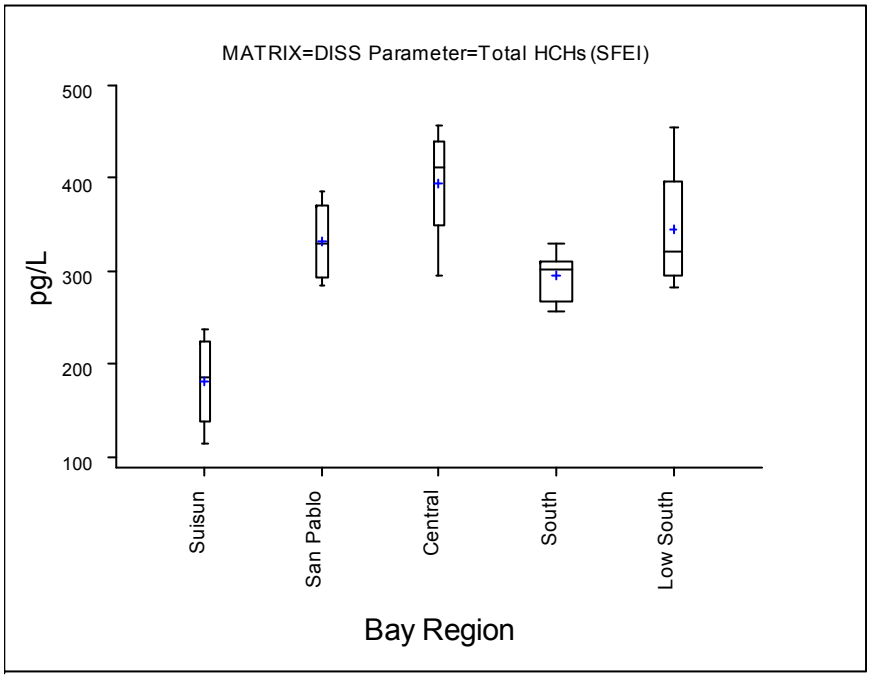


Figure 2.29b. Boxplot of dissolved ΣHCH concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

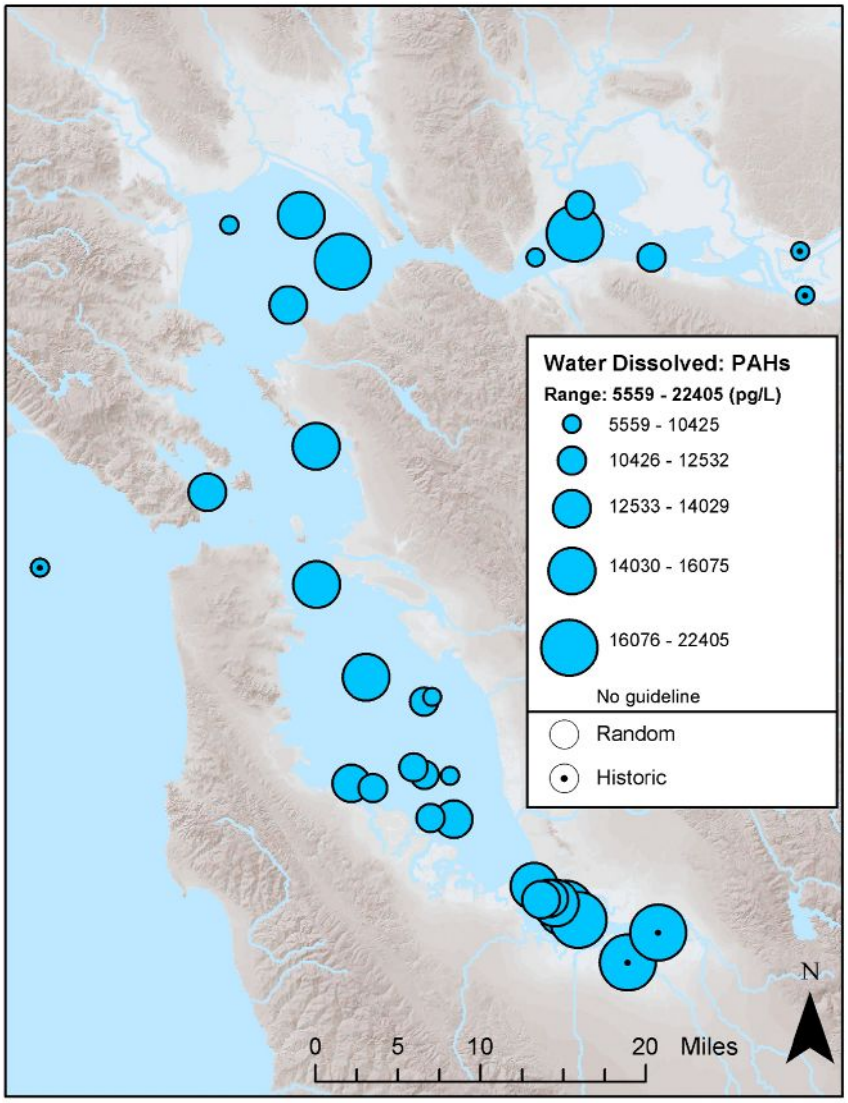


Figure 2.30a. Dissolved ΣPAH concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

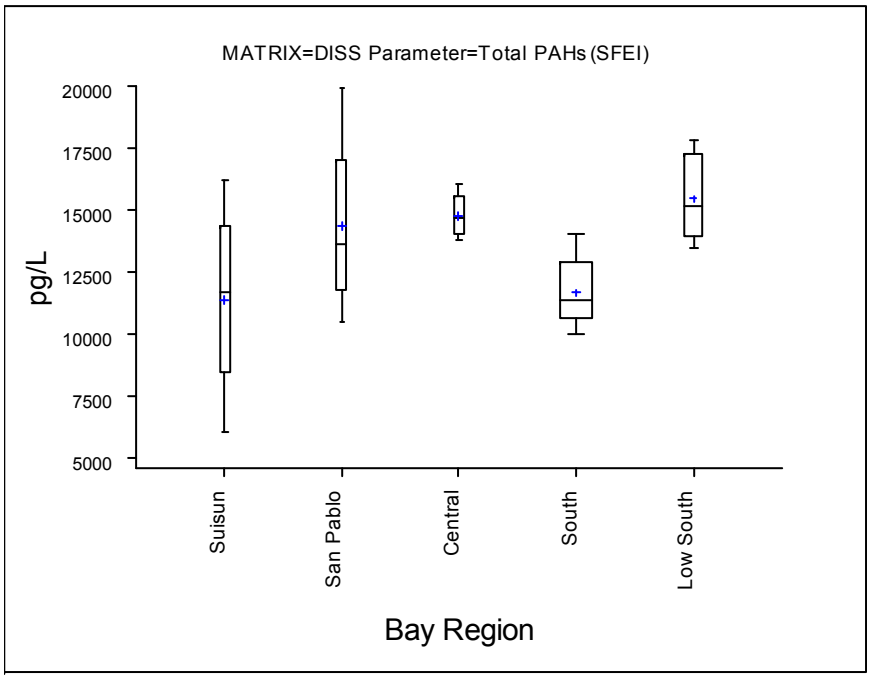


Figure 2.30b. Boxplot of dissolved ΣPAH concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

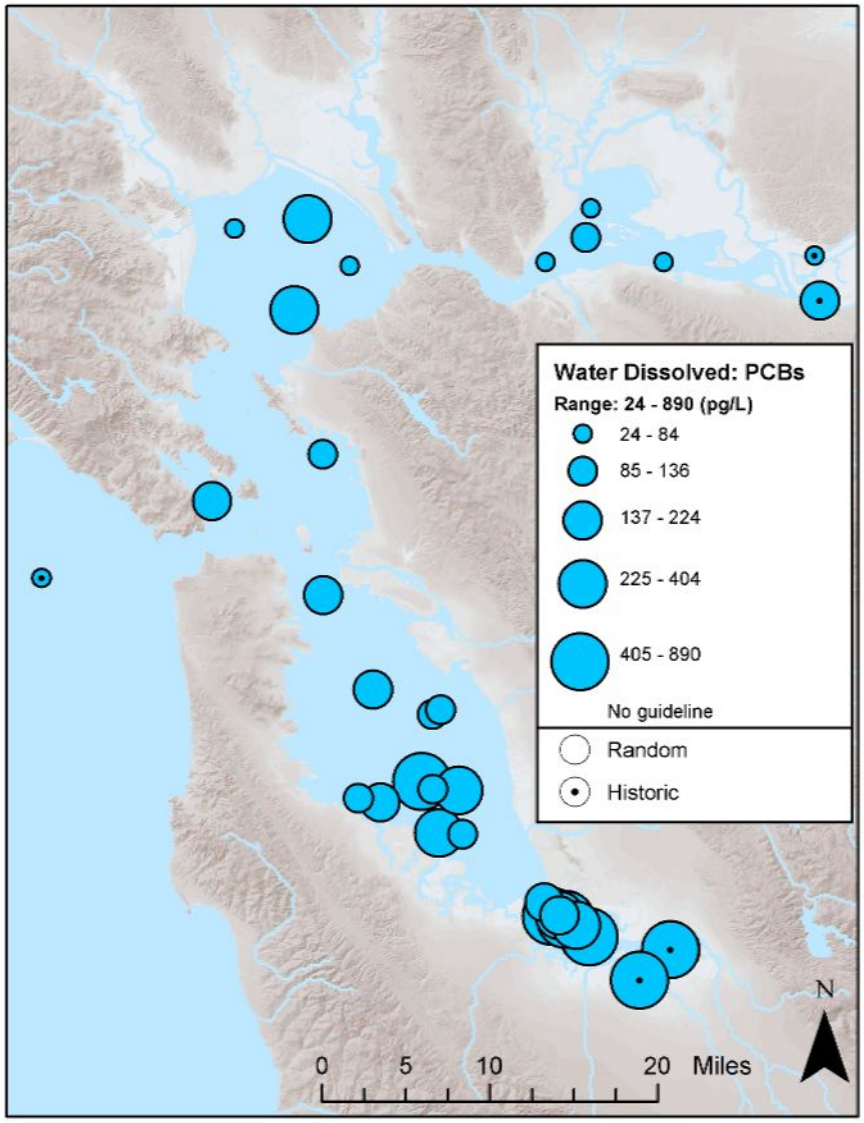


Figure 2.31a. Dissolved ΣPCB concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Organic contaminants are compared to guidelines on a total basis.

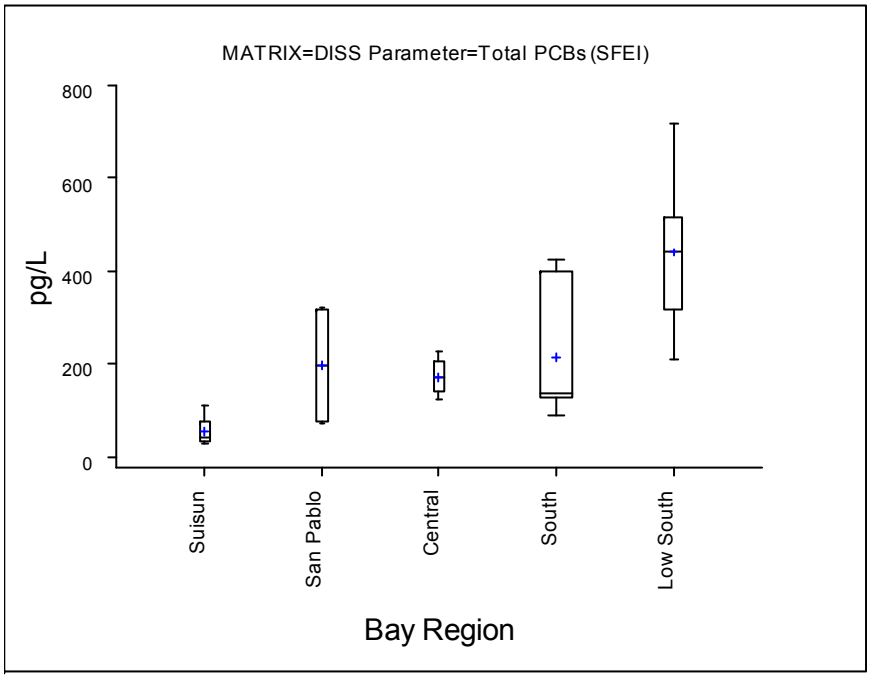


Figure 2.31b. Boxplot of dissolved ΣPCB concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

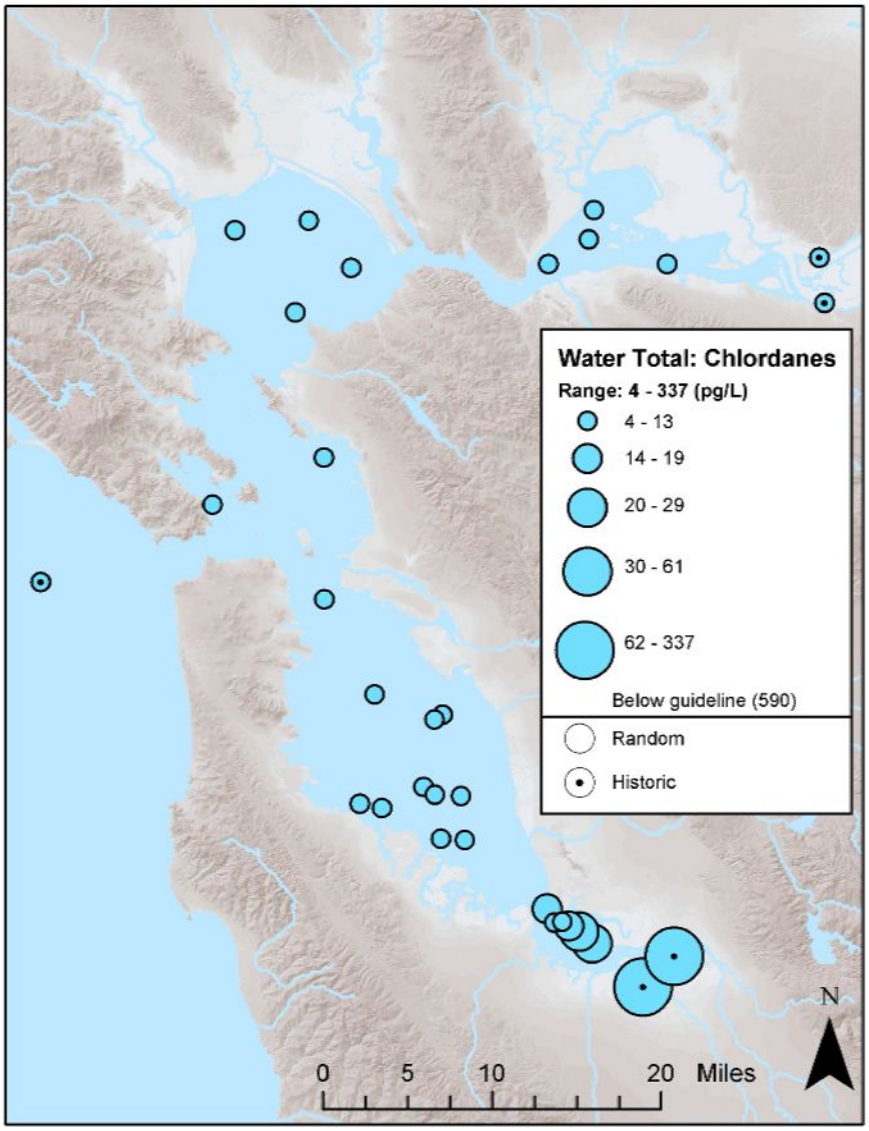


Figure 2.32a. Total ΣChlordane concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. All samples were below the regulatory CTR human health criterion of 590 pg/L.

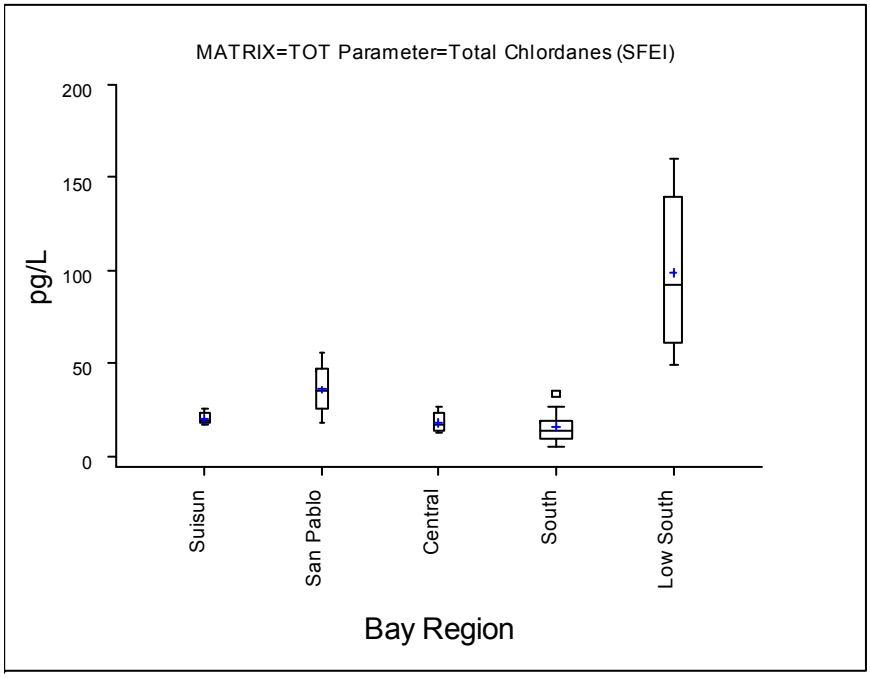


Figure 2.32b. Boxplot of total ΣChlordane concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

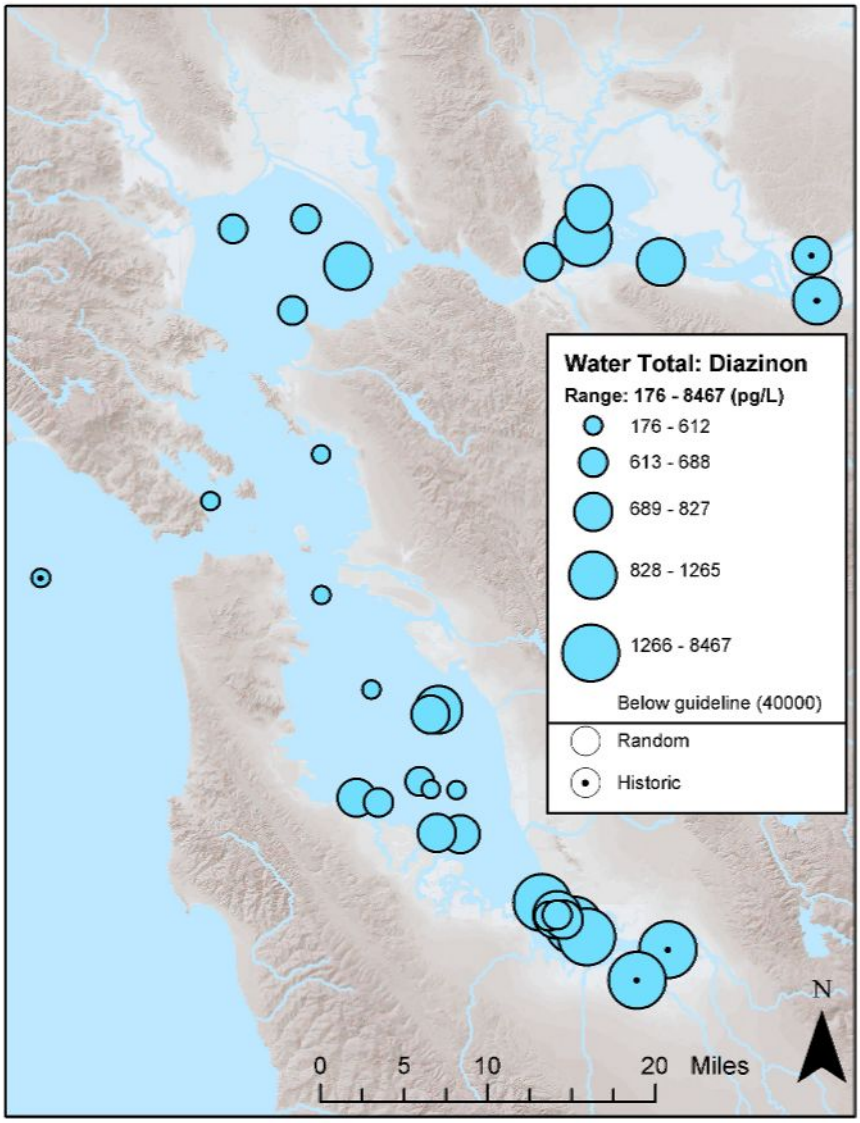


Figure 2.33a. Total diazinon concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. All samples were below then non-regulatory CA-Department of Fish & Game effects threshold of 40,000 pg/L.

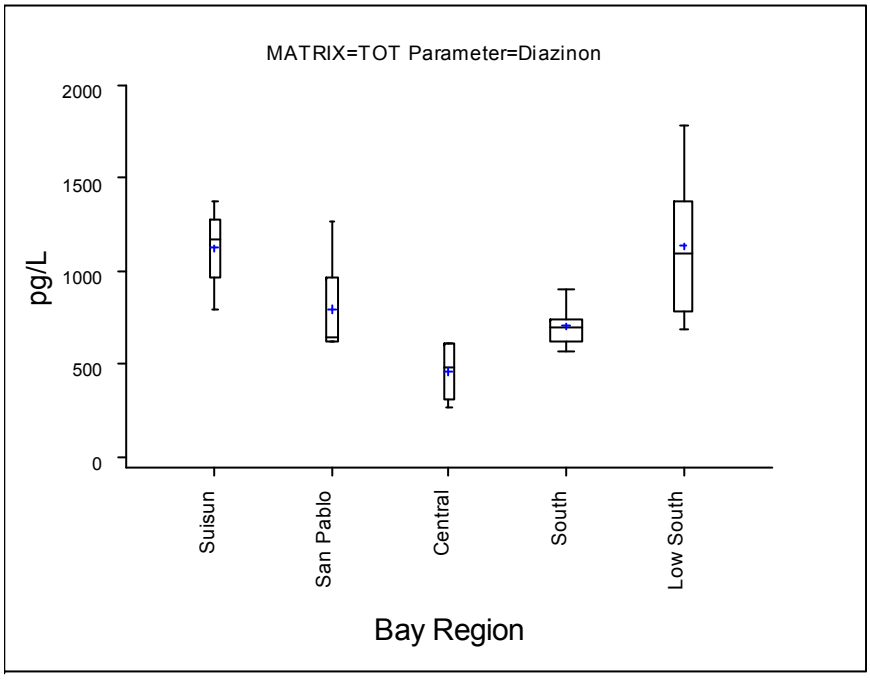


Figure 2.33b. Boxplot of total diazinon concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002.
Salt LSB is the new site specific water quality objective for the Lower South Bay. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

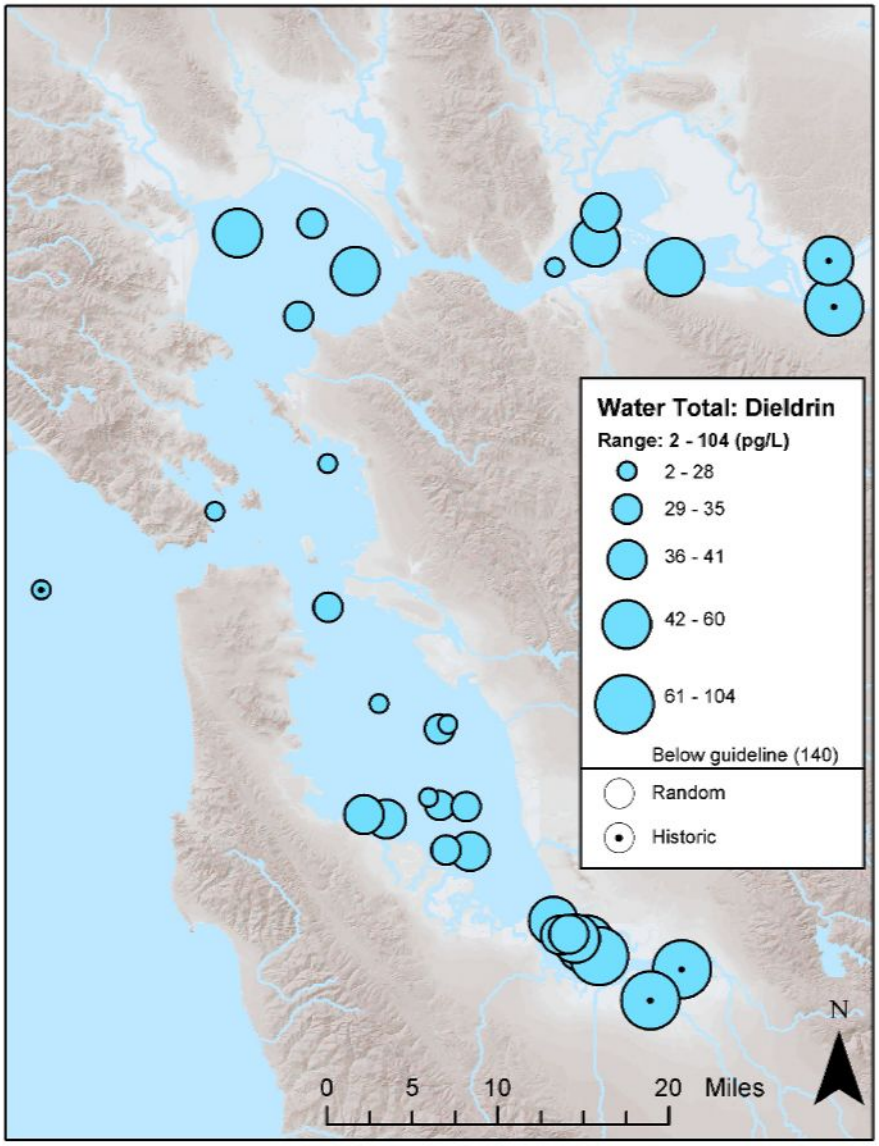


Figure 2.34a. Total dieldrin concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. . All samples were below the regulatory CTR human health criterion of 140 pg/L.

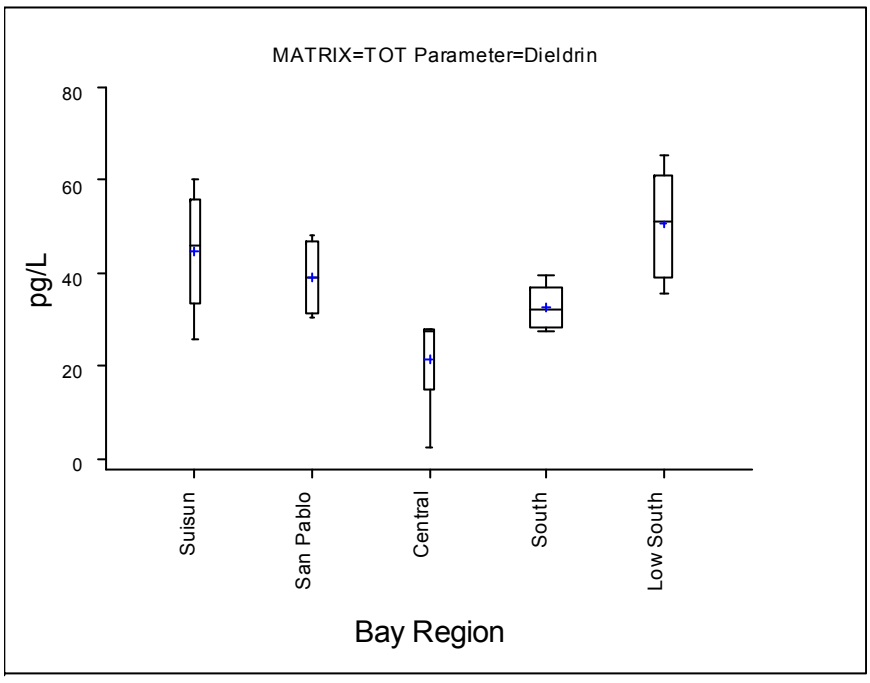


Figure 2.34b. Boxplot of total dieldrin concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

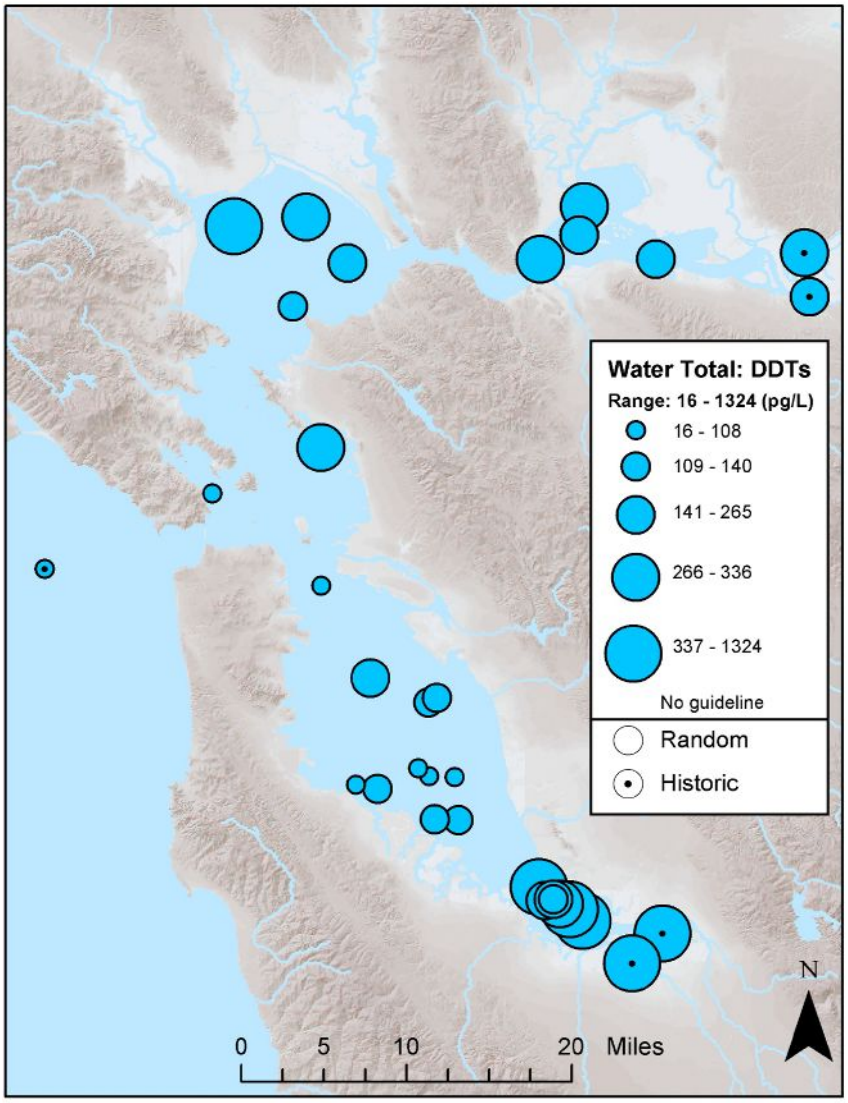


Figure 2.35a. Total ΣDDT concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. No guideline for total DDTs is available. The regulatory CTR criteria are for individual DDT compounds only. None of the samples were above any of those compound specific CTR Human Health criteria.

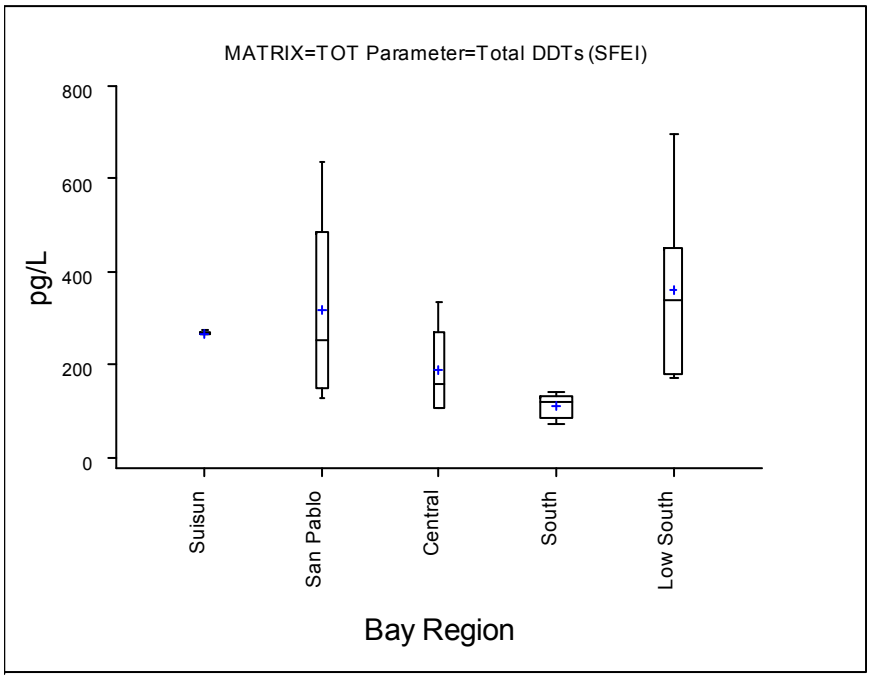


Figure 2.35b. Boxplot of total ΣDDT concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

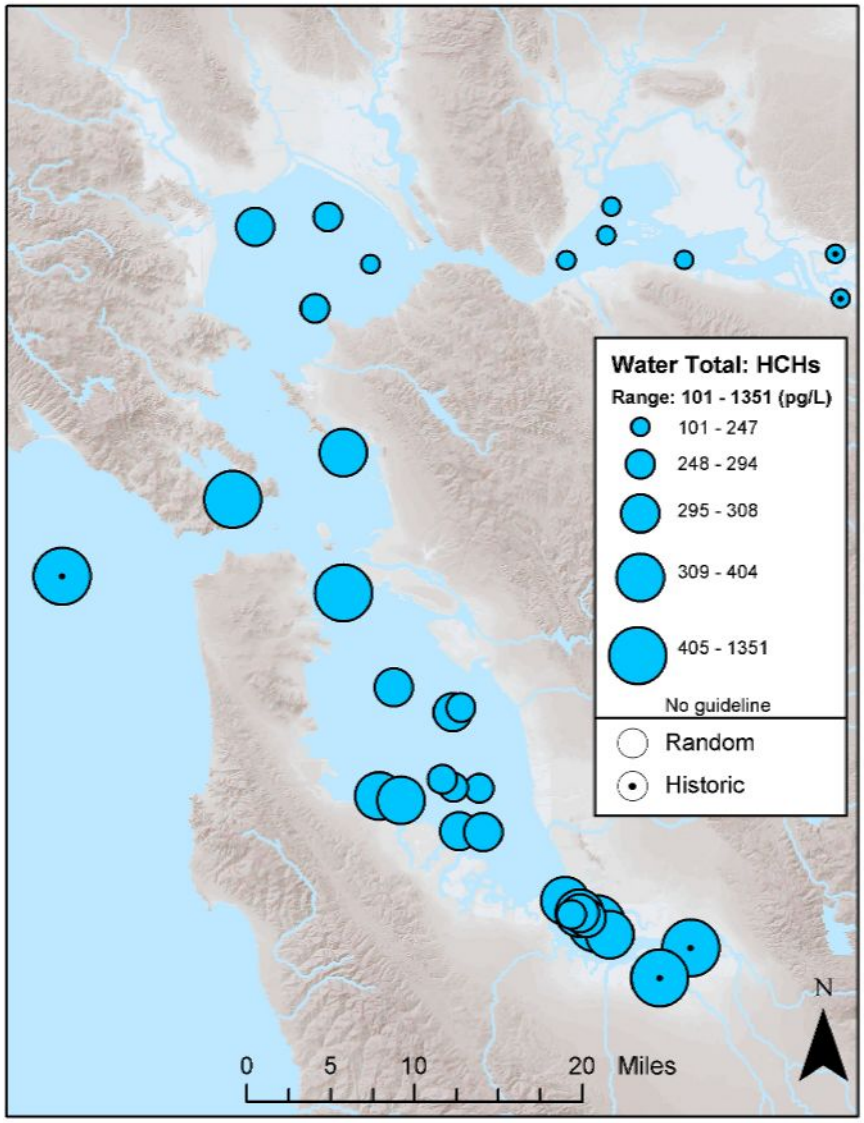


Figure 2.36a. Total ΣHCH concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. No guideline is available.

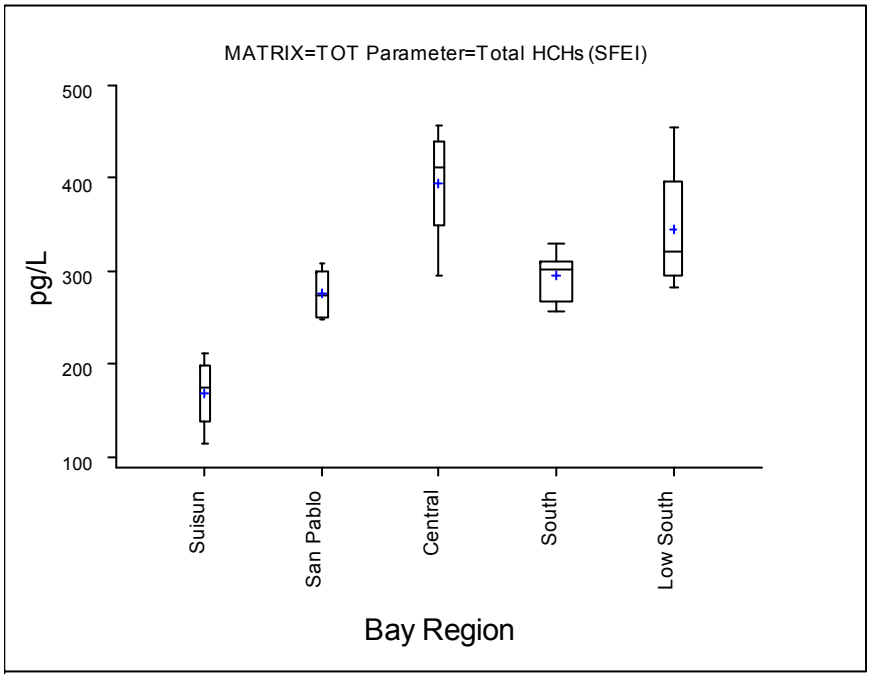


Figure 2.36b. Boxplot of total ΣHCH concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

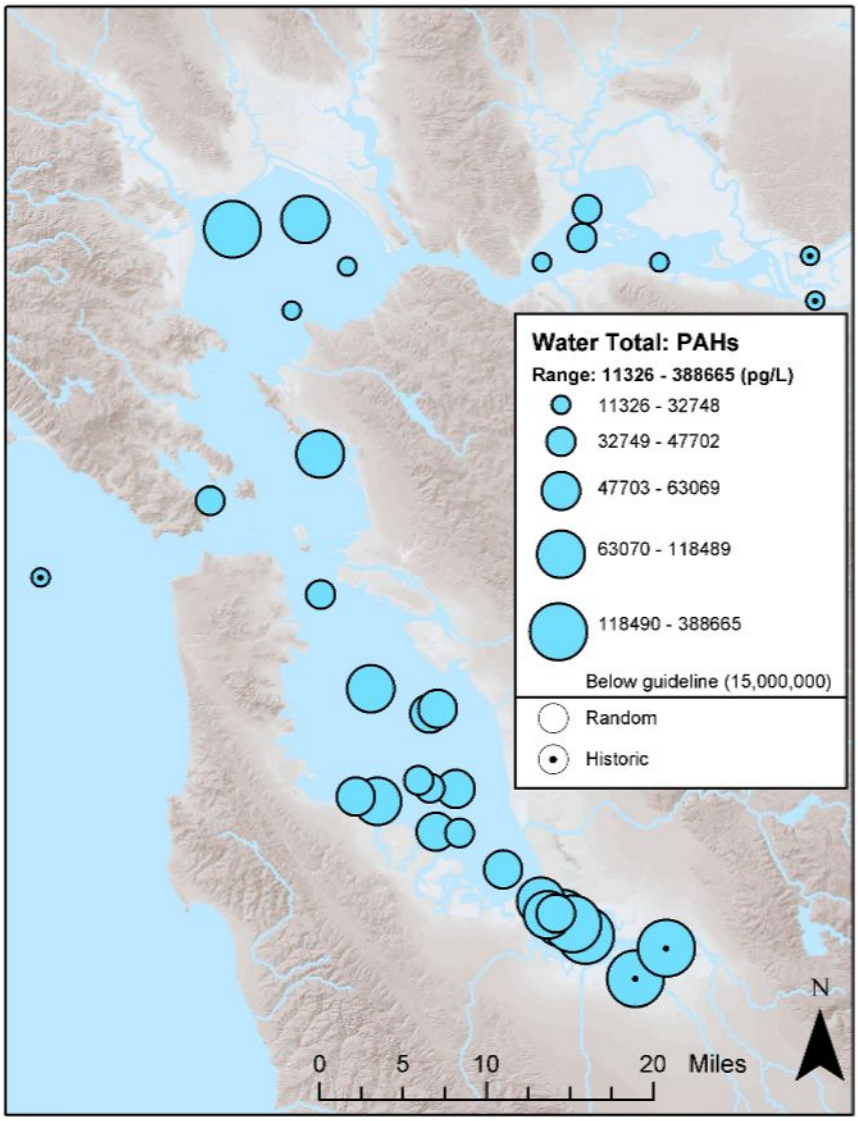


Figure 2.37a. Total ΣPAH concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The CTR lists human health criteria for ten individual PAHs. None of the samples were above the individual PAH criteria and none of the samples were above the Basin Plan objective for sum of PAHs of 15,000,000 pg/L.

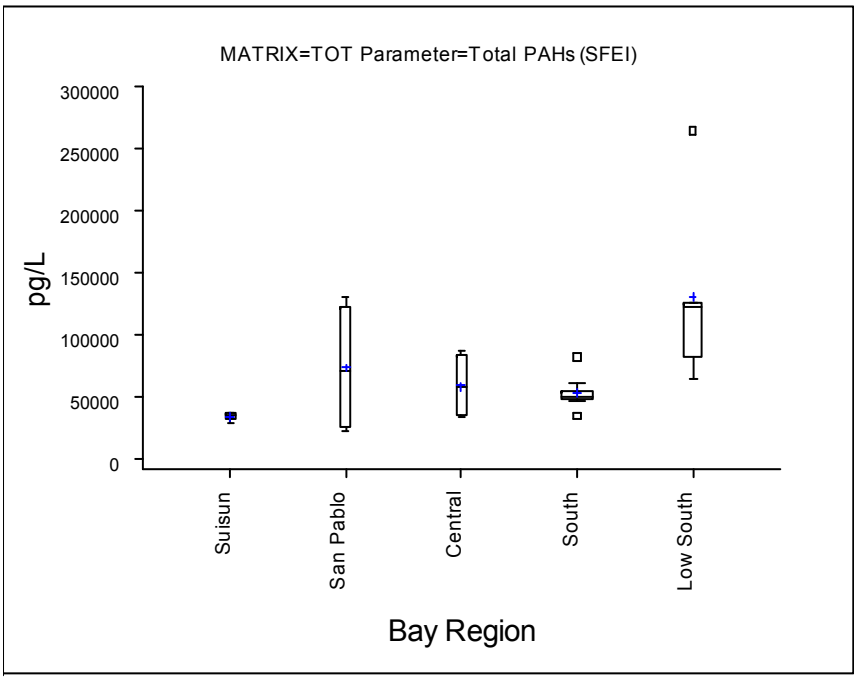


Figure 2.37b. Boxplot of total ΣPAH concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

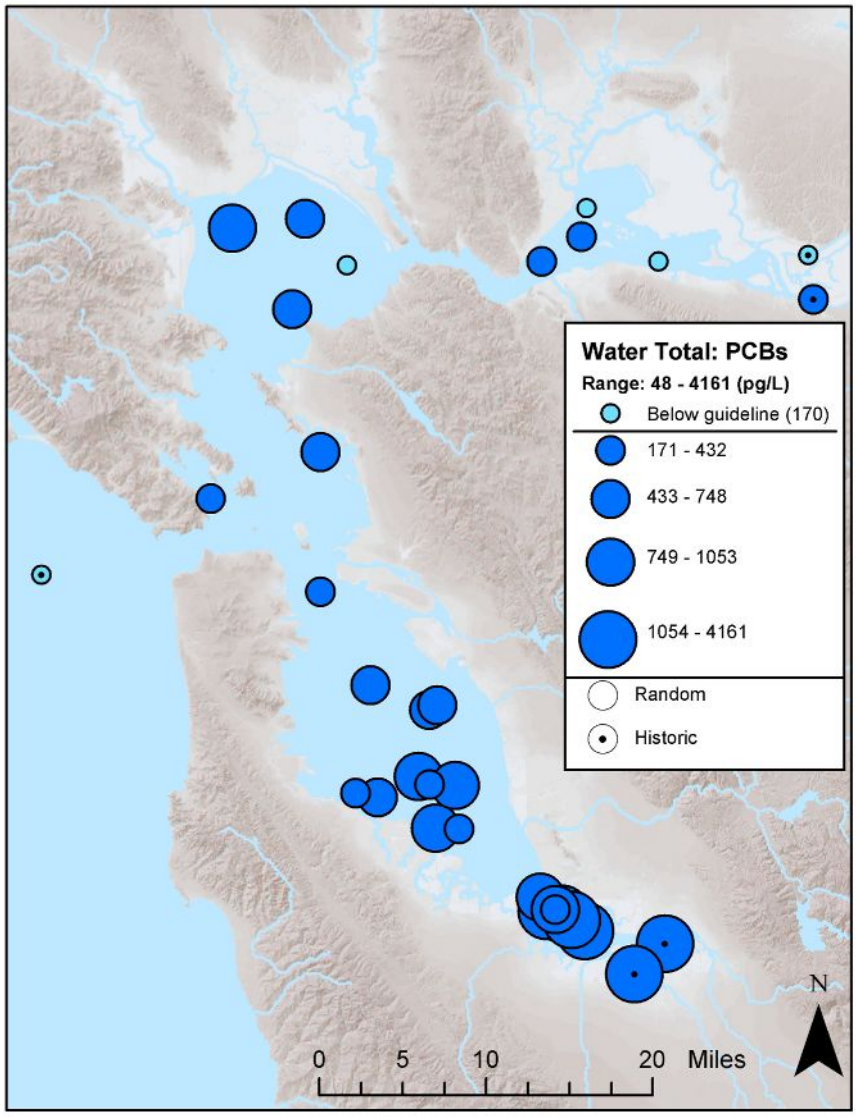


Figure 2.38a. Total ΣPCB concentrations in water (pg/L) sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. Twenty-eight out of thirty-three samples were above the regulatory CTR human health criterion of 170 pg/L.

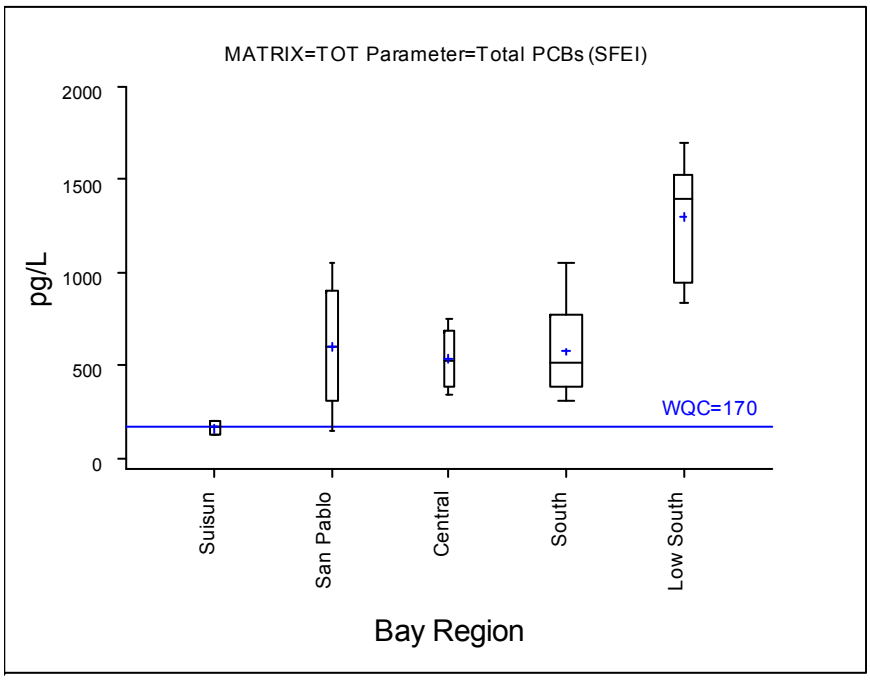


Figure 2.38b. Boxplot of total ΣPCB concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

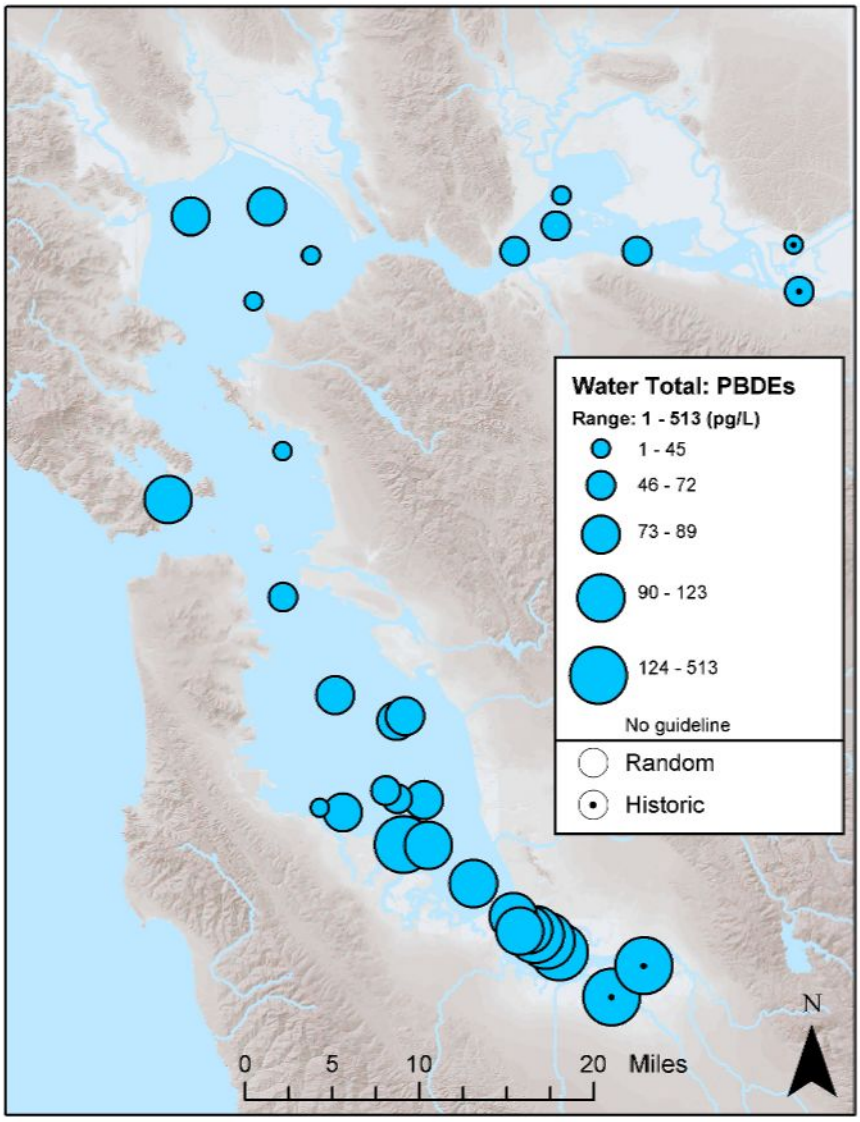


Figure 2.39a. Total ΣPBDE concentrations in water (pg/L) in the San Francisco Estuary in 2002. No guideline is available.

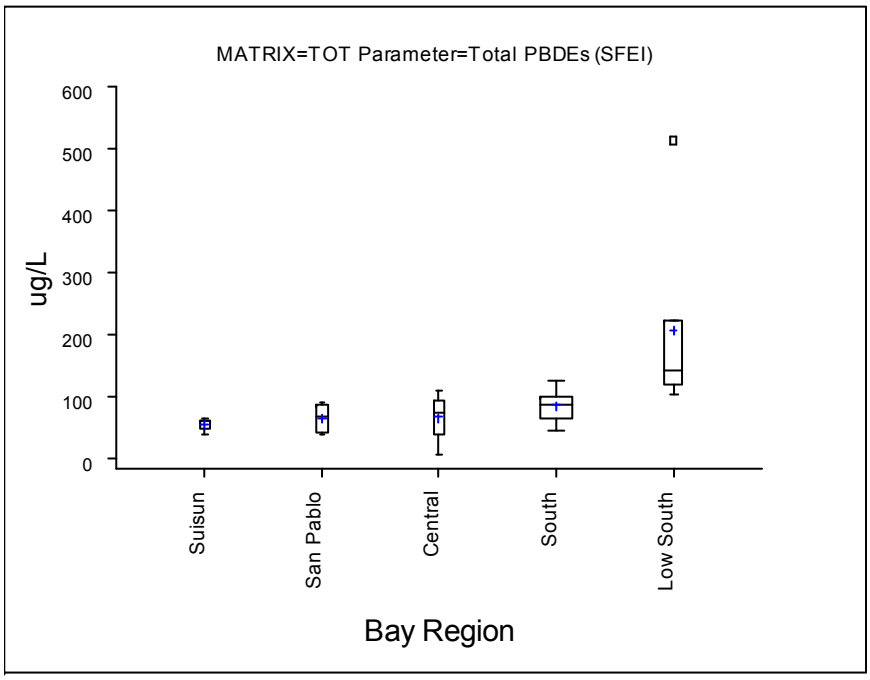


Figure 2.39b. Boxplot of total ΣPBDE concentrations in water by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

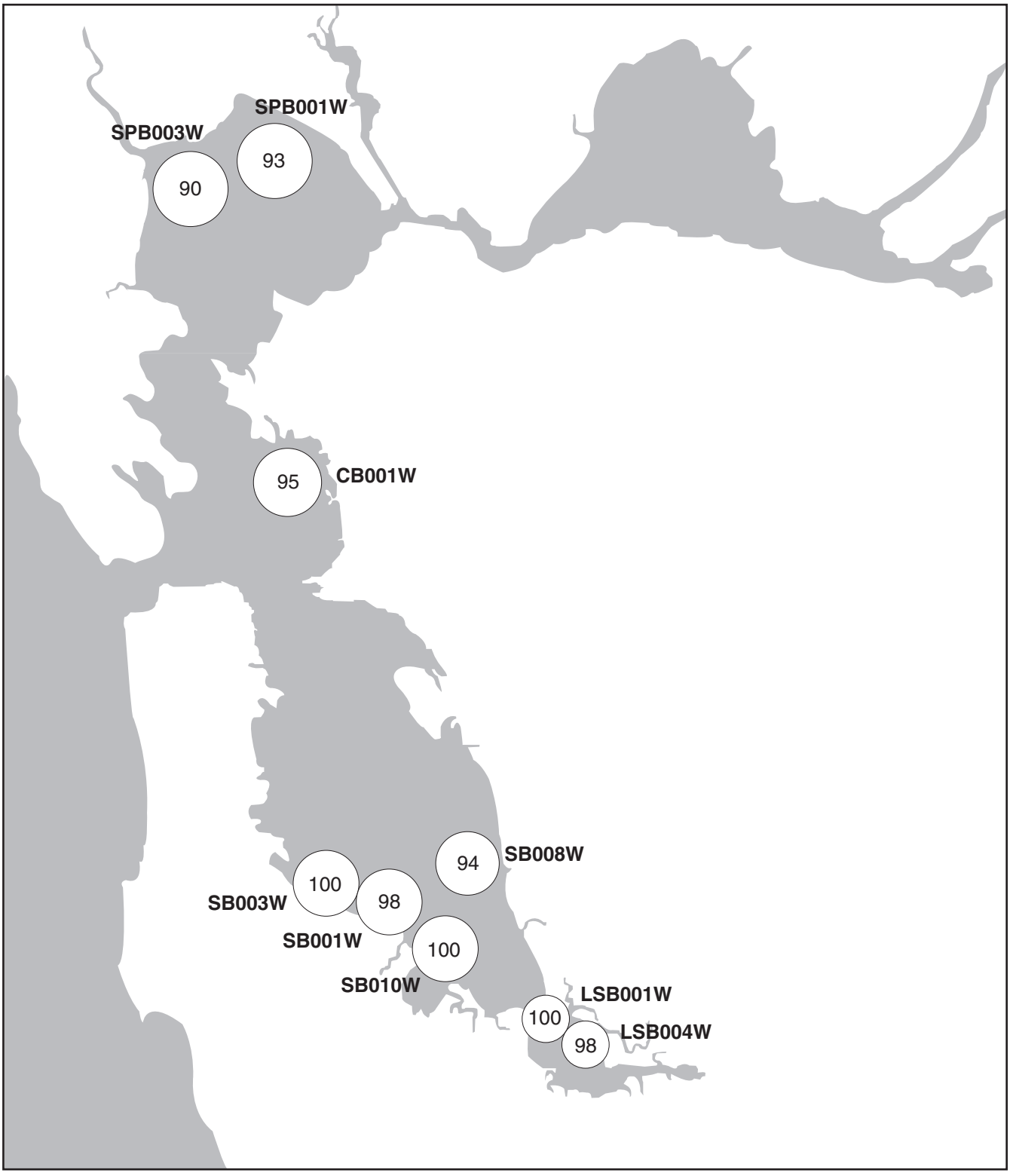
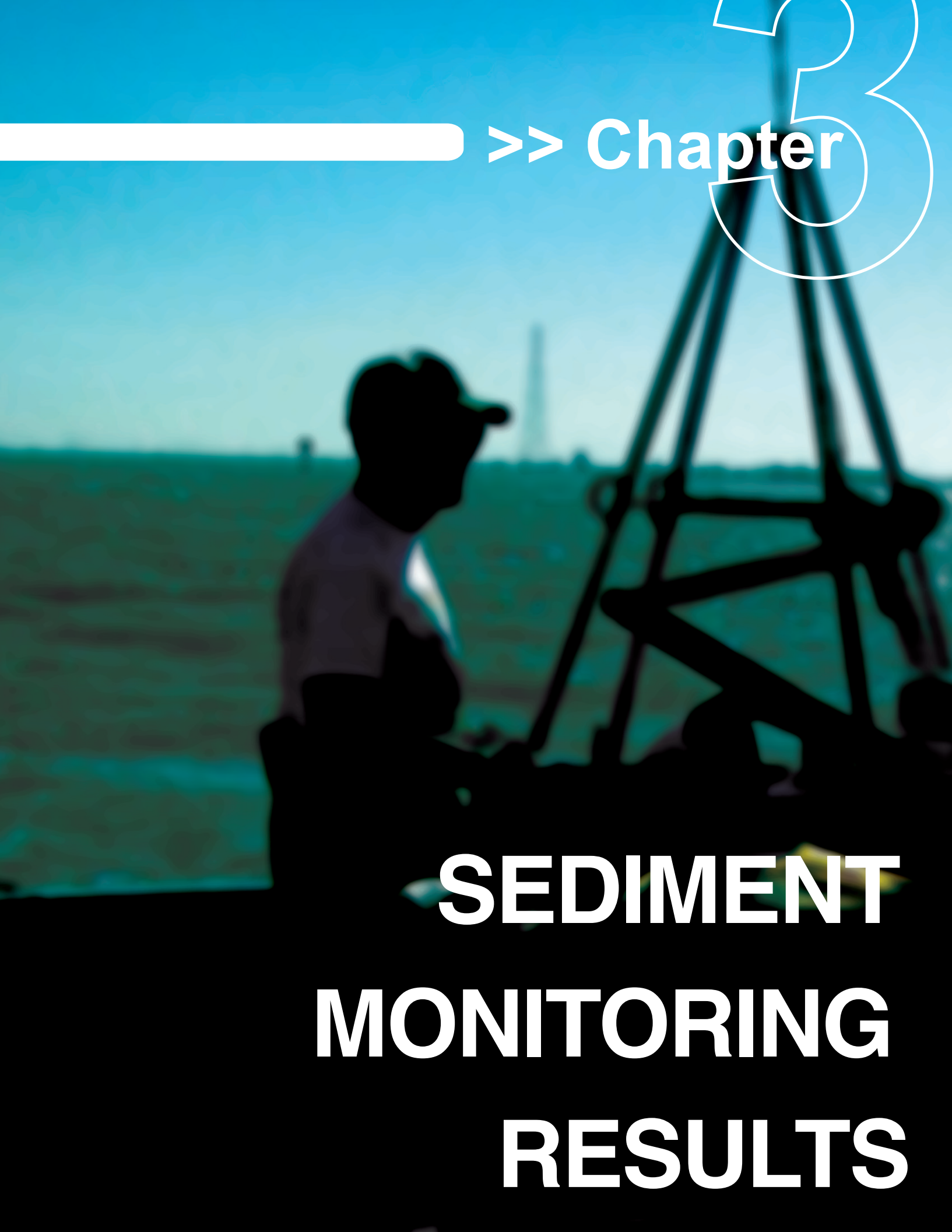


Figure 2.40. Aquatic bioassay results for July 2002. Significant toxicity in a seven-day *Americamysis bahia* (formerly *Mysidopsis bahia)* test was not observed at any of the sampling stations in July 2002. Toxicity was determined by statistical comparison to controls in clean artificial seawater.



>> Chapter 3

SEDIMENT MONITORING RESULTS

3.0 SEDIMENT MONITORING

John Ross, Sarah Lowe, and Cristina Grosso

3.1 Background

Since 1993, the San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) has routinely monitored contaminants in surface sediments (top 5 cm) collected at stations throughout the San Francisco Estuary. Sediments are monitored because they are a fundamental component of the Bay ecosystem, and they play a key role in the fate and transport of contaminants. Sediments serve as contaminant sources and sinks, and most contaminants are usually found in concentrations orders of magnitude higher in the upper few centimeters of sediments than in the water column. Sediment contamination information is used in making decisions related to many important management concerns: the identification of sediment "toxic hot spots" and reference areas; the clean-up of numerous sites in the region that require information about background contaminant levels; and the continued dredging throughout the Estuary that requires testing and comparisons to a reference, or background concentration. Information about sediments addresses several of the RMP Objectives (see Section 1.0 *Introduction*). Patterns in sediment contamination are described (Objective 1) and compared to several sets of sediment quality guidelines (Objective 4), while sediment bioassays address contaminant effects (Objective 3).

3.2 Approach

The RMP in 2002 implemented a stratified random sampling program (see Section 1 .0 *Introduction*). Sediment contaminant monitoring was conducted in the dry season (July-August) at 47 stations, including seven fixed historical stations (Sacramento River (BG20), San Joaquin River (BG30), Grizzly Bay (BF21), Pinole Point (BD31), Yerba Buena Island (BC11), Redwood Creek (BA41), and Coyote Creek (BA10)). At least one historical station was maintained per region to allow for analysis of long-term temporal trends. The evaluation of temporal trends, however, is not documented in this report, but has been deferred to the RMP's synthesis of information from the past ten years (1993-2002) of sediment monitoring in the Estuary. Additionally, two stations at the southern end of the estuary were monitored in cooperation with the Regional Board and the cities of San Jose (station C-3-0) and Sunnyvale (station C-1-3). Sediments collected from a subset of 28 random stations were used for conducting sediment bioassays. Station names, codes, location, and sampling dates are listed in Table 1.2 in the *Introduction* and shown in Figure 3.1.

3.2.1 Methods

The complete list of all parameters measured in the 2002 sediment samples is included in Table 1.4 in the *Introduction*. A detailed description of sample collection and laboratory analytical methods is documented in Section 6 *Description of Methods*. Contaminant concentration data can be downloaded from the RMP website using the Web Query Tool (http://www.sfei.org/rmp/data.htm).

3.2.2 Sediment Quality Guidelines

Currently, no Basin Plan numerical objectives or other regulatory criteria for sediment contaminant concentrations exist for the San Francisco Estuary. However, several sets of sediment quality guidelines (Table 3.1) are generally used as informal screening tools for sediment contaminant concentrations, even though they have no regulatory status.

Sediment quality guidelines developed by Long *et al.* (1995) are based on data compiled from numerous studies in the U.S. that included sediment contaminant and biological effects information. The guidelines were developed to identify concentrations of contaminants that were associated with biological effects in laboratory, field, or modeling studies. The effects range-low (ERL) value is the concentration equivalent to the lower 10th percentile of the compiled study data, and the effects range-median (ERM) is the concentration equivalent to the 50th percentile of the compiled study data. Sediment concentrations below the ERL are interpreted as being "rarely" associated with adverse effects. Concentrations between the ERL and ERM are "occasionally" associated with adverse effects, and concentrations above the ERM are "frequently" associated with adverse effects. Effects-range values for mercury, nickel, total PCBs, and total DDTs have low levels of confidence associated with them. The effects-range values used for chlordanes and dieldrin are from Long and Morgan (1990). Presently, no effects-range guidelines exist for selenium, but the Regional Board has suggested guidelines of 1.4 mg/kg (Wolfenden and Carlin, 1992), and 1.5 mg/kg (Taylor *et al*., 1992).

A set of quality guidelines developed by the San Francisco Bay Regional Water Quality Control Board is also used for sediment (Gandesbery, 1998; Gandesbery *et al*., 1999). Ambient Sediment Concentration (ASC) values are derived from samples collected from the cleanest areas of the Estuary by the RMP (1991-1996) and by the Bay Protection and Toxic Cleanup Program (BPTCP) for their 1995 Reference Site study, and are used to distinguish “ambient” from “contaminated” conditions. Given the fact that virtually no San Francisco Estuary mixed surface layer sediments are free of anthropogenic contaminants this approach was thought to define contemporary ambient contaminant levels. Different ASC values are used for sandy (>60% sand) and muddy (>40% fines) sediments. The ERL guideline values of Long *et al*. (1995) are indicated for comparative purposes on the sediment contaminant concentration charts (Figures 3.3–3.17).

The Regional Board is presently developing Total Maximum Daily Loads (TMDLs) which may result in proposed sediment targets for certain contaminants on the State’s "Impaired Waters" Section 303(d) list. A sediment target for mercury of 0.2 mg/kg has already been developed and proposed (Johnson and Looker, 2003), and a recent TMDL report proposes 2.5 µg/kg as a sediment target for PCBs (SFBRWQCB, 2004). Potentially, these target limits could be used as a new set of sediment quality guidelines, specific to the different regions of the Estuary.

3.2.3 Sediment Toxicity

Sediment bioassays are routinely conducted to determine the potential for adverse biological effects from the exposure to sediment contamination. Two types of sediment bioassays were conducted at 28 of the RMP stations in 2002 (Figure 3.19). Sampling dates are listed in Table 1.2 in Section 1.0 *Introduction*. Amphipods (*Eohaustorius estuarius*) were exposed to whole sediment for ten days with percent survival as the endpoint. Larval mussels (*Mytilus galloprovincialis*) were exposed to sediment elutriates (water-soluble fraction) for 48 hours with percent normal development as the endpoint. In addition to exposures with estuarine organisms, sediments from three stations that are heavily influenced by fresh water input were tested with a fresh water amphipod (*Hyalella azteca*) and a cladoceran (*Ceriodaphnia dubia*). The control for the *Eohaustorius* (amphipod) solid-phase test consisted of home sediment, which was clean, well-sorted fine-grained sand collected at the same place and time as the test amphipods. The *Mytilus* (mussel) sediment elutriate test negative control was clean seawater from Granite Canyon, California. The control for *Hyalella* consisted of reference sediment obtained from

USGS, and the *Ceriodaphnia* control consisted of moderately hard water (U.S. EPA, 1993). Methods of collection and testing are described in Section 6.0 *Description of Methods*, and the relevant quality assurance information is available online (http://www.sfei.org/rmp/data.htm).

When a sample is found to be toxic, it is interpreted as an indication of the potential for biological effects to estuarine organisms. However, since sediments contain numerous contaminants, it is difficult to determine which contaminant(s) may have caused the observed toxicity (see *3.3.3 Sediment Toxicity*).

A sample was considered toxic if:

1. There was a significant difference between the laboratory control and test replicates using a separate variance t-test (alpha = 0.01), and
2. The difference between the mean endpoint value (% survival for amphipods or % normal development for bivalves) in the control and the mean endpoint value in the test sample was greater than the 90th percentile minimum significant difference (MSD).

The reason two measures of a toxic hit must be met before a sample is considered toxic is that in many cases a small among-replicate variance will result in a significant t-test, even though the magnitude of the difference may be small. One way to ensure that statistical significance is determined based on large differences between means, rather than on small variation among replicates, is to use the MSD. MSD is a statistic that indicates the difference between the two means (the mean of the sample and control replicates) that will be considered statistically significant given the observed level of among-replicate variation and the alpha level chosen for the comparison. The detectable difference inherent to a bioassay protocol can be determined by identifying the magnitude of difference detected by the protocol 90% of the time (Schimmel *et al*., 1991; Thursby and Schlekat, 1993; Phillips *et al*., 2001). An additional set of t-tests (alpha = 0.05) is conducted and MSD values are calculated for each comparison. The MSDs are ranked in ascending order, and the 90th percentile value is identified. This value is greater than or equal to 90% of the MSD values generated. The 90th percentile MSD value is the difference that 90% of the t-tests will be able to detect as statistically significant and is equivalent to setting the level of statistical power at 0.90. The 90th percentile MSD threshold was established from 119 bioassay results for San Francisco Estuary (Marine Pollution Studies Laboratory unpublished data; Hunt *et al*., 1996). A recalculation in 2003 confirmed the 90th percentile MSD for *Eohaustorius* was 18.8%, but determined that it should be revised to 15.2% for the bivalve larvae test. For the July 2002 sediment bioassays, an amphipod bioassay was toxic if it had below 76.2% survival while the larval bivalve bioassay was toxic if it had less than 74.8% normal development, and there was a significant difference between the mean of the control and sample replicates using a separate variance t-test (alpha = 0.01).

3.3 Results and Discussion

The geochemistry of sediments is complex, and in order to interpret contaminant concentrations measured in sediments, it is necessary to understand how hydrology (flows) and physical sediment characteristics may affect contaminant concentrations. Conductivity, temperature, and depth (CTD) profiles of the water column were collected at all RMP sediment stations. Although not presented in this report, these data are available upon request from the San Francisco Estuary Institute. Several sediment quality parameters that may affect sediment contaminant concentrations (grain-size, organic carbon, and porewater pH) were also monitored.

The list of parameters measured in the sediment samples is included in Table 1.4 in the *Introduction*. New to the analyte list in 2002 are the organic compounds polybrominated

diphenyl ethers (PBDEs), musks, and phthalates. Methylmercury and polychlorinated biphenyl concentrations were unavailable at time of reporting. Chromium was not measured in 2002. Sediment quality parameters, station depths, and all available contaminant concentrations are accessible through the RMP Web Query Tool (http://www.sfei.org/rmp/data.htm).

3.3.1 Spatial Distributions

Sediment contaminant concentrations measured in the San Francisco Estuary exhibit considerable spatial and temporal variation. High contaminant concentrations can reflect proximity to a source, anthropogenic or otherwise, as illustrated by the RMP's Estuary Interface Pilot Study results from Coyote Creek and Guadalupe River in the South Bay (SFEI, 1999; Leatherbarrow *et al*., 2002). However, complex sediment transport dynamics within the Estuary confound this simplistic model. For example, sediments with more silt- and clay-sized particles contain higher concentrations of most contaminants than coarser, sandier sediments because finer grained sediments' electromagnetic and other physical properties enhance the ability of adsorption of various contaminants (Luoma, 1990; Horowitz, 1991). The strength and magnitude of freshwater inflows to the estuary, which transport sediments and contaminants in both the dissolved and particulate fractions of the flows, may radically alter sediment type and contaminant distribution (Krone, 1979). As a consequence RMP sediment monitoring provides information only about the condition of surface sediments (upper 5 cm) at the time and location of sampling.

A majority of the highest sediment contaminant concentrations (10 out of 15 parameters, and all organics) were measured at stations in the South Bay and/or Lower South Bay (Figures 3.3–3.17). One station in the South Bay (SB006S) had the highest concentration of chlordanes, dieldrin, DDTs, and HCHs; dieldrin and HCH concentrations were the highest ever measured by the RMP. The highest concentration of arsenic was measured in San Pablo Bay (SPB001S), whereas the highest concentrations of copper (SU006S), nickel (SU008S), and selenium (SU008S) were found at sampling locations in Suisun Bay. Stations in the South (SB002S) and Suisun Bay (SU005S) regions had the highest measured concentrations of cadmium. Individual stations with coarse sediments (>60% sand: two historic, four random, and San Jose (C-3-0)) had considerably lower concentrations for the majority of contaminants (12 out of 15) and these are identified in Figure 3.2.

In order to compare sediment contaminant concentrations RMP sampling stations were grouped into their respective regions. The five regions, each containing eight random stations, are different from those used in previous years: Lower South Bay (LSB*nnn*S), South Bay (SB*nnn*S), Central Bay (CB*nnn*S), San Pablo Bay (SPB*nnn*S), and Suisun Bay (SU*nnn*S). Differences among regions were examined using the non-parametric Kruskal-Wallis test for multiple comparisons (Zar, 1984). If the null hypothesis stating that the sample distributions were from the same population was rejected ($p<0.05$), then a non-parametric multiple comparison for equal sample sizes was performed in a manner paralleling the Tukey test, with rank means being used instead of means (Zar, 1984). Non-detects (NDs) were replaced with a value of one-half the method detection limit (MDL) for trace metals and dieldrin, and for the organic totals NDs were estimated as one-half the average MDL of the summed parameters.

The unweighted contaminant concentrations of lead ($H=21.2$, $p<0.0005$) and zinc ($H=13.8$, $p=0.008$) were significantly higher in the Lower South Bay compared to the Suisun and South Bays. Lower South Bay sediments were also significantly higher in silver compared to the Suisun and San Pablo Bays ($H=16.4$, $p=0.003$), and significantly higher in nickel than the South

Bay (H=10.3, p=0.036). Sediments from the Lower South Bay and South Bay were documented to be significantly lower in cadmium than samples from Suisun Bay, and cadmium in the South Bay was measured at significantly lower concentrations than in San Pablo Bay (H=17.5, p=0.002). Significantly lower sediment PAHs concentrations were observed in Suisun Bay compared to sediments from the Central Bay, South Bay, and Lower South Bay (H=22.3, p<0.0005). No significant (p<0.05) differences were found in the sediment concentrations of arsenic, copper, mercury, selenium, DDTs, chlordanes, dieldrin, HCHs, and PBDEs among the five estuary regions.

The highest incidences of ERL exceedance were observed at Central Bay (CB073S), South Bay (SB006S), Lower South Bay (LSB003S and LSB007S), and Coyote Creek (BA10) (see Table 3.2). ERL guideline exceedances and sediment contaminant concentrations tended to be lowest at the coarse sediment stations (>60% sand): Sacramento River (BG20), San Joaquin River (BG30), Suisun Bay (SU001S, SU003S), South Bay (SB073S), and San Jose (C-3-0). Low incidences of ERL exceedance were also observed in August 2002 at the non-coarse stations of Suisun Bay (SU007S), Central Bay (CB006S), and South Bay (SB004S).

3.3.2 Temporal Trends

The maintenance of fixed historical sampling stations, at least one per region, permits analysis of long-term temporal trends, but this evaluation has been deferred to the RMP's synthesis of information from the past ten years (1993-2002) of sediment monitoring in the Estuary.

3.3.3 Sediment Toxicity

Toxicity tests, described in *Section 3.2.3*, were conducted to determine whether sediments were toxic to sensitive benthic organisms. Since these bioassays were conducted using non-resident organisms exposed in laboratory conditions, the results may not necessarily indicate the occurrence of actual ecological impacts.

Estuary sediments were toxic to either amphipods or larval mussels in 12 out of 28 (43%) of the 2002 RMP samples (Table 3.2). Patterns of toxicity for the two test organisms vary within the Estuary (Figure 3.19). Historical stations located in the Suisun Bay and Rivers regions of the Estuary (Sacramento River (BG20), San Joaquin River (BG30), and Grizzly Bay (BF21)) have been consistently toxic to bivalve larvae since 1994. A pattern repeated in 2002, and strengthened with the observation of toxicity to larval mussels at the stations of SU001S and SU005S. Central Bay sediments continue to show an increase in the incidence of amphipod toxicity at Yerba Buena Island (BC11). Amphipod toxicity was observed in the Central Bay (CB001S) and South Bay (Redwood Creek (BA41), and SB003S). Bioassay results for 2002 indicate sediments from Suisun Bay (SU003S, and SU007S), San Pablo Bay (Pinole Point BD31, SPB001S, SPB005S, and SPB007S), Central Bay (CB003S, CB005S, and CB007S), South Bay (SB005S, SB007S, and SB073S), Lower South Bay (LSB003S, LSB005S, and LSB007S), and San Jose (C-3-0) were not toxic to either amphipods or larval mussels. Sediments from Yerba Buena Island (BC11) and Coyote Creek (BA10) were toxic to both amphipods and mussel larvae. Seasonal patterns were not examined because no sampling occurred in the winter, but prior to 2000 sediments were usually more toxic during the wet sampling period (SFEI 2000; 2001).

Causes of toxicity to the amphipods and bivalve larvae are poorly understood. Analyses using several years of monitoring data suggest that amphipod toxicity is associated with the cumulative effects of mixtures of contaminants (Thompson *et al.*, 1999). Several individual contaminants

were identified as probable determinants of toxicity at some sites. For example, toxicity at Grizzly Bay (BF21) was related to covarying patterns of total chlordane, silver, and cadmium from 1991 through 1996. Seasonal variation in PAHs at some stations was related to survival. Sediment elutriates (water soluble fraction) have been observed as being toxic to bivalve larvae for the Sacramento and San Joaquin Rivers, and Grizzly Bay samples since 1993 (SFEI 2000, 2001). Toxicity identification evaluations (TIEs) conducted on the sediment elutriates from the Sacramento and San Joaquin Rivers and Grizzly Bay in 1997 and 1998 indicated that dissolved trace metals, particularly copper, could be partially responsible for the toxicity, but organic contaminants were also identified as possible toxic components from the Sacramento River site (Phillips *et al*., 2000). These results suggest that sediment toxicity at the different RMP stations may be related to different contaminants and may vary with time.

Previous studies by RMP investigators have demonstrated the complex nature of sediment toxicity due to the numerous contaminant and non-contaminant factors in sediments. Solid phase sediment toxicity to amphipods has been frequently observed at Redwood Creek (BA41) and Grizzly Bay (BF21). Although exposure to pore water from these sites did not produce toxicity, exposure to bulk sediment did, suggesting that the toxicity is associated with ingestion and assimilation of contaminants that are adsorbed to ingested sediment particles. Amphipods accumulated PAHs, organochlorine pesticides, and PCBs from exposures to both bulk sediment and pore water, but not at levels known to cause mortality. The majority of the contaminants accumulated in amphipods were PAHs, which may have been a key causative agent of the observed toxicity. However, mixtures of contaminants were also cited to be important possibly due to synergistic effects (Anderson *et al*., 2000). Anderson *et al.* (2003) summarized ten years of toxicity testing by the RMP (http://www.sfei.org/rmp/pulse/pulse2003.pdf).

3.3.4 Assessment of Sediment Quality

Estuary sediments are evaluated through comparisons to several sets of sediment quality guidelines described in *Section 3.2.2 Sediment Quality Guidelines*. Although these guidelines hold no regulatory status, they provide concentration guidelines that are useful in assessing the potential for toxic and other benthic effects.

Sediment contamination and toxicity results were used to evaluate the quality of the 2002 RMP samples (Table 3.2). Sediment contamination was estimated for each site by considering the number of contaminants in a sample that exceeded the San Francisco Estuary Ambient Sediment Concentration (ASC: Gandesbery *et al.*, 1999), Effects-Range guidelines (ERL and ERM: Long *et al.*, 1995), and the ERM quotients (Long *et al*., 1998). The number of sediment contaminants above the ERL or ERM guidelines has been used previously to predict potential biological effects (Long *et al*., 1998). Long *et al*. (1998) found samples with more than four ERM exceedances showed toxicity in 68% of amphipod tests, while 51% of samples were toxic to amphipods when more than nine ERLs were above the guidelines. Based on these results the 2002 RMP sediment samples were considered potentially toxic if either four or more ERMs, nine or more ERLs, or half (22) of the ASC values were exceeded.

ERM values were used to calculate a mean ERM quotient (mERMq) for each sample. The mERMq has been used in previous RMP reports and San Francisco Estuary publications, as an index of cumulative sediment contaminant concentrations (Thompson *et al.*, 1999; Hunt *et al*., 2001a,b; Fairey *et al*., 2001; Thompson and Lowe, ms). The primary reason for using the mERMq is that it provides a measure of potential additive contaminant effects. For example, amphipod survival has been found to be significantly and inversely correlated to mERMq

(Thompson *et al.*, 1999), suggesting that contaminants individually present in relatively low concentrations in sediments may act together to adversely influence amphipod survival. In these past reports and publications, however, the mERMq has been calculated in several different ways. However, if comparisons to other U.S. estuaries are to be accomplished, a standard method of calculation is necessary. Therefore, the calculation of mERMq was changed in order to make the RMP ERM quotients comparable to other studies from around the U.S. (Hyland *et al.*, 1999; Long *et al*., 2002; Hyland *et al.*, 2003). In the past, RMP mERMqs were calculated using 13 contaminants, including nickel, but the revised calculations use 24 contaminants (Hyland *et al.*, 1999), excluding nickel (Table 3.1). Samples that did not have values for at least 19 of the 24 parameters were not included in the calculations. The resulting values are considerably lower than the values calculated in previous years, and are heavily weighted with PAHs. Concentrations for chromium and PCBs were unavailable in 2002 and are not included in the calculations.

Long *et al*. (1998) showed that 49% of sediment samples were toxic to amphipods when mERMq values were above 0.5, and 71% of samples were toxic when mERMq values were greater than 1.0. Mean ERM quotients, calculated with 24 contaminants, were used in a previous study of the San Francisco Estuary in which values greater than 0.15 were associated with increased risks of benthic impact (Thompson and Lowe, ms). These values were used to evaluate the 2002 RMP sediment samples for potential adverse ecological effects. Statistical analysis shows that mERmq values were significantly higher in the Lower South Bay and Central Bay regions compared to Suisun Bay (Kruskal-Wallis, H=14.5, p=0.006; Figure 3.18), but no region or sample had a mERMq value above 0.15 (Table 3.2). Stations CB073S, SB006S, LSB003S, LSB007S, and Coyote Creek (BA10) had seven contaminants above the ERL guidelines. Twelve sediment samples were toxic (Sacramento River (BG20), San Joaquin River (BG30), Grizzly Bay (BF21), SU001S, SU005S, SPB003S, Yerba Buena Island (BC11), CB001S, Redwood Creek (BA41), SB003S, LSB001S and Coyote Creek (BA10); however, all had mERMq values below 0.15 and also ERL, ERM, and ASC exceedences below the number considered to be potentially toxic. Sediments from the Central Bay station CB073S had a high number of ASC (26) and ERL (7) exceedences, but were not tested for toxicity.

Sediment evaluations are useful tools that incorporate sediment contamination and toxicity into a weight of evidence assessment of the condition of sediments in the Estuary. Each component is analyzed independently and weighted equally, but although they should be related the results do not always agree. The complexity of sediment evaluations demonstrate the need to consider as much data as possible in assessing the condition of Estuary sediments and the importance of performing future studies to reconcile and understand the observed contradictions.

3.4 References

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Table 3.1. Guidelines to evaluate chemical concentrations in sediment (in dry weight).

Effects Range-Low (ERL) and Effects Range-Median (ERM) values from Long *et al.* (1995, 1998).
Effects Range-Low; values between this and the ERM are in the possible effects range.
Effects Range-Median; values above this are in the probable effects range.

San Francisco Bay Ambient Sediment Concentrations (ASC) from Gandesbery *et al*. (1999).
Ambient sediment levels from background sediments in the Estuary allow one to assess whether a site has elevated levels or is "degraded".

Background sediment concentrations for selected trace elements in the San Francisco Bay, from Hornberger *et al*. (1999)
Chromium and Nickel ranges were seen throughout the core. All TEs, except Ag, measured by ICAPES. Ag measured by GFAAS.

Parameter	unit	ERL	ERM	ASC_{sandy} <40% fines	ASC_{muddy} >40% fines	Background Concentrations (Bay wide ranges)	
						Total	Near Total
Arsenic	mg/Kg	8.2	70 †	13.5	15.3		
Cadmium	mg/Kg	1.2	9.6 †	0.25	0.33		
Chromium *	mg/Kg	81	370 †	91.4	112	110 - 170	70 - 120
Copper	mg/Kg	34	270 †	31.7	68.1	20 - 55	20 - 41
Mercury	mg/Kg	0.15	0.71 †	0.25	0.43		0.05 - 0.07
Nickel	mg/Kg	20.9	51.6	92.9	112	70 - 100	50 - 100
Lead	mg/Kg	46.7	218 †	20.3	43.2	20 - 40	10 - 20
Selenium	mg/Kg			0.59	0.64		
Silver	mg/Kg	1	3.7 †	0.31	0.58	0.7 - 0.11	0.7 - 0.11
Zinc	mg/Kg	150	410 †	97.8	158	60 - 70	50 - 100
Total HPAHs (SFEI)	µg/Kg	1700	9600	256	3060		
Fluoranthene	µg/Kg	600	5100 †	78.7	514		
Perylene	µg/Kg			24	145		
Pyrene	µg/Kg	665	2600 †	64.6	665		
Benz[*a*]anthracene	µg/Kg	261	1600 †	15.9	244		
Chrysene	µg/Kg	384	2800 †	19.4	289		
Benzo[*b*]fluoranthene	µg/Kg			32.1	371		
Benzo[*k*]fluoranthene	µg/Kg			29.2	258		
Benzo[*a*]pyrene	µg/Kg	430	1600 †	18.1	412		
Benzo[*e*]pyrene	µg/Kg			17.3	294		
Dibenz[*a,h*]anthracene	µg/Kg	63.4	260 †	3	32.7		
Benzo[*g,h,i*]perylene	µg/Kg			22.9	310		
Indeno[1,2,3-*c,d*]pyrene	µg/Kg			19	382		
Total LPAHs (SFEI)	µg/Kg	552	3160	37.9	434		
1-Methylnaphthalene	µg/Kg			6.8	12.1		
1-Methylphenanthrene	µg/Kg			4.5	31.7		
2,3,5-Trimethylnaphthalene	µg/Kg			3.3	9.8		
2,6-Dimethylnaphthalene	µg/Kg			5	12.1		
2-Methylnaphthalene	µg/Kg	70	670 †	9.4	19.4		
Naphthalene	µg/Kg	160	2100 †	8.8	55.8		
Acenaphthylene	µg/Kg	44	640 †	2.2	31.7		
Acenaphthene	µg/Kg	16	500 †	11.3	26.6		
Fluorene	µg/Kg	19	540 †	4	25.3		
Phenanthrene	µg/Kg	240	1500 †	17.8	237		
Anthracene	µg/Kg	85.3	1100 †	9.3	88		
Total PAHs (SFEI)	µg/Kg	4022	44792	211	3390		
p,p'-DDE	µg/Kg	2.2	27 †				
Total DDTs (SFEI)	µg/Kg	1.58	46.1 †	1.58	46.1		
Total Chlordanes (SFEI)	µg/Kg	0.5	6	0.42	1.1		
Dieldrin **	µg/Kg	0.02	8	0.18	0.44		
TOTAL PCBs (NIST 18)	µg/Kg			5.9	14.8		
Total PCBs (SFEI)	µg/Kg	22.7	180 †	8.6	21.6		

* Chromium concentrations were not measured in 2002 sediment samples.

** Method detection limit (MDL) for the July cruise is greater than the ERL and ASC-sandy guidelines, therefore, conclusions regarding these benchmarks could not be drawn.

† Values used to calculate mean ERM quotients (Hyland *et al*. 1999).

Table 3.2. Summary of sediment quality for the RMP in 2002.

San Jose (C-3-0) sediment only analyzed for trace metals.

NA = not available, . = not tested, * indicates number of exceedances above ASC guidelines for sandy samples.

Code	Site Name	Date	% Fines	mERMq	No. of ASC above Guidelines	No. of ERL above Guidelines	No. of ERM above Guidelines	Toxic to Amphipods?	Toxic to Bivalves?
BG20	Sacramento River	7/31/02	14	0.0215	2*	2	2	no	yes
BG30	San Joaquin River	7/31/02	28	0.0239	3*	2	2	no	yes
BF21	Grizzly Bay	7/31/02	87	0.0634	1	5	1	no	yes
SU001S	Suisun Bay	8/1/02	36	0.0202	3*	2	2	no	yes
SU003S	Suisun Bay	8/1/02	26	0.0274	3*	2	2	no	no
SU004S	Suisun Bay	7/31/02	97	0.0626	1	5	1	.	.
SU005S	Suisun Bay	7/31/02	60	0.0591	2	4	2	no	yes
SU006S	Suisun Bay	7/31/02	89	0.0697	1	5	1	.	.
SU007S	Suisun Bay	8/1/02	45	0.0278	1	2	2	no	no
SU008S	Suisun Bay	7/31/02	73	0.0561	4	4	1	.	.
SU073S	Suisun Bay	8/1/02	98	0.0650	1	4	1	.	.
BD31	Pinole Point	8/1/02	92	0.0743	1	5	1	no	no
SPB001S	San Pablo Bay	8/2/02	97	0.0675	2	6	2	no	no
SPB002S	San Pablo Bay	8/1/02	97	0.0645	0	4	1	.	.
SPB003S	San Pablo Bay	8/2/02	97	0.0733	0	4	1	no	yes
SPB004S	San Pablo Bay	8/2/02	80	0.0814	1	4	1	.	.
SPB005S	San Pablo Bay	8/2/02	71	0.0765	0	4	1	no	no
SPB006S	San Pablo Bay	8/1/02	71	0.0573	0	5	0	.	.
SPB007S	San Pablo Bay	8/2/02	96	0.0662	0	3	1	no	no
SPB008S	San Pablo Bay	8/2/02	95	0.0706	1	4	1	.	.
BC11	Yerba Buena Island	8/8/02	64	0.0621	0	4	1	yes	yes
CB001S	Central Bay	8/8/02	76	0.1003	1	6	1	yes	no
CB002S	Central Bay	8/7/02	93	0.1116	3	5	1	.	.
CB003S	Central Bay	8/8/02	97	0.0714	0	4	1	no	no
CB005S	Central Bay	8/8/02	90	0.0759	0	3	0	no	no
CB006S	Central Bay	8/7/02	65	0.0568	0	2	1	.	.
CB007S	Central Bay	8/8/02	93	0.0764	0	4	1	no	no
CB008S	Central Bay	8/8/02	75	0.1020	1	5	1	.	.
CB073S	Central Bay	8/8/02	35	0.0885	26*	7	1	.	.
BA41	Redwood Creek	8/6/02	71	0.0789	0	4	1	yes	no
SB002S	South Bay	8/6/02	94	0.0909	1	4	1	.	.
SB003S	South Bay	8/7/02	95	0.1144	5	6	0	yes	no
SB004S	South Bay	8/7/02	55	0.0562	0	2	0	.	.
SB005S	South Bay	8/7/02	57	0.0647	0	3	0	no	no
SB006S	South Bay	8/6/02	98	0.0906	2	7	2	.	.
SB007S	South Bay	8/7/02	51	0.0626	0	3	1	no	no
SB008S	South Bay	8/7/02	66	0.0648	0	3	0	.	.
SB073S	South Bay	8/7/02	24	0.0285	19*	0	0	no	no
LSB001S	Lower South Bay	8/6/02	99	0.0729	0	4	1	no	yes
LSB002S	Lower South Bay	8/6/02	42	0.0528	0	3	0	.	.
LSB003S	Lower South Bay	8/6/02	99	0.0928	3	7	1	no	no
LSB004S	Lower South Bay	8/5/02	99	0.0849	0	5	1	.	.
LSB005S	Lower South Bay	8/5/02	99	0.0819	0	5	1	no	no
LSB006S	Lower South Bay	8/5/02	100	0.0885	0	5	1	.	.
LSB007S	Lower South Bay	8/6/02	99	0.1063	3	7	1	no	no
LSB008S	Lower South Bay	8/5/02	100	0.0940	0	6	1	.	.
BA10	Coyote Creek	8/5/02	100	0.0906	1	7	1	yes	yes
C-3-0	San Jose	8/5/02	33	NA	2*	1	1	no	no
C-1-3	Sunnyvale	8/5/02	87	0.0864	1	6	1	.	.

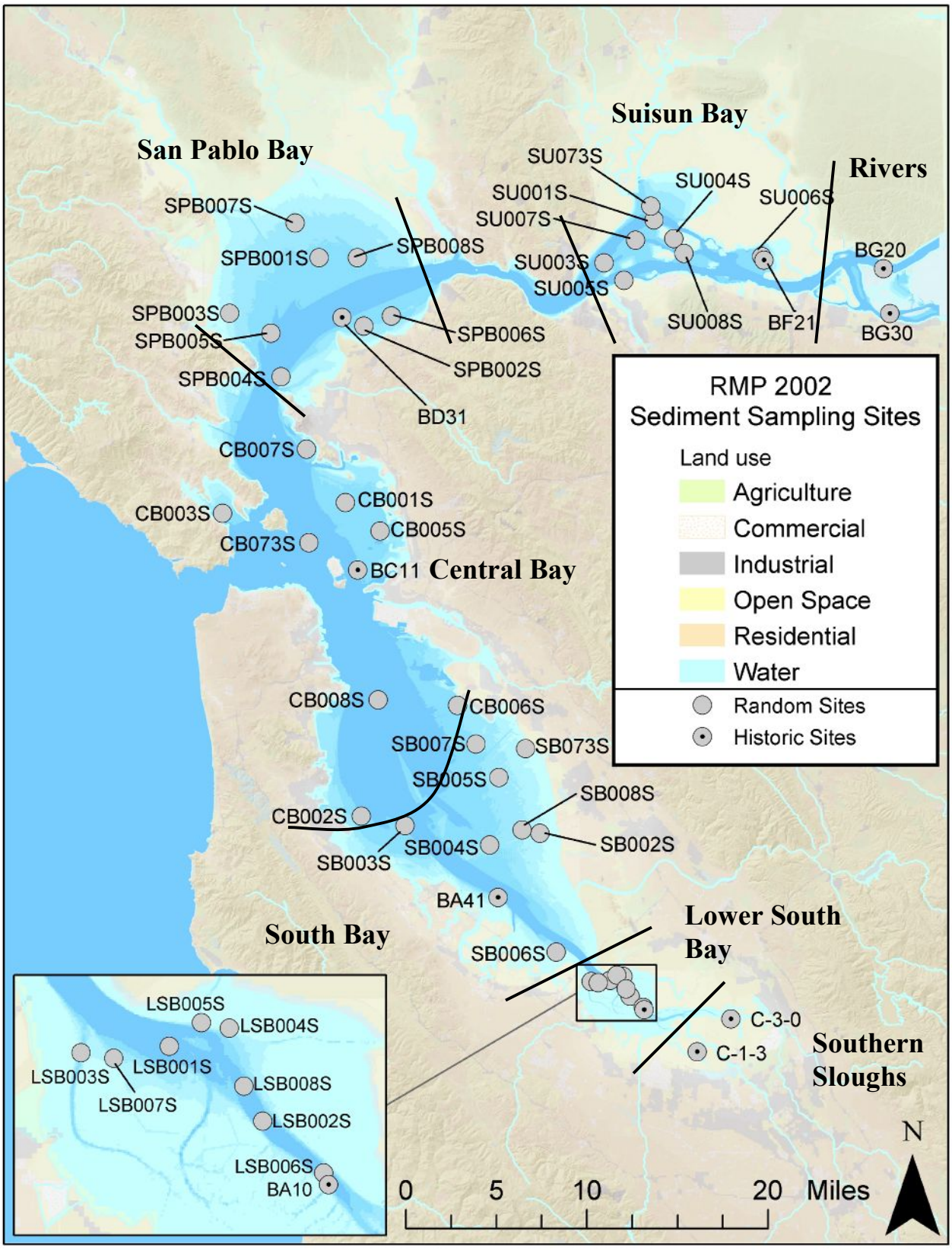

Figure 3.1. Map of the RMP Status and Trends sediment monitoring effort at both randomly selected and historic fixed sampling sites. 49 stations were sampled in the San Francisco Estuary in 2002

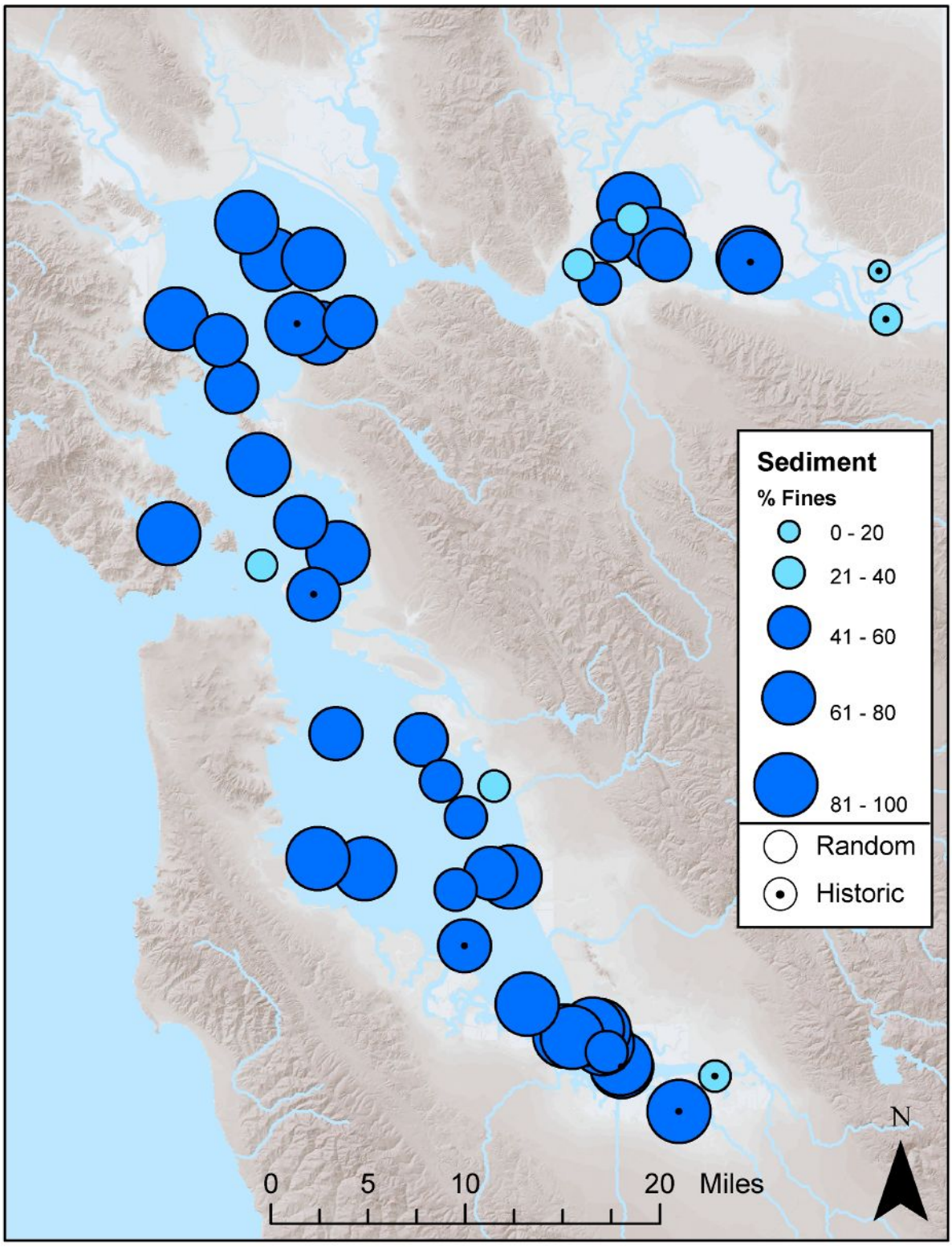

Figure 3.2. Percent fines (< 63 µm) for sediments sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002.

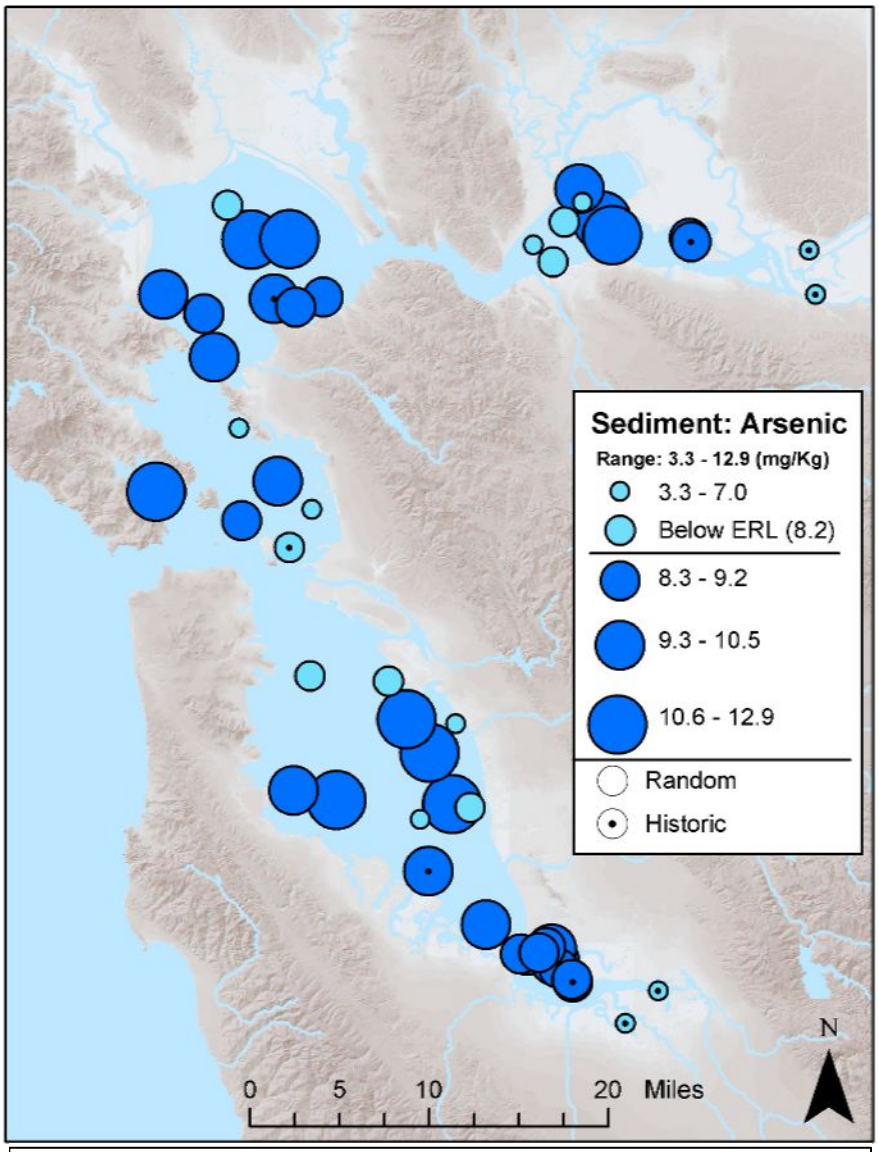

Figure 3.3a. Arsenic concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

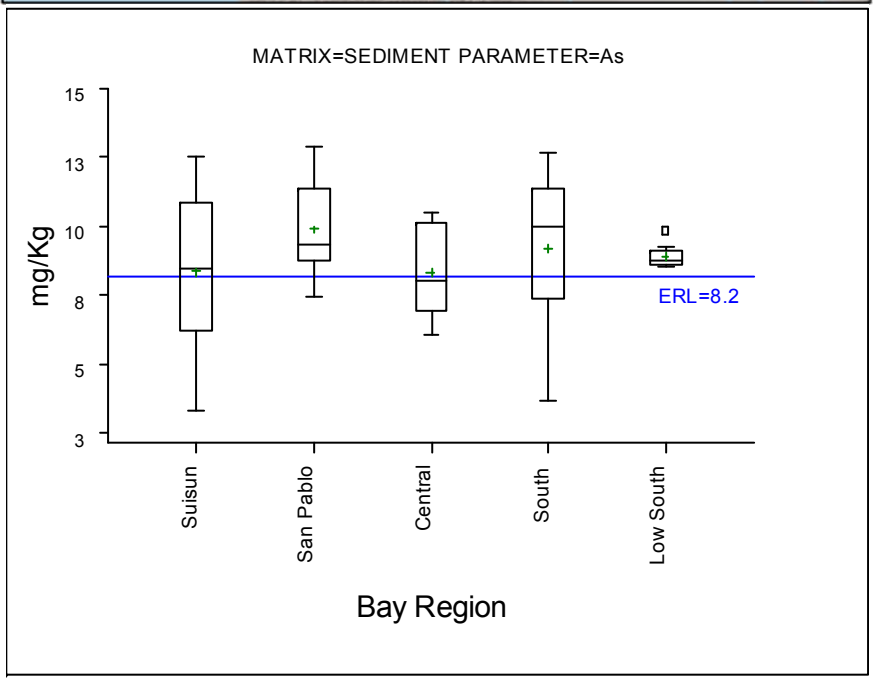

Figure 3.3b. Boxplot of arsenic concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

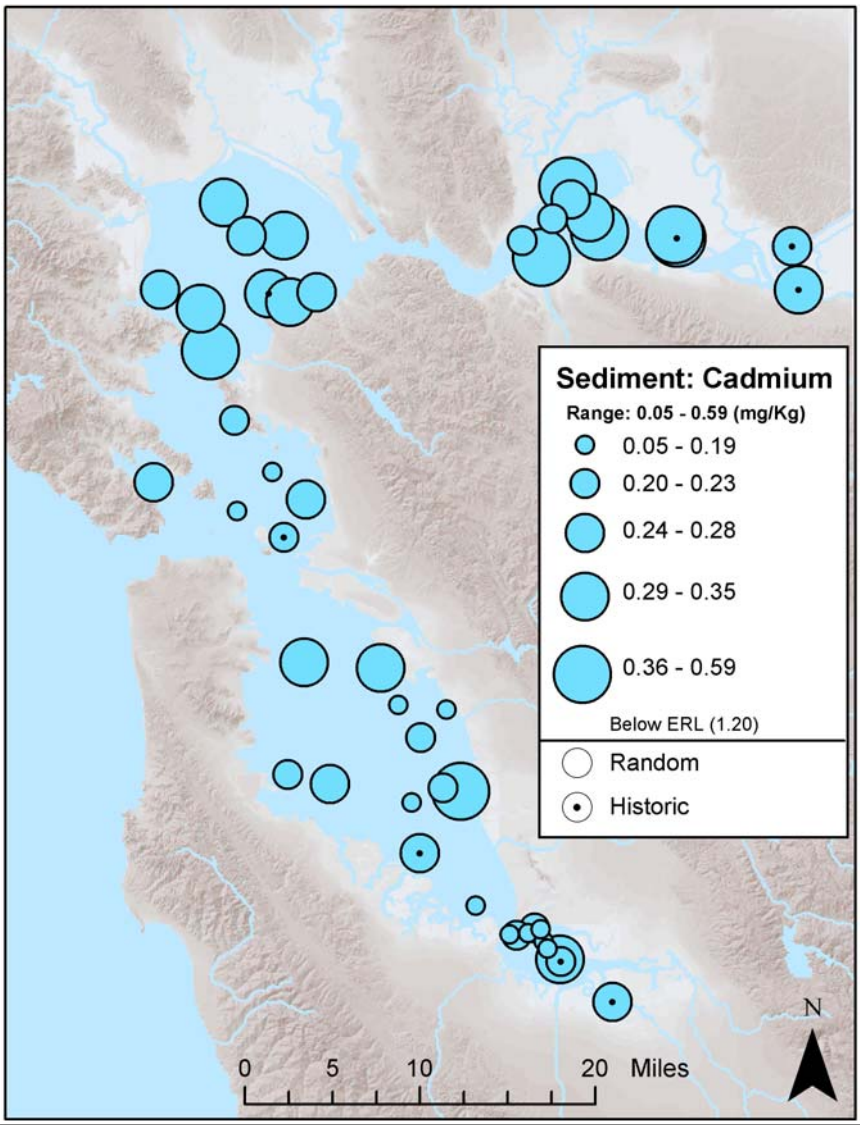

Figure 3.4a. Cadmium concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

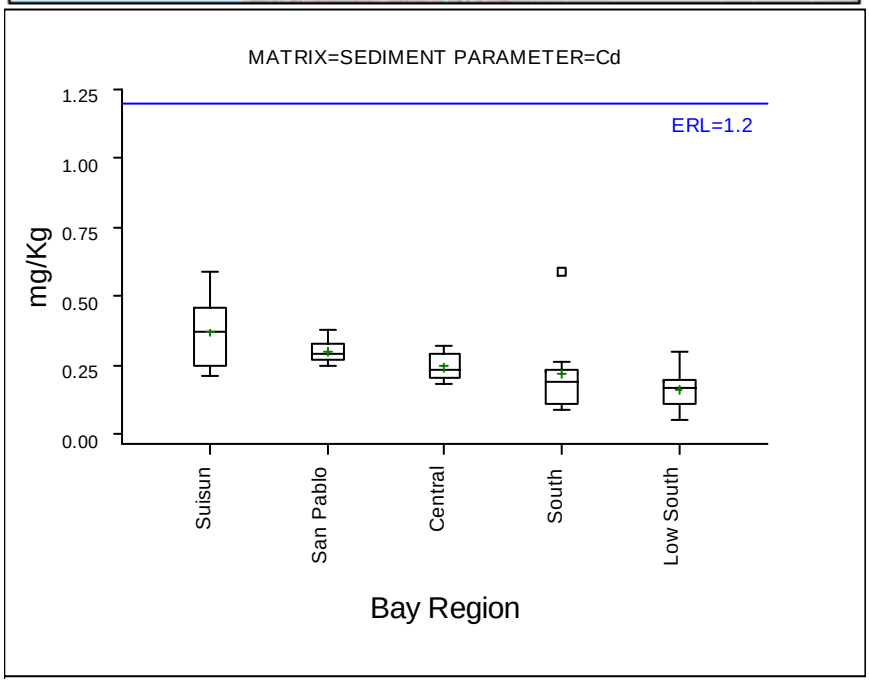

Figure 3.4b. Boxplot of cadmium concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

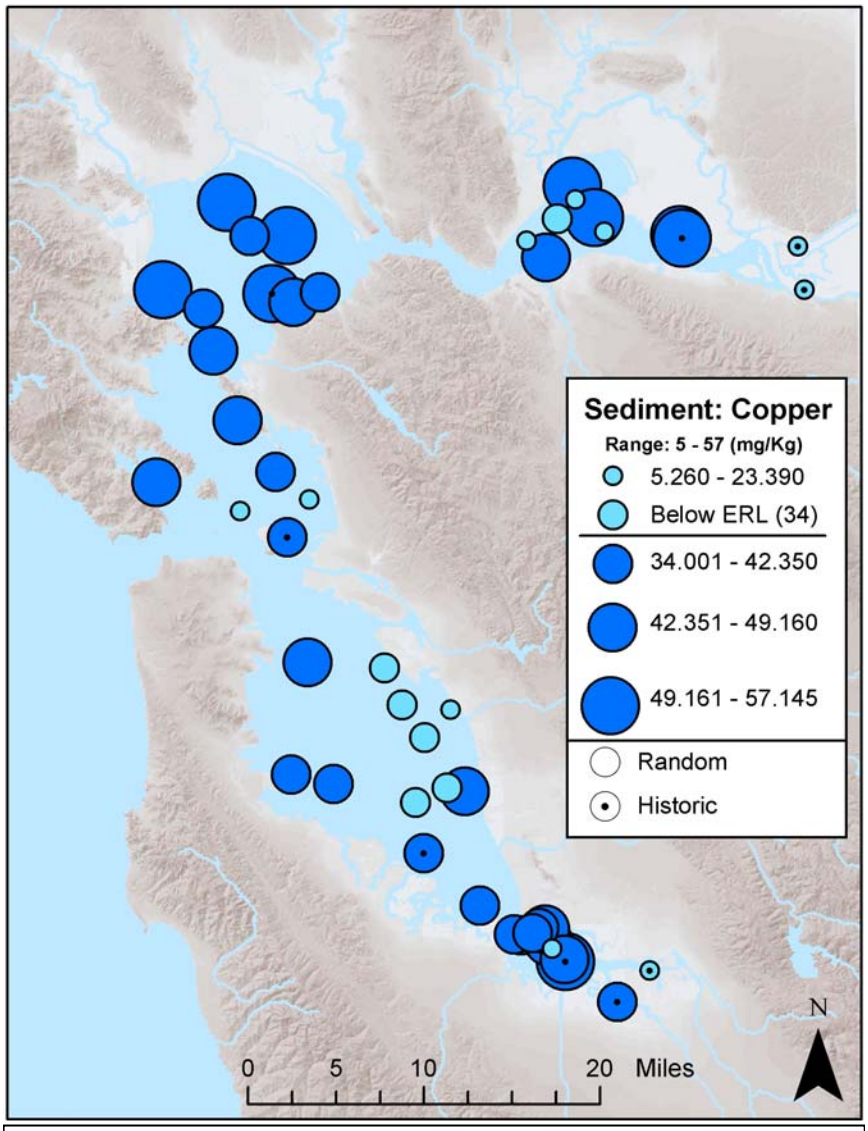

Figure 3.5a. Copper concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

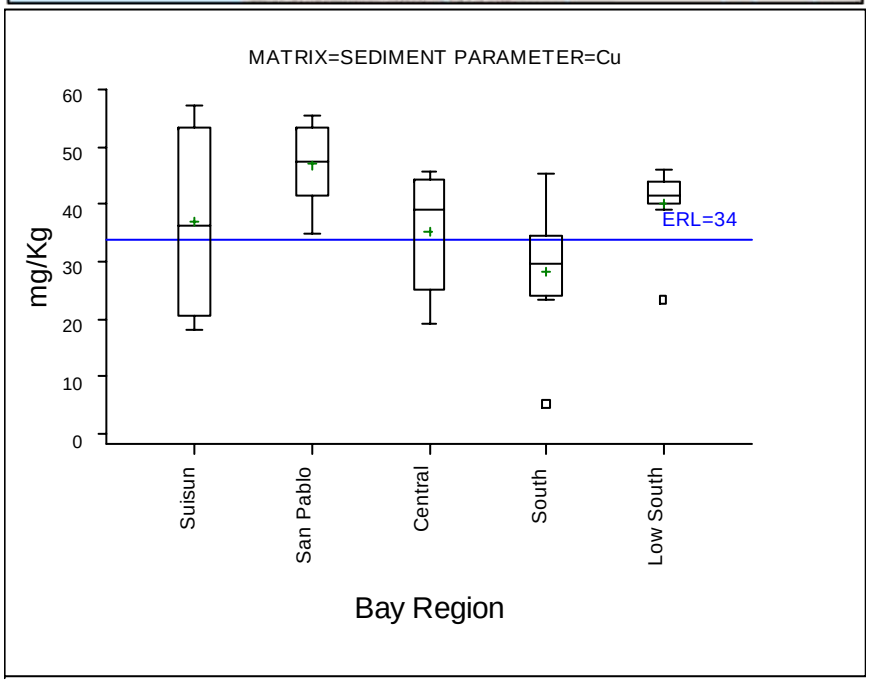

Figure 3.5b. Boxplot of copper concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

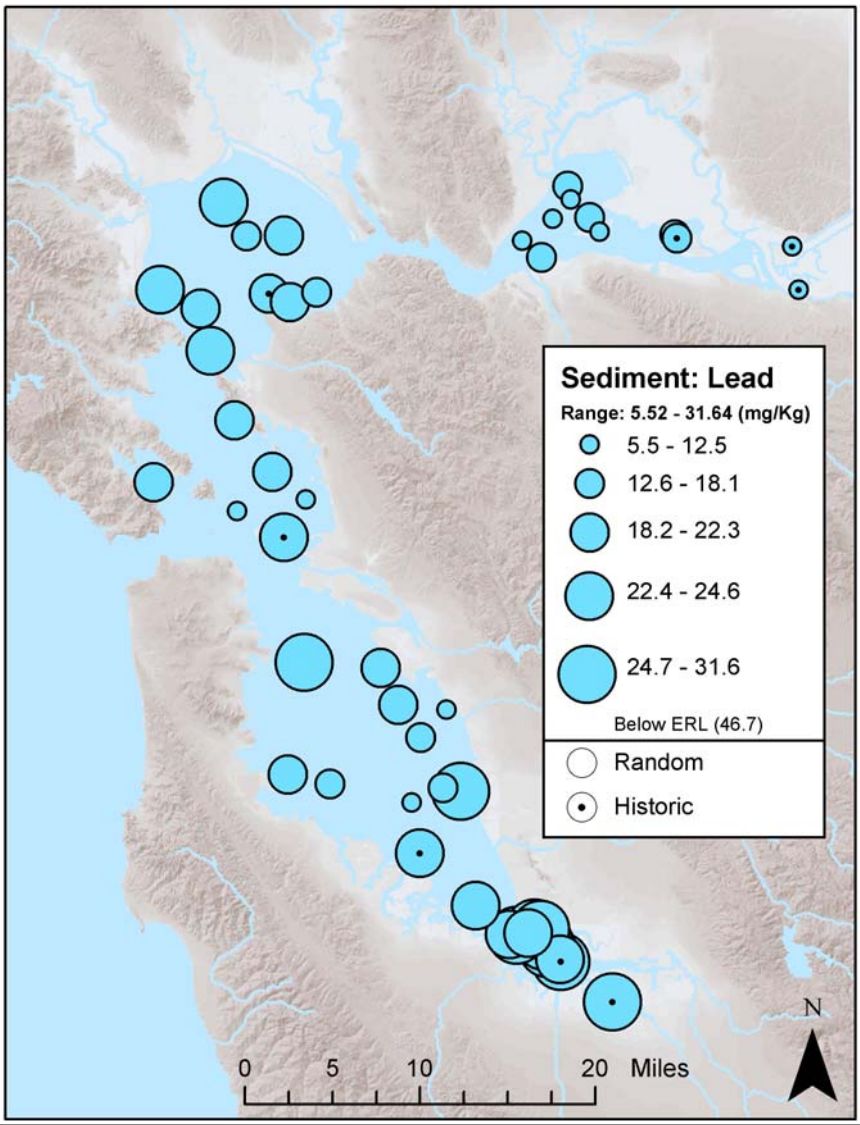

Figure 3.6a. Lead concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

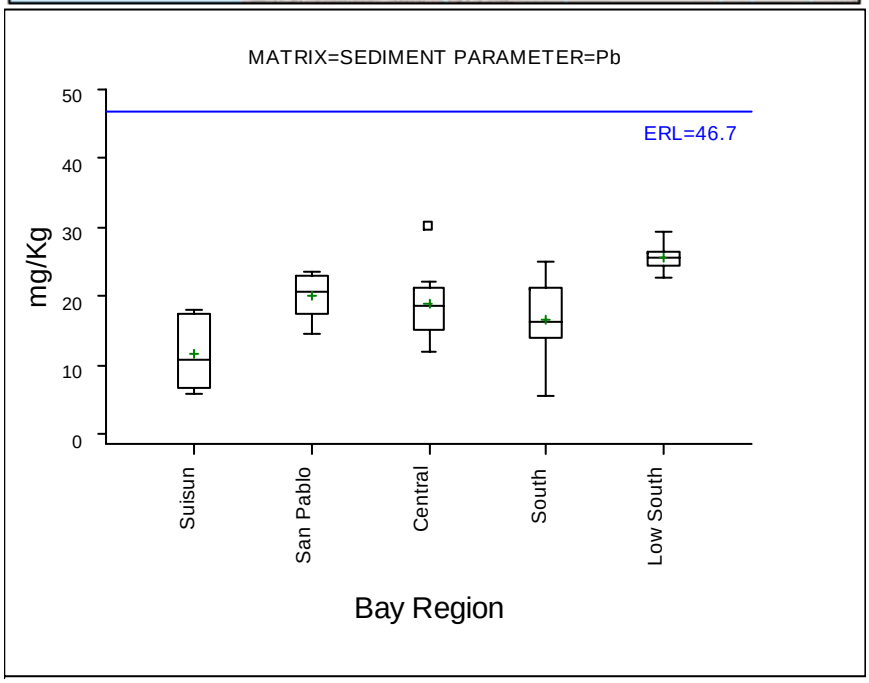

Figure 3.6b. Boxplot of lead concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

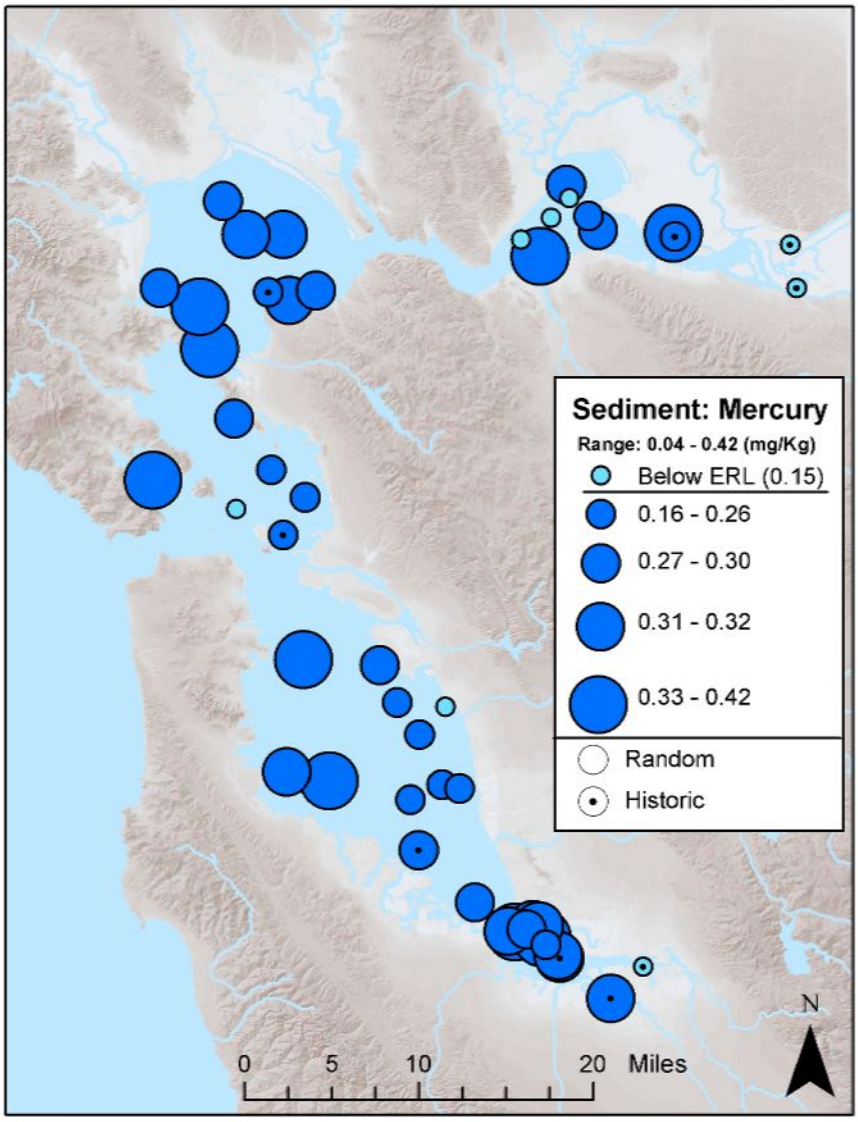

Figure 3.7a. Mercury concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance. The recent TMDL target is 0.20 mg/Kg. The same samples as depicted here were above that target as well.

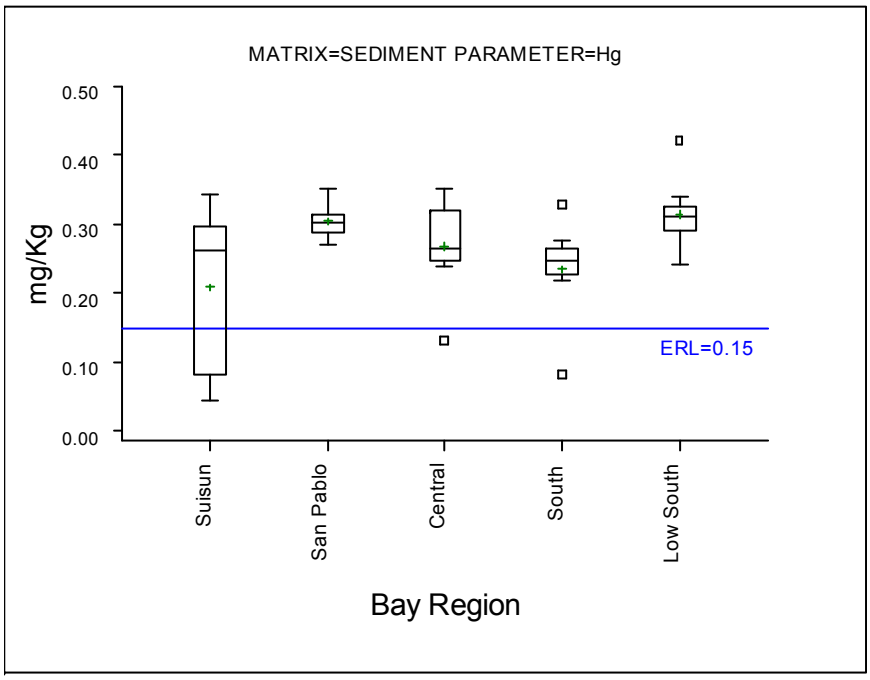

Figure 3.7b. Boxplot of mercury concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

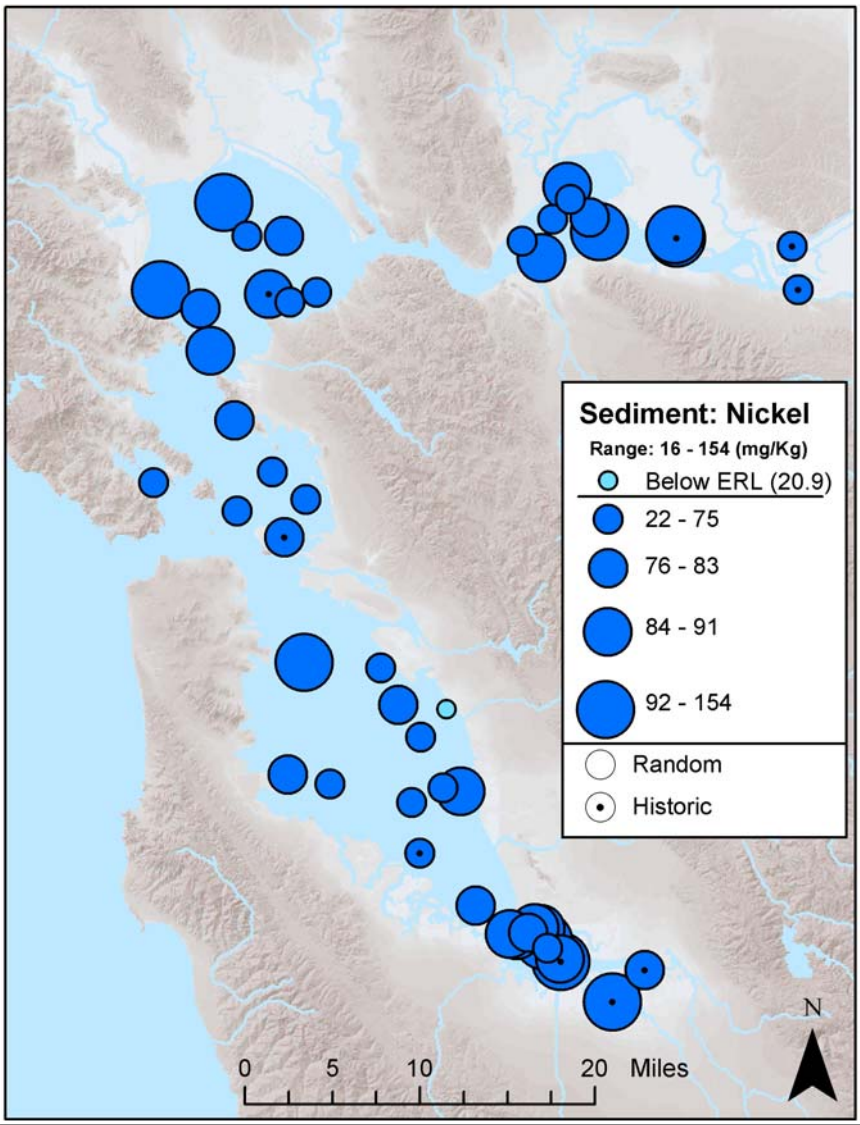

Figure 3.8a. Nickel concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

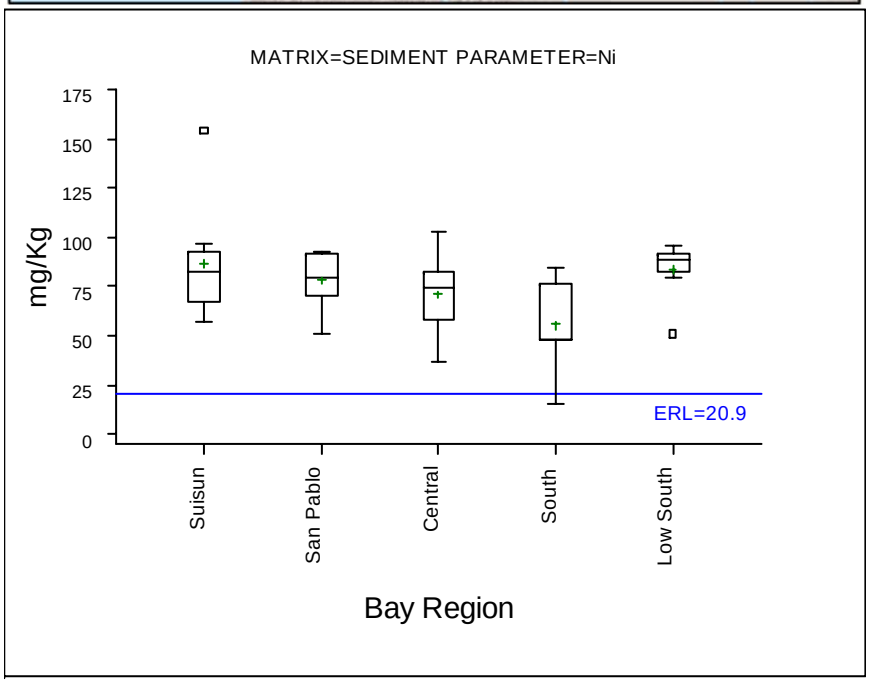

Figure 3.8b. Boxplot of nickel concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

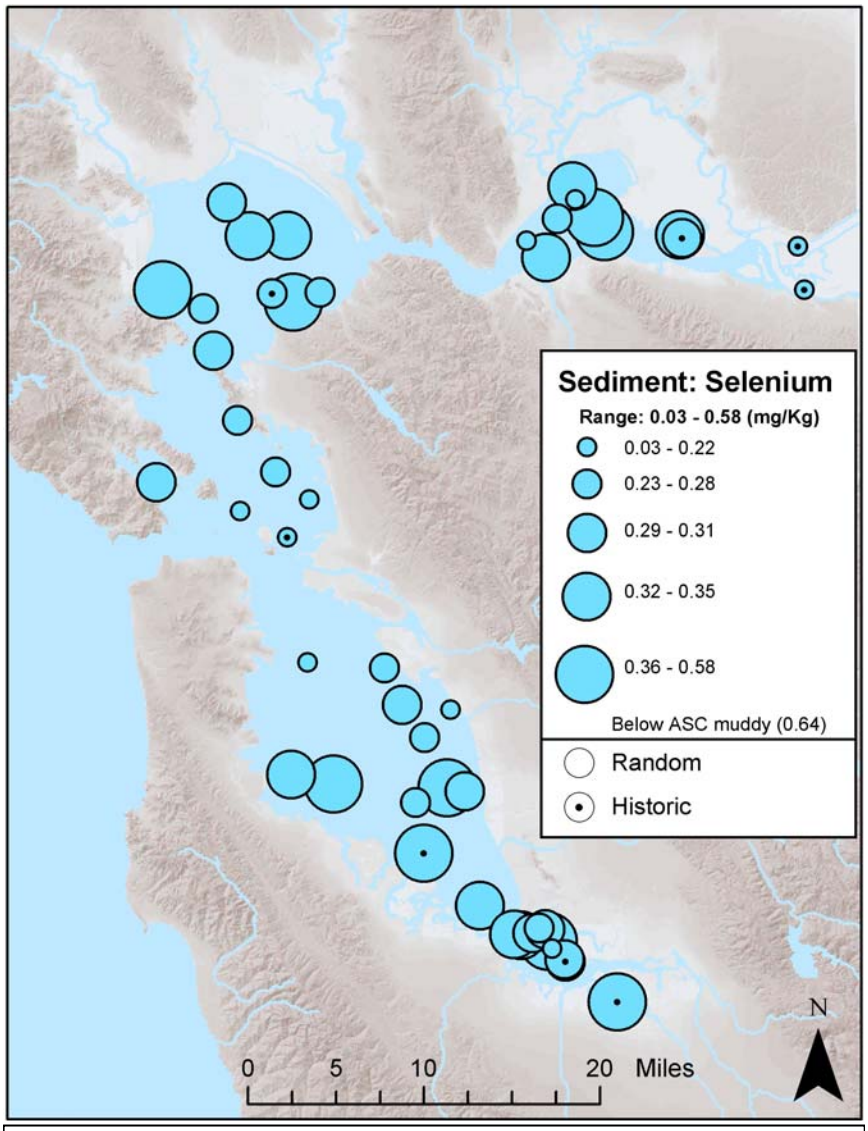

Figure 3.9a. Selenium concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ASC-muddy value is shown as a reference only and has no regulatory significance.

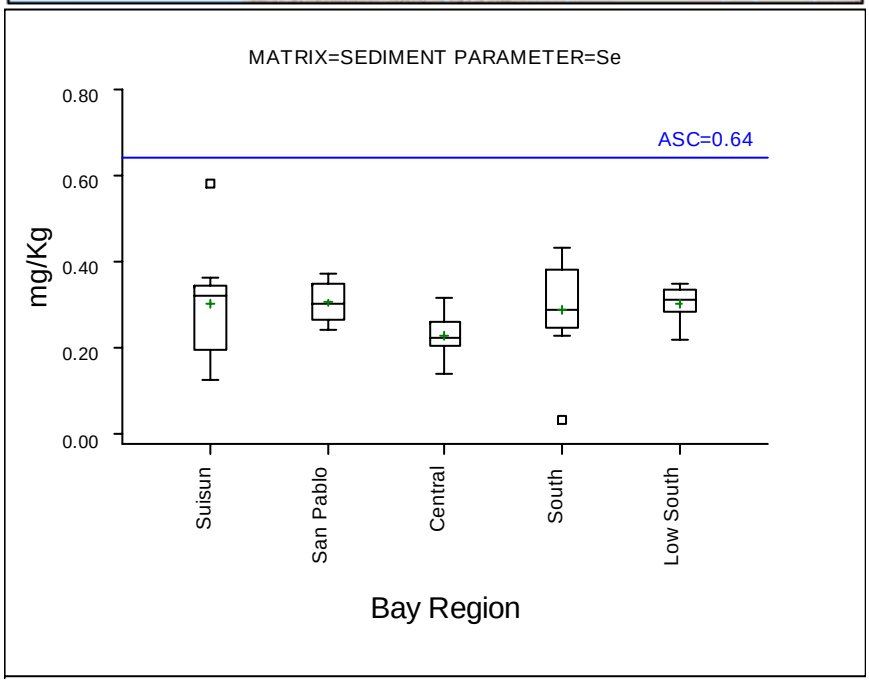

Figure 3.9b. Boxplot of selenium concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

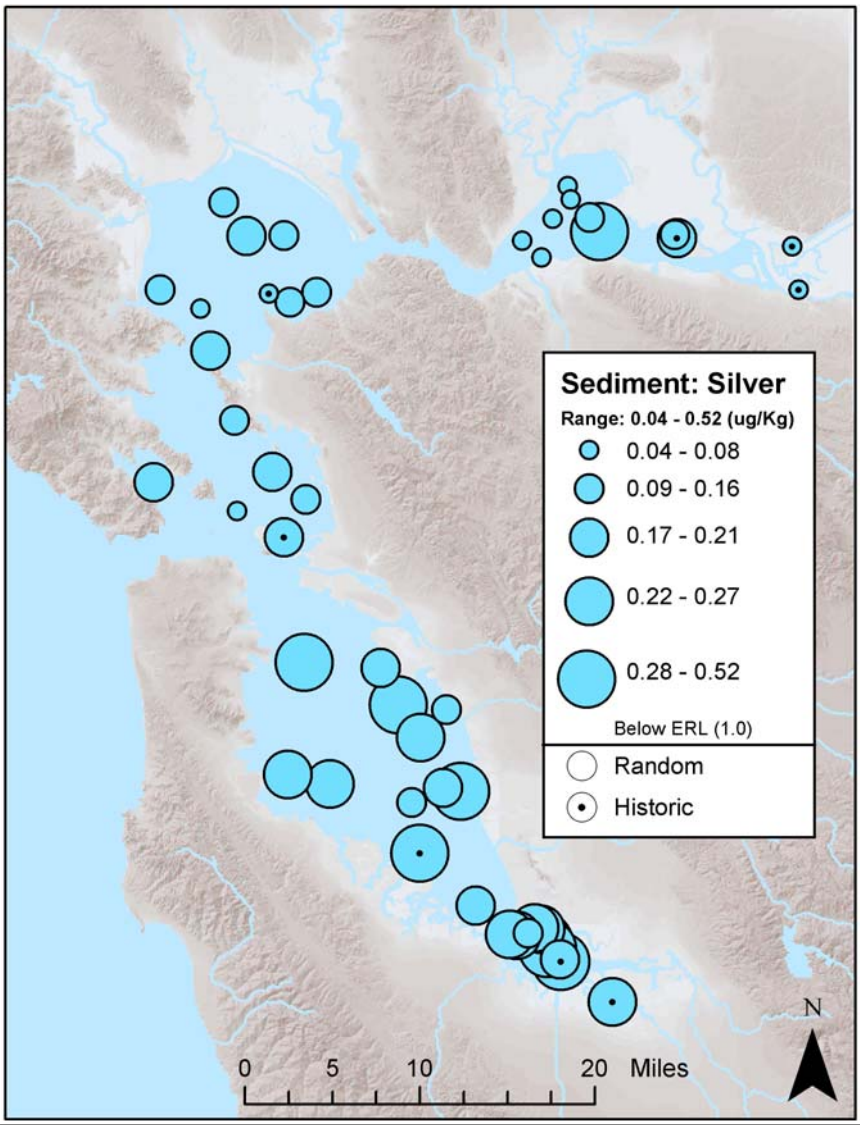

Figure 3.10a. Silver concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

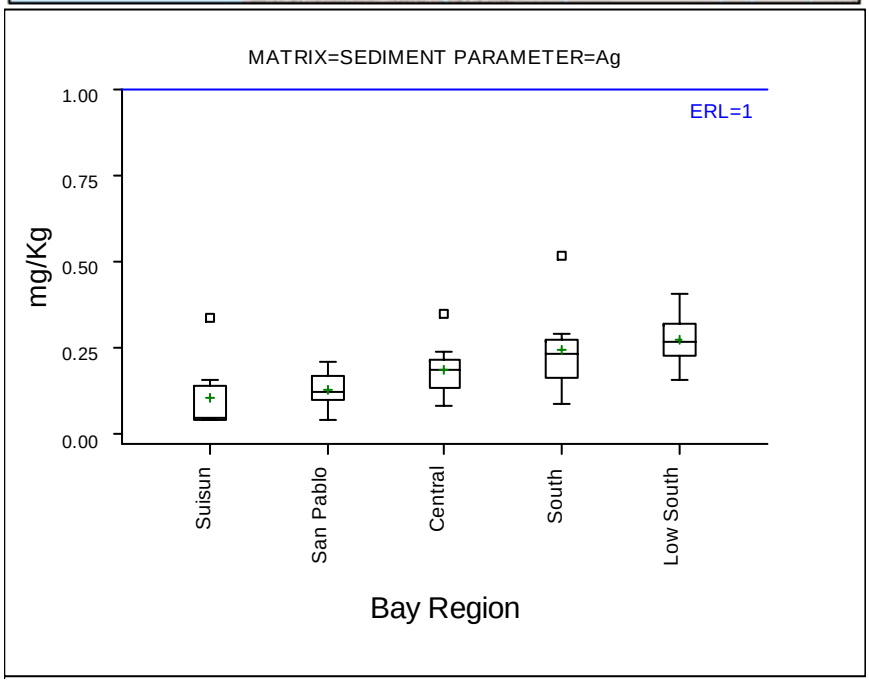

Figure 3.10b. Boxplot of silver concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

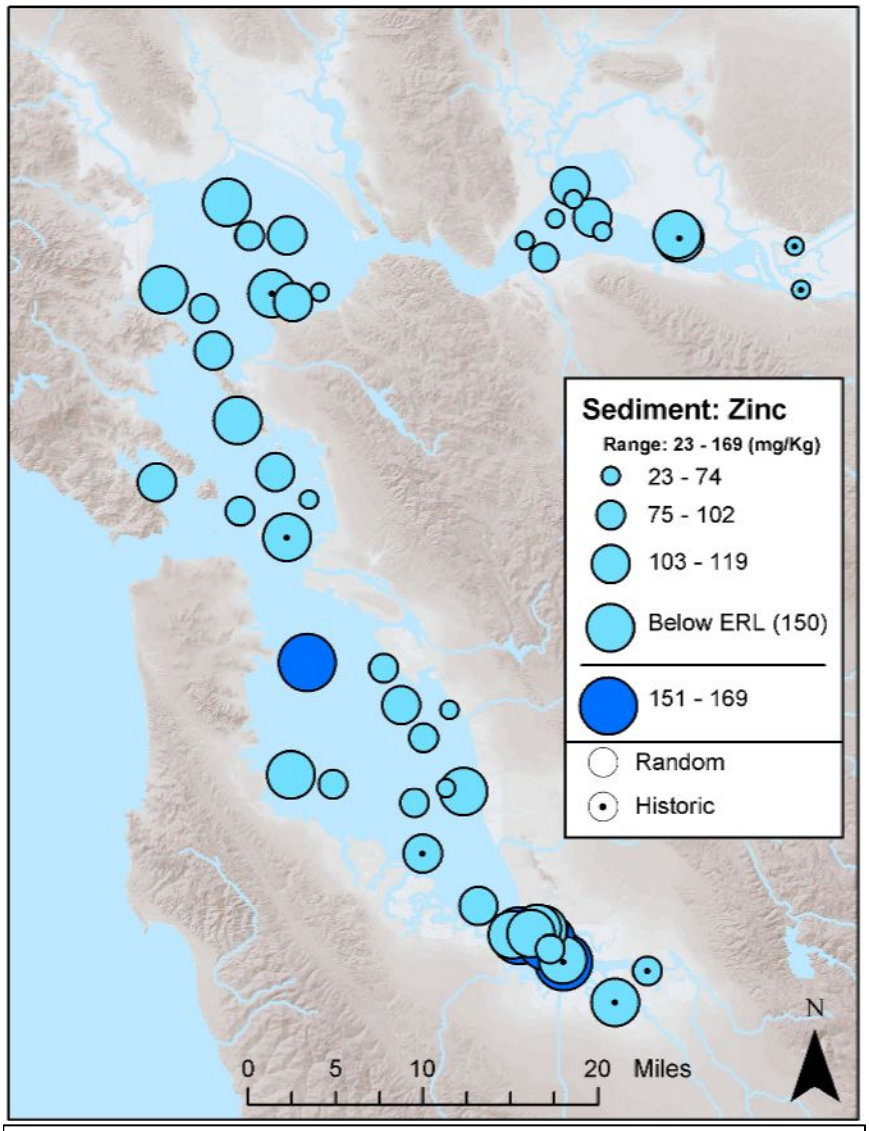

Figure 3.11a. Zinc concentrations in sediments in mg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

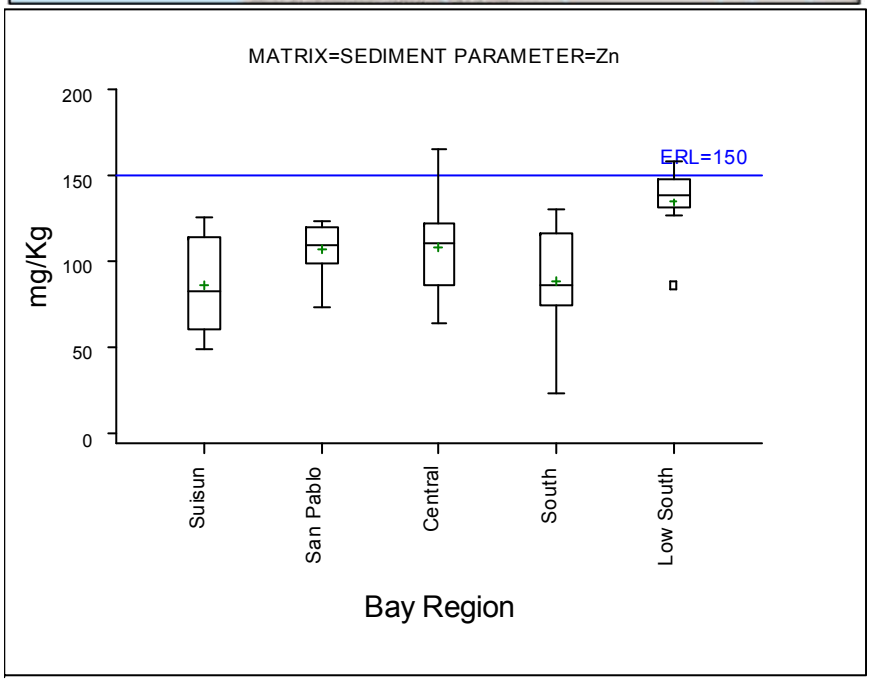

Figure 3.11b. Boxplot of zinc concentrations in sediments in mg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

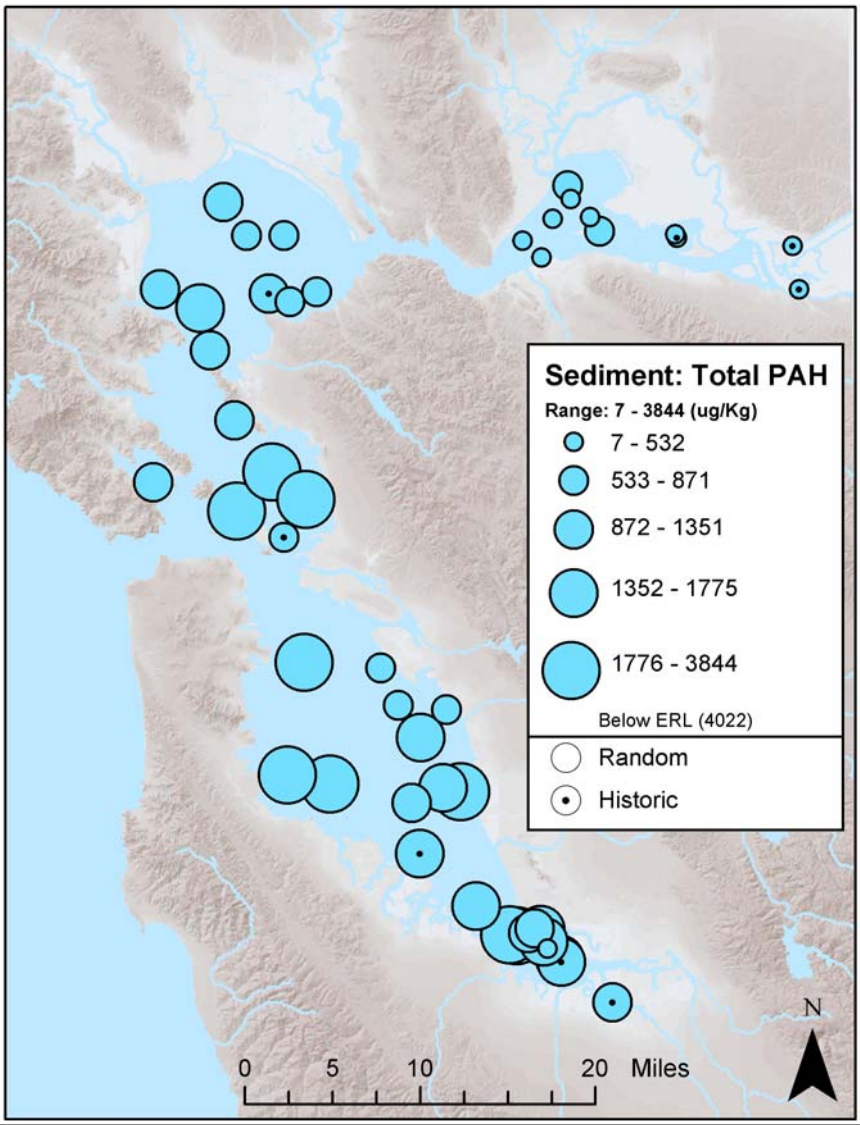

Figure 3.12a. Sum of PAH concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

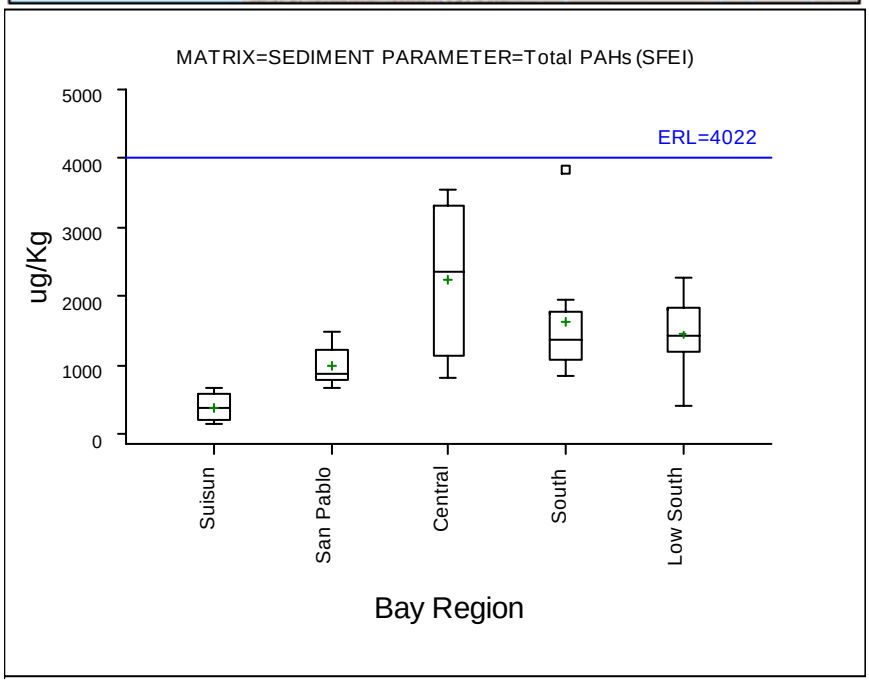

Figure 3.12b. Boxplot of sum of PAH concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

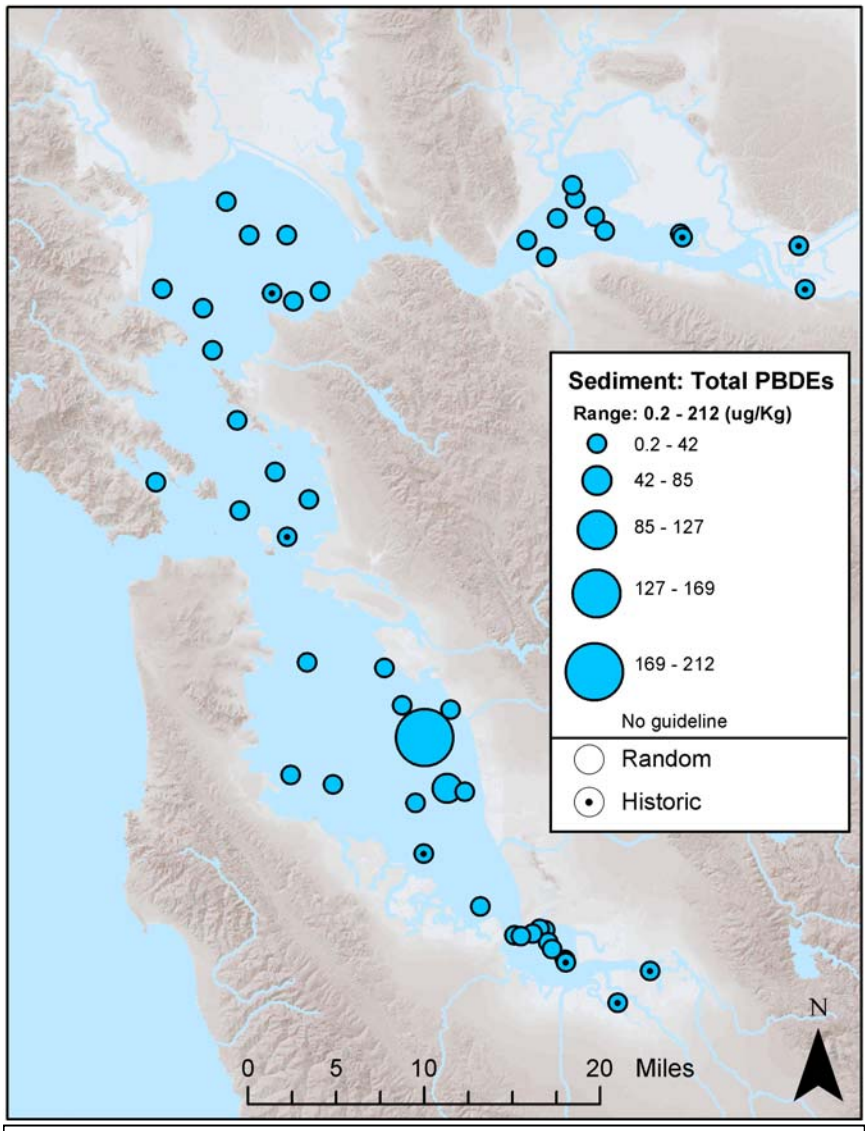

Figure 3.13a. Sum of PBDE concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. No guideline value is available for PBDEs.

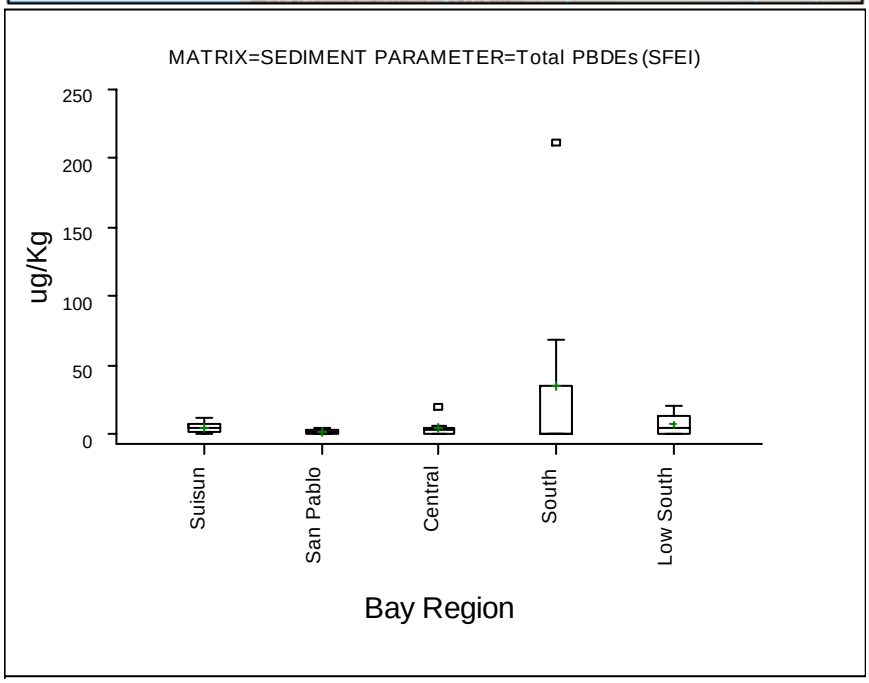

Figure 3.13b. Boxplot of sum of PBDE concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

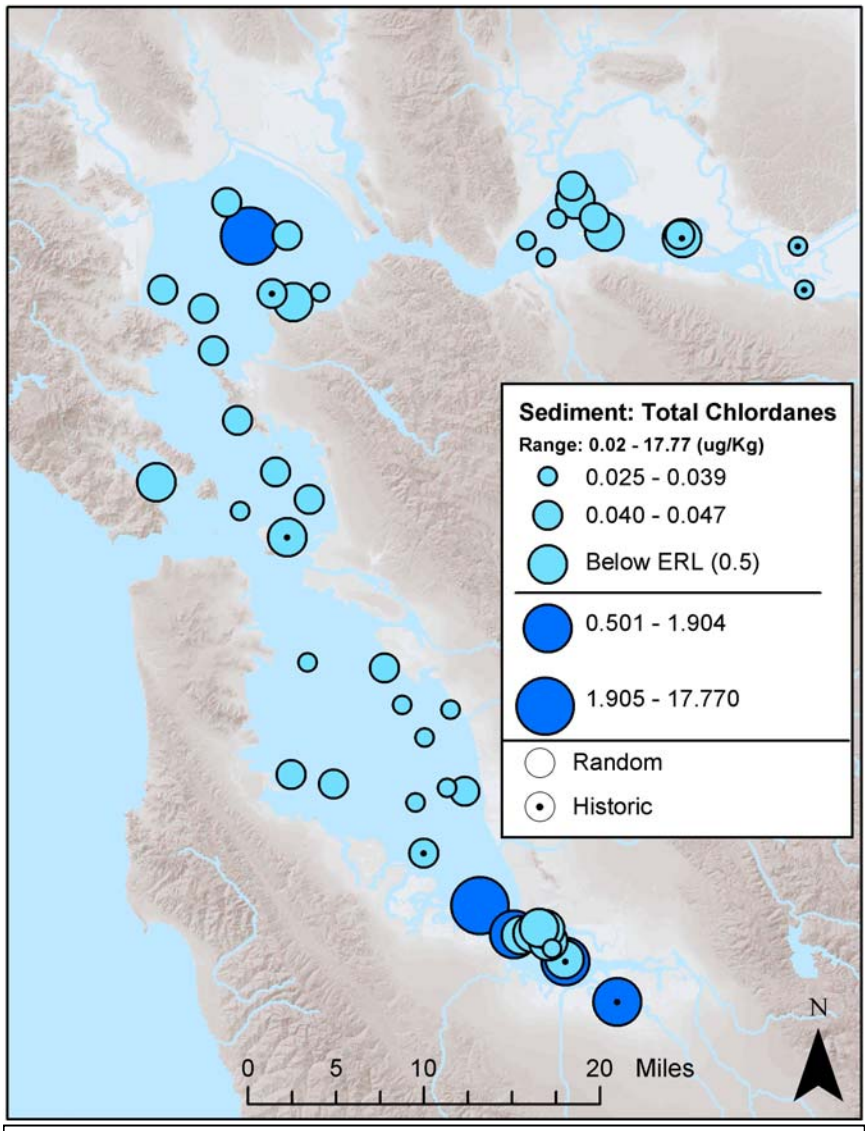

Figure 3.14a. Sum of chlordane concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

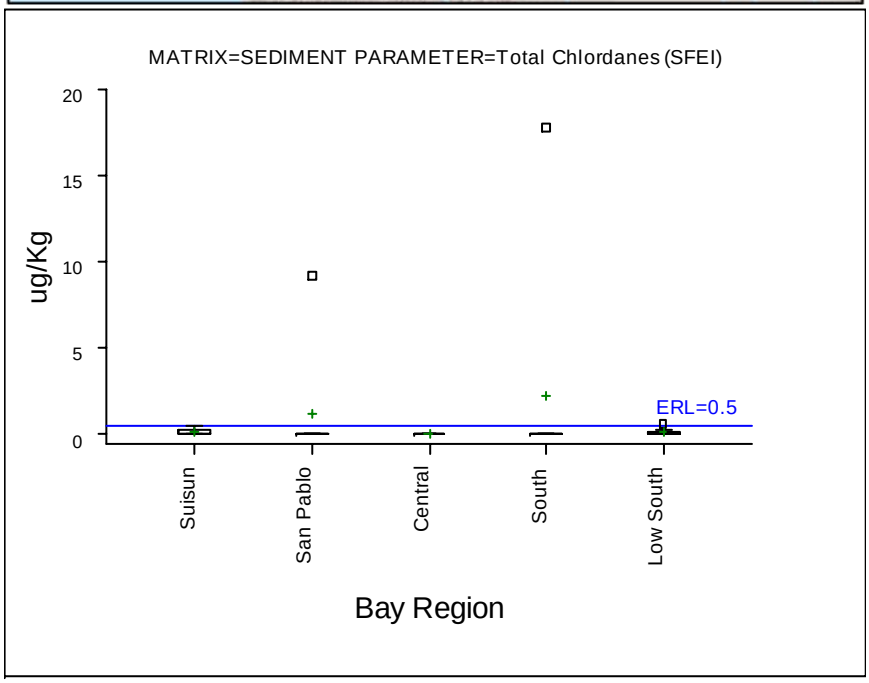

Figure 3.14b. Boxplot of sum of chlordane concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

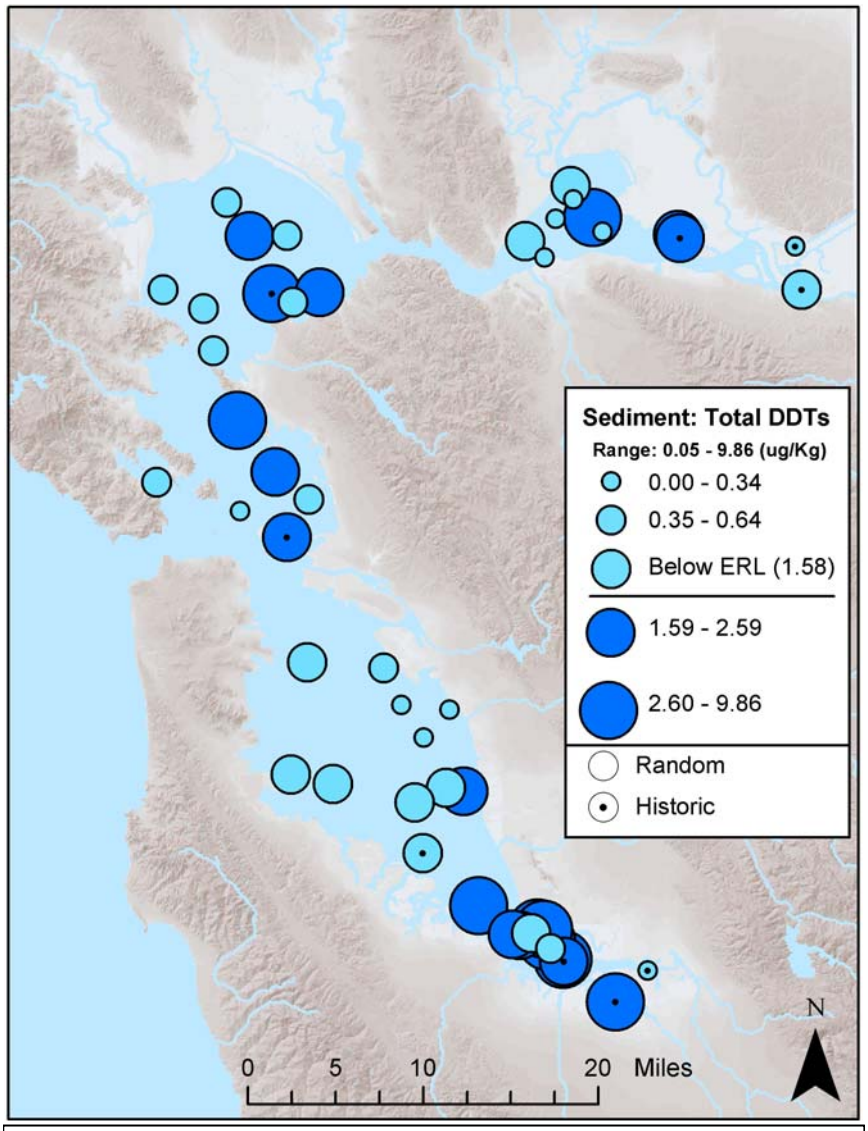

Figure 3.15a. Sum of DDT concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance.

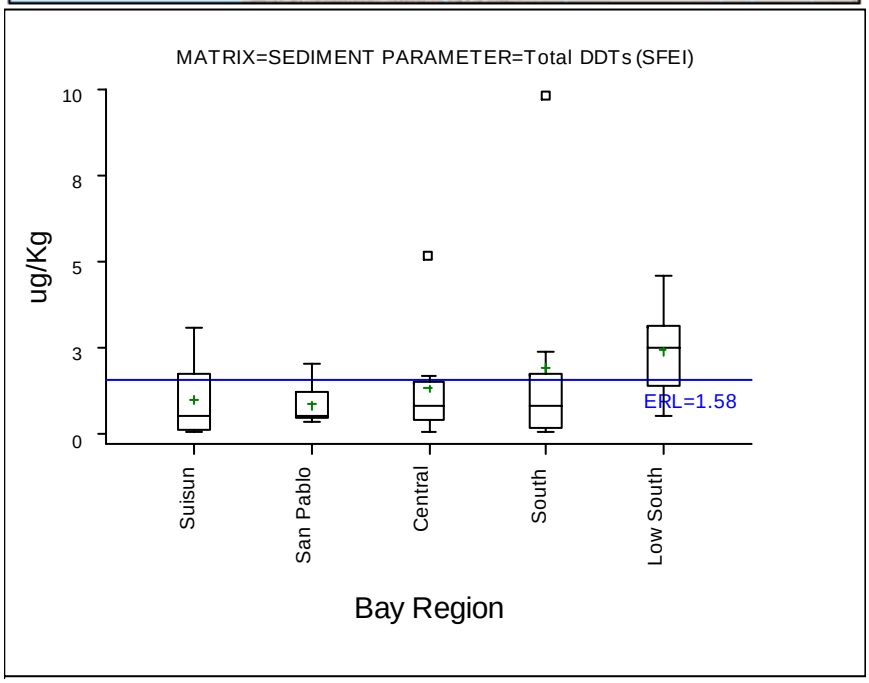

Figure 3.15b. Boxplot of sum of DDT concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

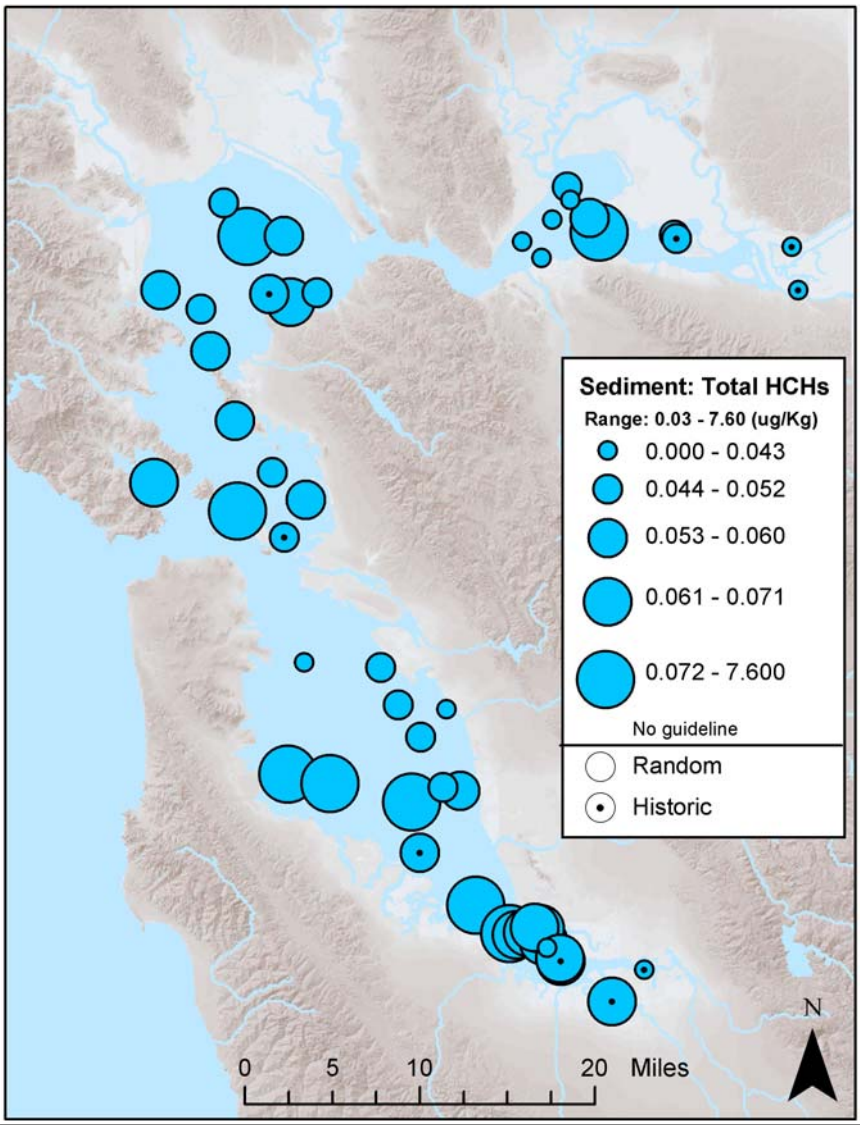

Figure 3.16a. Sum of HCH concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. No guideline is available for HCHs.

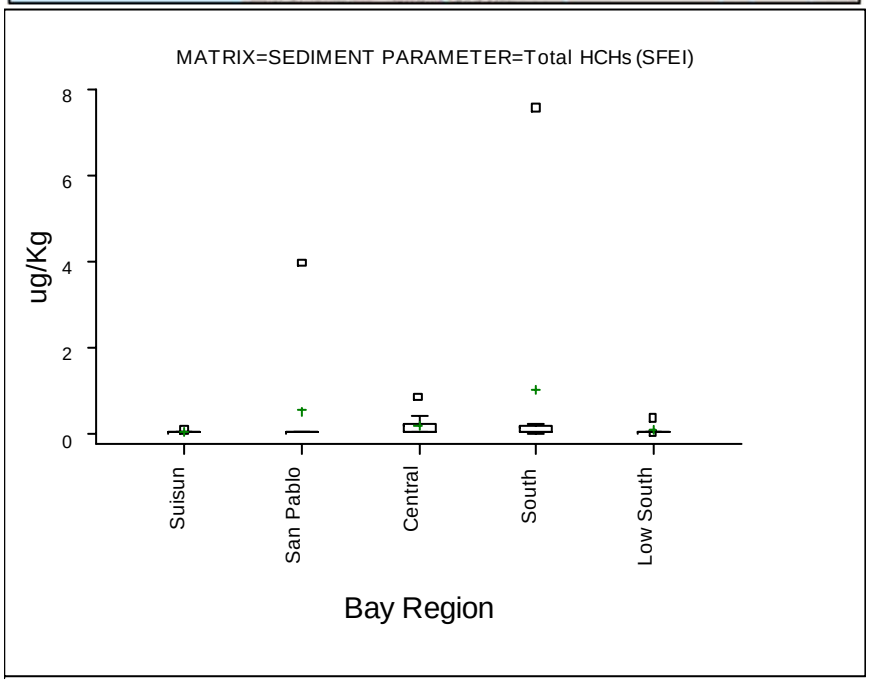

Figure 3.16b. Boxplot of sum of HCH concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

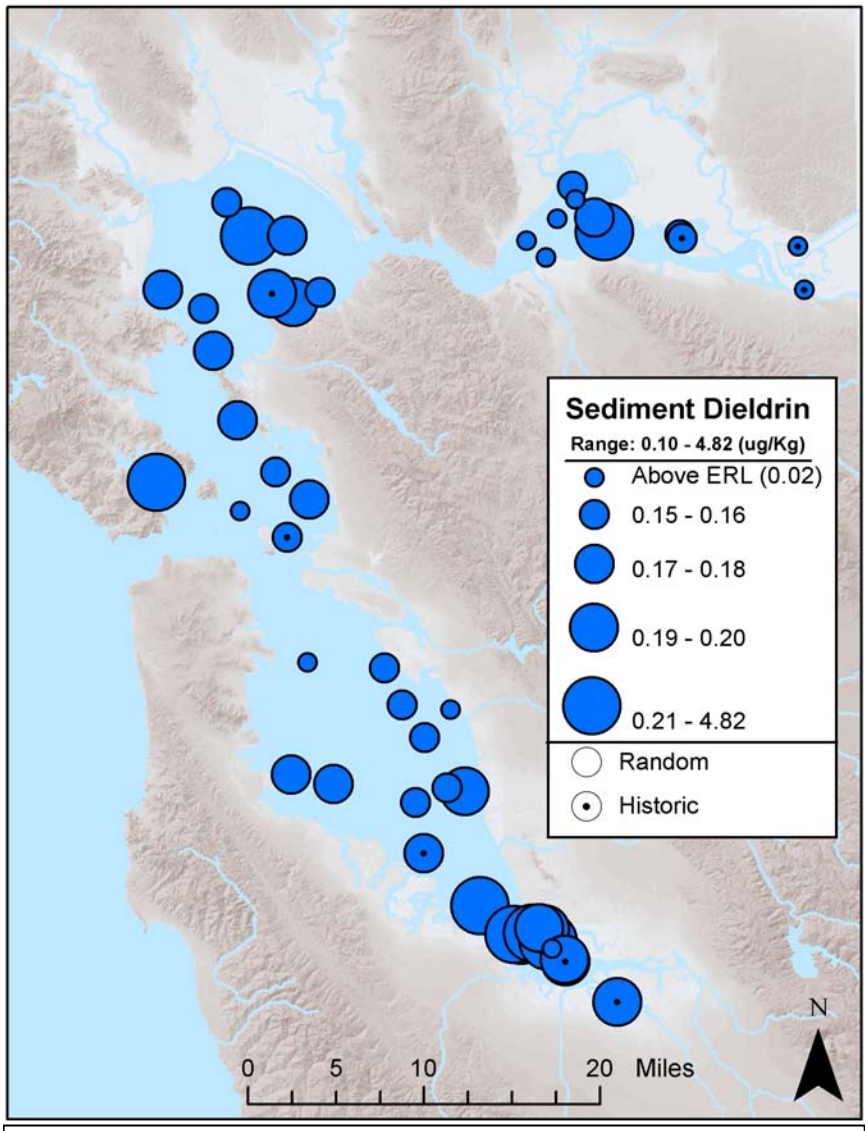

Figure 3.17a. Dieldrin concentrations in sediments in µg/Kg, dry weight, at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002. The ERL value is shown as a reference only and has no regulatory significance. The method detection limit (MDL) is greater than the ERL and ASC-sandy guidelines; therefore, conclusions regarding these benchmarks cannot be drawn (see Table 3.1). The ERM guideline value is 8 µg/Kg, dry weight.

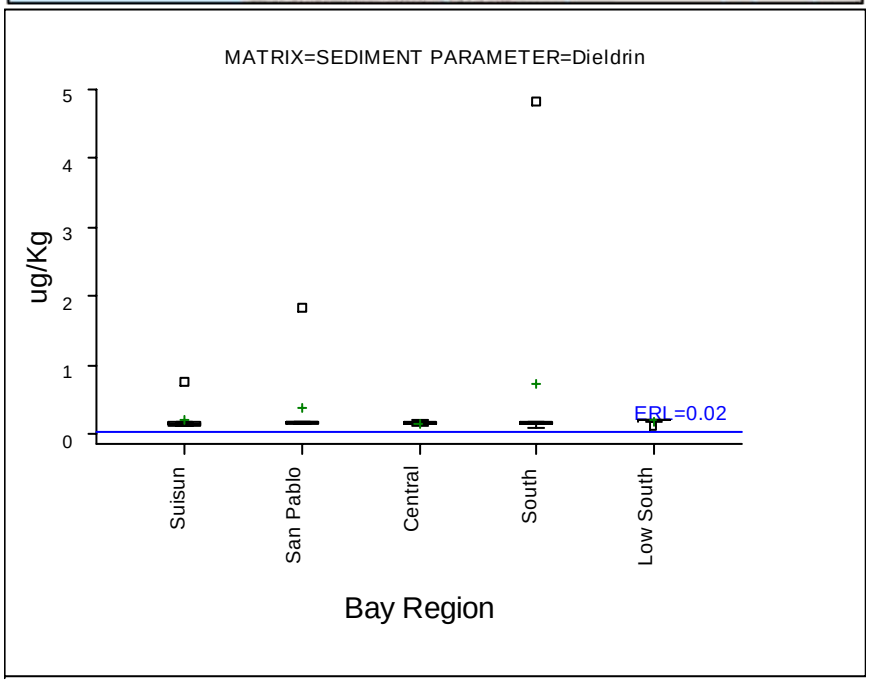

Figure 3.17b. Boxplot of dieldrin concentrations in sediments in µg/Kg, dry weight, by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

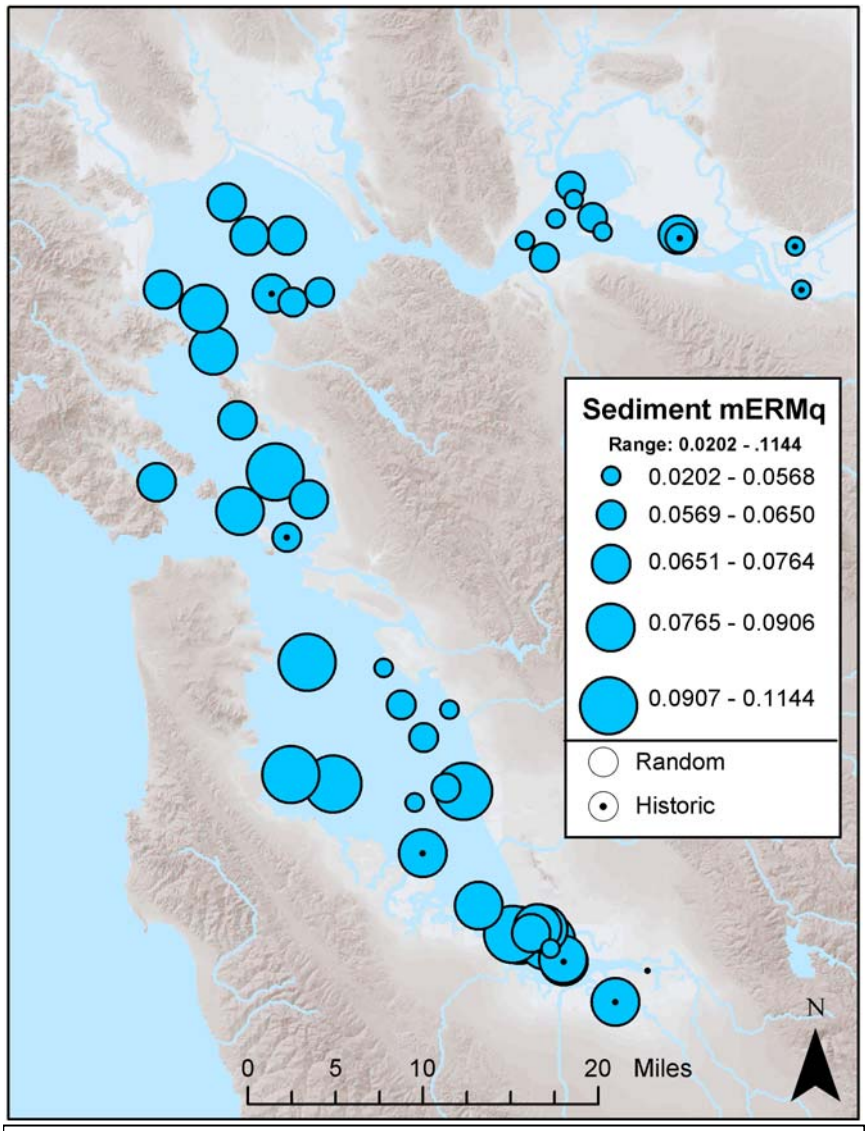

Figure 3.18a. Sediment mERMq values at stations sampled at both randomly selected and historic fixed RMP sites in the San Francisco Estuary in 2002.

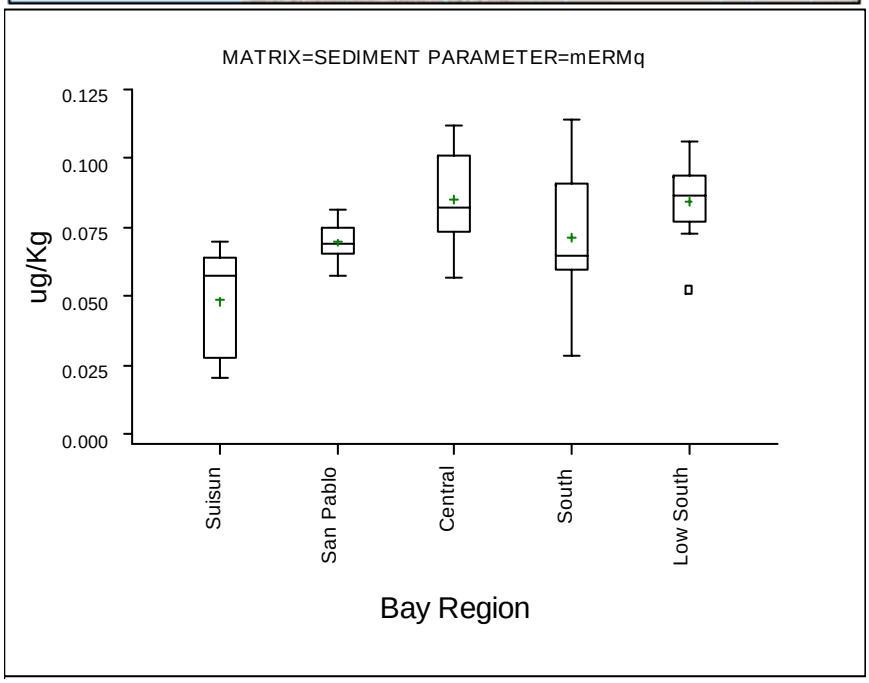

Figure 3.18b. Boxplot of sediment mERMq values by region for the random sites sampled in the San Francisco Estuary in 2002. See *Section 1.3.1 Reporting* for an explanation of the schematic boxplot.

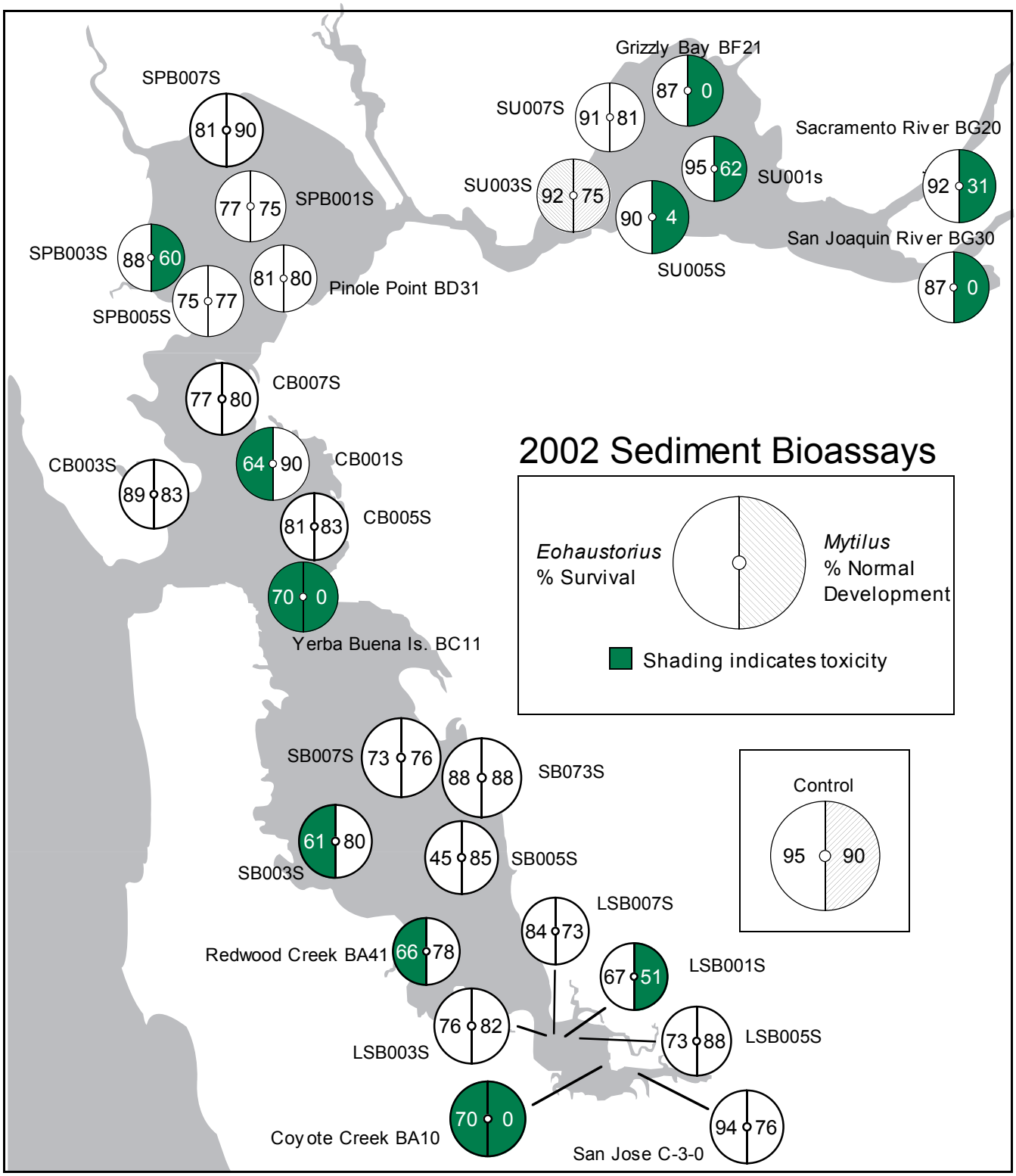

Figure 3.19. Sediment bioassay results for 2002. Sediments were not toxic (see Section 3.4 Sediment Toxicity) to either amphipods, *Eohaustorius estuarius*, or mussel, *Mytilus galloprovincialis*, larvae at 16 out of 28 stations. Amphipod toxicity was observed at three stations: Central Bay (CB001S) and South Bay (Redwood Creek (BA41), SB003S). Sediment samples from nine stations were toxic to larval mussels: Sacramento River (BG20), San Joaquin River (BG30), Suisun Bay (Grizzly Bay (BF21), SU001S, SU005S), San Pablo Bay (SPB003S), Yerba Buena Island (BC11), Lower South Bay (LSB001S), and Coyote Creek (BA10). Sediments from Yerba Buena Island (BC11) and Coyoye Creek (BA10) were toxic to both amphipods and larval mussels.

BIVALVE MONITORING RESULTS

>> Chapter 4

4.0 BIVALVE MONITORING

Jennifer Hunt, Nicole David, Sarah Lowe and Daniel Oros

4.1 Background

The San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) has been analyzing bivalve tissue samples for trace contaminants since 1993. Bivalves bioaccumulate chemical contaminants through their food, by ingesting sediment and assimilating contaminants that are sorbed to particles and by filtering dissolved contaminants directly from the water column. Bivalves act as transfer vectors of contaminants to higher trophic levels of the aquatic and sediment food web. Contaminant concentrations in tissue can accumulate to levels much greater than those found in ambient water and sediment due to the organism's inability to metabolize certain contaminants (Vinogradov, 1959) and a high affinity of some contaminants for lipid rich tissue in bivalves (Stout and Beezhold, 1981). Biomonitoring using bivalves has been widely applied by the California State Mussel Watch Program (Phillips, 1988; Rasmussen, 1994) and other studies (Young *et al.,* 1976; Wu and Levings, 1980; Hummel *et al*., 1990; Martincic *et al.,* 1992, Gunther *et al.,* 1999; O'Connor, 2002).

Bivalves are good organisms for biomonitoring contaminants since they accumulate contaminants from the ambient environment, have limited mobility and are fairly resistant to contamination effects (O'Connor, 2002). The RMP is continuing the long-term monitoring of the State Mussel Watch Program, which monitored sites throughout the Estuary beginning in 1976. Comparable RMP stations that are still monitored include Pinole Point, Red Rock, Horseshoe Bay, Yerba Buena Island, Alameda, Redwood Creek and Dumbarton Bridge. Biomonitoring using bivalves has been thoroughly described in the literature (Luoma and Linville, 1996; Gunther and Davis, 1997; Gunther *et al.,* 1999).

4.2 Approach

The bivalve sampling component of the RMP did not change in 2002 and monitoring continued at fixed mooring stations in the Estuary. The study area ranged from Coyote Creek (BA10) in the Lower South Bay to the Sacramento River region in the northern Estuary (Figure 4.1).

As in previous years, bivalves for transplanting were collected from various reference stations; mussels (*Mytilus californianus*) from Bodega Head, mussels (*Mytilus edulis*) from Tomales Bay, and oysters (*Crassostrea gigas*) were purchased from Hog Island Oyster Company in Tomales Bay. Resident clams (*Corbicula fluminea*) were collected from the Sacramento and San Joaquin River stations near the end of the deployment period. All bivalves collected from reference stations were kept on ice and deployed within 72 hours.

Bivalves were deployed at a total of 12 fixed mooring stations within the Estuary for a period of 90-100 days. Bivalve monitoring was conducted during the dry season (June through August). The RMP Design Integration Workgroup determined that it is

sufficient to analyze tissue concentrations in bivalves only once per year during the dry season, when Estuary conditions are more consistent on an interannual basis. The 2002 bivalve deployment marks the third year of annual dry season monitoring.

In 2000 and 2001, a special study was implemented to test a new system of bivalve deployment. Because predation of deployed bivalves can increase mortality especially at the Central Bay stations Horseshoe Bay (BC21) and Yerba Buena Island (BC10), bivalves in cages were deployed along side the bagged bivalves at certain stations in order to determine which deployment method yields higher bivalve survival. This study continued in 2002 with eight stations having both caged and bagged bivalves. Due to the high predation at Horseshoe Bay and Yerba Buena Island, only caged bivalves were deployed at these stations. This is the third year of this study. Additional cages were deployed but not maintained to determine if the mid-deployment maintenance cruise was necessary.

In 2002, *M. edulis* and *M. californianus* were deployed at all mooring stations, including historical *C. gigas* stations, to determine if a single mussel species could be deployed at all sampling stations. Deployment of a single mussels species will allow for comparison of bioaccumulation of contaminants across stations in the Estuary. Currently, spatial comparisons are limited to those stations that deploy the same species since different species bioaccumulate/metabolize contaminants at different rates. As in previous years, *C. gigas* was deployed at Coyote Creek, Petaluma River, San Pablo Bay, Davis Point and Napa River. All three species were measured for survival while only *M. californianus* and *C. gigas* were analyzed for trace organic concentrations. Organic analysis and growth parameters were determined only for maintained, bagged bivalves (except at Yerba Buena Island and Horseshoe Bay where maintained, caged bivalves were analyzed for growth and chemistry).

4.2.1 Methods

Table 1.4 in the Introduction lists the parameters measured in bivalve tissue in 2002. Section 6 – *Description of Methods* summarizes field and analytical methods and provides information on additional RMP sampling and analysis reference documentation. Data are available for downloading via the RMP website using the Web Query Tool @ http://www.sfei.org/rmp/data.htm.

Samples were analyzed for synthetic trace organics, which included PAH, PCBs, pesticides, polybrominated diphenyl ethers (PBDEs), musks, phthalates, p-nonylphenol and triphenylphosphate. PBDEs, phthalates, p-nonylphenol, triphenylphosphate, and musks were added in 2002 based on the findings of an RMP special study (http://www.sfei.org/rmp/reports/unidentified_contaminants/unidentifiedcont.pdf) that identified new organic contaminants from chromatograms generated from previous RMP monitoring efforts.

Contaminant concentrations in tissue of transplanted bivalves were measured before deployment (T-0 or background concentrations) and at the end of the 90-100 deployment period. Resident clams from the Sacramento River and San Joaquin River stations were

only collected at the end of the sampling period. Survival and growth indices were also measured. Because of potential individual variability in contaminant concentrations and the small tissue mass, composites of up to 30 individual bivalves were made for each species from each deployment site for analyses of trace contaminants. RMP tissue concentrations are reported in µg/kg dry weight or ppb. Conversion to dry weight reduces the variability in results that occur due to variable moisture and lipid content of the samples.

Calculated Measures of Bioaccumulation

Accumulation Factors

In addition to reporting the measured tissue concentrations prior to and following deployment, this report uses accumulation factors (AF) to indicate accumulation or depuration (loss of contaminants from bivalve tissue by metabolism) during the 90-100 day deployment period (Table 4.2). The accumulation factor is calculated by dividing the final contaminant concentration in transplants by the initial bivalve concentration at T-0 for that species. For example, an accumulation factor of 1.0 indicates that the concentration of a specific contaminant at the end of the deployment period was the same compared to the T-0 contaminant concentration. AFs less than 1.0 indicate that the bivalves decreased in contaminant concentration during the deployment period due to depuration, while an AF greater than 1.0 indicates accumulation. Accumulation factors are not calculated in *C. fluminea* for the Sacramento and San Joaquin River stations, since they were collected as resident clams and not transplanted from a background site outside of the Estuary. For this calculation, if an analyte was below the Method Detection Limit (MDL) and reported as not detectable (ND), then one-half of the average MDL was assigned as the final concentration. However, if both the final and T-0 concentrations were ND, then no accumulation factor was calculated.

4.2.2 Biological Growth and Survival

In 2001 the RMP calculated the growth mean and the condition index (CI) as indicators of bivalve health. In 2002, the RMP discontinued the CI and utilized the growth mean as the sole health indicator. Because the CI is the ratio of dry tissue weight to shell cavity volume, it could be affected by changes in either tissue weight or shell size. For example, either a decrease in tissue weight with stable shell size or an increase in shell size with stable tissue weight could be interpreted as a decrease in CI. Consequently, the interpretation of CI as an indicator of health can be problematic. The growth mean is a measure of growth of the bivalves at a particular site in comparison to the mean T-0 dry weight. The growth of each bivalve was estimated by subtracting from its individual dry weight the mean dry weight of the T-0 sample for that species. The mean of the difference for all the individuals at a particular site was then calculated to give the growth mean for that site. A negative growth mean indicates that the deployed bivalves had reduced weight in comparison to the T-0 sample. A negative growth mean can be a sign of stress in the organism or of weight loss due to reproduction processes. Percent lipid and percent moisture measurements were also made before and after deployment.

Percent survival results include survival of both caged and bagged bivalves where available. Percent survival is a measure of how many individual bivalves were alive at the end of the 90-100 day deployment period compared to the total number that were deployed. Mortality can occur from predation and intolerance to salinity and temperature regimes. Only bivalves that were alive at the end of the deployment period were composited for contaminant analysis.

Since the winter cruise of 1999, comparisons between the traditionally used *M. californianus* and the hybrid Bay mussel (*Mytilus galloprovincialis* / trossulus / edulis) have been conducted. This comparison evaluates potential artifacts introduced by using an open-ocean intertidal mussel (*M. californianus*) as an indicator species versus a related species adapted to more variable estuarine conditions (*M. edulis*). Deployment of a single species at all sampling stations would allow for comparison between stations. Data from 2000 and 2001 deployments showed that *M. californianus* had slightly higher survival rates across all stations (where predation was not an issue) but that both species had survival rates higher than 90%. Side by side deployment of both species occurred again during 2002 including at those stations that were traditionally *C. gigas* deployment stations. *C. gigas* are deployed at stations with lower expected salinities because the tolerance of this organism to freshwater exposure is higher than mussels (as low as 10‰), but their optimum salinity range for adult growth is reported at 35‰ (Mann *et al.,* 1994). *M. californianus* has a salinity tolerance range of 17 – 53‰ (Morris *et al.,* 1980) and transplants have survived well at the more saline stations in the Estuary (Gunther *et al.,* 1999). *C. fluminea* has a salinity tolerance range of 0 – 3‰ and is well suited for living at the less saline river stations (Foe and Knight, 1986). Side by side deployment will determine if either mussel species can survive in the lower salinity areas of the Estuary. Three years of data are now available to determine if a single mussel species can be deployed at all stations.

4.2.3 Guidelines

The RMP has used various screening values and guidelines to assess contaminant concentrations in bivalve tissue. The 1996 Annual Report (http://www.sfei.org/rmp/RMP_Annual_Reports/1996_RMP_Annual_Report.pdf) reviewed several tissue guidelines. Starting with the 2001 monitoring results, the RMP began using screening values (Table 4.1) developed by Brodberg and Pollock, (1999) for monitoring contaminant concentrations in finfish. These values are, on the whole, more conservative than other screening values previously used by the RMP and are also used by the Office of Environmental Health Hazard Assessment (OEHHA) in screening contaminants in shellfish and finfish for human consumption assessment. These screening values were developed following U.S. EPA guidance (U.S. EPA, 1995) for evaluation of contaminants in fish tissue in a study from two California Lakes and are defined as concentrations of target analytes in fish or shellfish tissue that are of potential public health concern (Brodberg and Pollack, 1999). Exceedance of screening values is considered an indication that more intensive site-specific monitoring and/or an evaluation of human health risk should be conducted. The calculations were based on a 70 kg adult, using a cancer risk of 10^{-5} for carcinogens. A consumption rate of 21 grams of fish per day was used. Although these screening values are applied to human consumption of

contaminated fish/shellfish, exceedance of the screening value may also indicate the potential for health risks in wildlife that consume contaminated fish/shellfish. The screening values are used for comparison purposes only and do not suggest a possible public health concern. The transplanted bivalves in the RMP are temporary residents of the Estuary and are used as indicators of bioavailable contaminants for status and trends analyses. No follow-up action is triggered when bivalve values exceed guidelines. A wet-to-dry weight conversion was applied to the guideline values for comparative purposes, using a multiplication factor of 7, which is based on average moisture content in bivalves of 85% (SFEI, 1998).

4.3 Results and Discussion

Bivalve monitoring is conducted in the Estuary to measure contaminant accumulation during the dry season as a measure of the potential bioavailability of contaminants of concern. The combination of recent special studies to improve deployment methods and evaluate salinity tolerances of deployed species has helped the RMP refine the bivalve monitoring component of the Status and Trends program. Starting in 2003, *M. californianus* were deployed at all stations including formerly *C. gigas* stations to increase the intra-species spatial coverage of the Estuary. The RMP will continue to use the study results to adjust future bivalve monitoring effort.

4.3.1 Spatial distributions

Spatial distributions of bioaccumulative contaminants in bivalves are limited to stations where the same species were deployed. The side-by-side deployment study using *C. gigas* and *Mytilus* provided survival information that allowed the RMP to decide to deploy only one species throughout the Estuary in 2003 (with the exception of the freshwater resident clam regions).

Trace Organics

In 2002, Coyote Creek, Dumbarton Bridge, Redwood Creek, Alameda, Yerba Buena Island, San Pablo Bay and Davis Point exceeded the screening value for total PCBs (Table 4.2). All other analytes for other stations were below their associated screening values. Screening values were compared with the T-1 concentrations. Note that transplanted bivalves are deployed in the Estuary for a 90-100 day period (except stations BG20 and BG30) and therefore are indicators of bioavailable contaminant accumulation over this time period. High contaminant concentrations indicate the potential for contaminant exposure in the Estuary for resident organisms. Accumulation factors ranged from 1.0 to 60 for all species. The highest factor, indicating accumulation, was for total PBDEs at Davis Point (*C. gigas*). The highest calculated AFs were for total PBDEs at the Redwood Creek (*M. californianus*), Alameda (*M. californianus*), Yerba Buena Island (*M. californianus*), San Pablo Bay (*C. gigas*), Davis Point (*C. gigas*) and Napa River (*C. gigas*) stations. The only analytes detected in resident clams from the San Joaquin and Sacramento River stations were PCBs, DDTs, PBDEs and dieldrin. There is currently no screening value for PBDEs.

Most of the trace organic analytes measured by the RMP do not have associated screening values. AFs for these analytes ranged from 0.1 – 86. The highest AF was for

Galaxolide at Davis Point (*C. gigas*). The highest AFs (above 35) were for Galaxolide (San Pablo Bay, Davis Point and Napa River – all *C. gigas*), PCB 099 (Alameda – *M. californianus*), PCB 153 (Alameda - *M. californianus*), PCB 187 (Alameda - *M. californianus*; Coyote Creek – *C. gigas*) and Tonalide (Napa River – *C. gigas*). Galaxolide and Tonalide are musk compounds that were added to the RMP analyte list in 2002. Musks are used in many personal care products and some have been shown to bioaccumulate in tissues and induce toxicity.

Growth and Survival

Low salinity at the Davis Point (BD40) and Napa River (BD50) stations during the deployment period may have contributed to the high mortality seen in oysters. Low salinity can affect survivability in oysters. Average salinity measurements across the water column for bagged bivalves at the Napa River site during deployment and collection times were 13 and 22 ‰, respectively. Average salinity at the Davis Point site during deployment and collection times was 16 and 26 ‰, respectively. *C. gigas* survival was low at Napa River (25%) and at Davis Point (29.2%). *M. californianus* survival at Napa River and Davis Point was 0% and 90%, respectively, and *M. edulis* survival was 89% and 100%, respectively. *M. edulis* had the highest survival among all three species at these stations. For other stations, bivalve survival between the mussel species was comparable except at Yerba Buena Island. At Yerba Buena Island, *M. edulis* survival was 65% compared with *M. californianus* survival of 81%. From the 2000 and 2001 data, preliminary results show that mortality due to predation decreases in cages and that cages do not hinder bivalve growth during deployment (Dane Hardin, AMS, personal communication). For 2002 sampling, survival was comparable between the caged and bagged bivalves except for Redwood Creek (Table 4.3). *M. edulis* survival at this site was 100% for the caged and 75% for the bagged bivalves.

4.3.2 Bivalve Trends

The maintenance of fixed bivalve deployment stations permits analysis of long-term temporal trends, but this evaluation has been deferred to the RMP's synthesis of information from the past ten years (1993-2002) of bivalve tissue monitoring in the Estuary.

4.4 References

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Table 4.1. California Screening Values calculated according to U.S. Environmental Protection Agency guidance (U.S. EPA, 1995). Calculations were based on a 70 kg adult and a fish consumption value of 21 g/day. Guidelines were specifically developed for a California lake fish study and should be used as reference values in bivalve tissue concentrations only (Brodberg and Pollack, 1999). No follow-up actions are associated with bivalve tissue concentrations above these screening values. Screening values have been converted to dry weight using a conversion factor of 7, which is based on an 85% average moisture content in bivalves.

PARAMETER	Screening Value (dry weight)	unit
Cd	21	ppm
Se*	14	ppm
Dieldrin	14	ppb
Endrin	7,000	ppb
gamma-HCH	210	ppb
Heptachlor Epoxide	28	ppb
Hexachlorobenzene	140	ppb
Total Chlordanes (SFEI)	210	ppb
Total DDTs (SFEI)	700	ppb
Total PCBs (SFEI)	140	ppb

* The RMP uses the selenium screening value recommended by the California Office of Environmental Health Hazard Assessment from Fan et al., 1988. All other analyte screening values are from the California lake fish study (Brodberg and Pollack, 1999). The Se SV for the lake study is 140 ppm dry weight.

Table 4.2. 2002 bivalve accummulation factors (AF) and final contaminant concentrations that were above the method detection limit (MDL) and had screening values. Endrin, gamma-HCH, Heptachlor Epoxide, and Hexachlorobenzene were not detected (ND) at all sites. If both the final concentration and T-0 reference concentrations were ND, no AF was calculated and the result is reported as ND. If either the final concentration or the T-0 was ND, then 1/2 the MDL was used to calcualte the AF. Results are in ug/kg dry weight. Survival for BC10 and BC21 are from the caged deployment method. Growth mean (g) is determined by subtracting the avg. T-0 dry weight from each individual bivalve at each station and then taking the mean of the differences.

										Dieldrin		**Sum Chlordanes**		**Sum DDTs**		**Sum PCBs**		**Sum PBDEs**	
SITE CODE	SITE NAME	DATE	CRUISE NUMBER	MATRIX	% Survival	% Lipids	% Moisture	Growth Mean	AF	Result	AF	Result	AF	Result	AF	Result	AF	Result
BA10	Coyote Creek	9/3/02	2002-08	CGIG	94.4	0.6	91	-0.28		ND	6	11	8	63	10	220	22	23
BA30	Dumbarton Bridge	9/3/02	2002-08	MCAL	98.8	1.1	85	0.17	2	10	8	14	5	34	16	164	19	20
BA40	Redwood Creek	9/3/02	2002-08	MCAL	98.8	1.2	86	-0.04	2	10	9	16	5	32	17	176	39	40
BB71	Alameda	9/3/02	2002-08	MCAL	96.3	1.1	87	-0.04	1	9	6	10	5	35	27	275	46	47
BC10	Yerba Buena Island	9/5/02	2002-08	MCAL	81.3	1.6	84	1.17	1	8	5	8	5	32	15	149	37	37
BC21	Horseshoe Bay	9/5/02	2002-08	MCAL	99.4	1.6	83	1.11	1	6		ND	3	20	8	82	13	13
BC61	Red Rock	9/5/02	2002-08	MCAL	87.5	1.2	86	0.27	1	7	13	22	5	33	12	126	18	18
BD15	Petaluma River	9/4/02	2002-08	CGIG	98.6	0.3	94	-0.81		ND		ND	5	44	5	105	9	9
BD20	San Pablo Bay	9/4/02	2002-08	CGIG	88.9	1.2	90	0.33		ND	3	5	8	68	7	149	34	36
BD30	Pinole Point	9/4/02	2002-08	MCAL	98.8	1.1	86	0.73	1	9	2	4	5	35	9	91	15	15
BD40	Davis Point	9/6/02	2002-08	CGIG	29.2	1.7	87	NA		ND	9	16	11	93	7	143	60	64
BD50	Napa River	9/6/02	2002-08	CGIG	25	0.4	94	NA		ND		ND	7	57	5	104	45	48
BG20	Sacramento River	8/27/02	2002-08	CFLU	NA	0.7	93	NA	NA	ND	NA	ND	NA	80	NA	120	NA	85
BG30	San Joaquin River	8/27/02	2002-08	CFLU	NA	0.8	93	NA	NA	8	NA	ND	NA	91	NA	142	NA	106
T-0[1]	Bodega Head	5/31/02	2002-08	MCAL	NA	0.8	85	NA		6		ND		7		11		ND
T-0	Tomales Bay	5/31/02	2002-08	CGIG	NA	2.1	85	NA		ND		ND		8		22		ND
T-1[2]	Bodega Head	9/8/02	2002-08	MCAL	NA			0.11										
T-1	Tomales Bay	9/8/02	2002-08	CGIG	NA			4.51										

[1] T-0 samples were collected from the reference/source sites and archived for later growth & chemical analysis

[2] T-1 samples were collected from the reference/source sites at the end of the deployment period and evaluated for growth.

Table 4.3. 2002 bivalve percent surival by site and species for maintained bagged and caged deployment methods and unmaintained caged methods. Species include: Mytilus californianus (MCAL), Mytilus edulis (MEDU), Crassostrea gigas (CGIG), and resident Corbicula fluminea (CFLU)

SITE CODE	SITE NAME	MATRIX	Survival Per Species (bagged)	Survival Per Species (caged)	Survival Per Species (caged) unmaintained
BA10	Coyote Creek	CGIG	94.4	NA	NA
	Coyote Creek	MCAL	93.8	97.5	100
	Coyote Creek	MEDU	88.8	87.5	92.5
BA30	Dumbarton Bridge	MCAL	98.8	NA	NA
	Dumbarton Bridge	MEDU	92.5	NA	NA
BA40	Redwood Creek	MCAL	98.8	97.5	97.5
	Redwood Creek	MEDU	75	100	97.5
BB71	Alameda	MCAL	96.3	97.5	100
	Alameda	MEDU	91.3	100	97.5
BC10	Yerba Buena Island	MCAL	NA	81.3	NA
	Yerba Buena Island	MEDU	NA	65	NA
BC21	Horseshoe Bay	MCAL	NA	98.8	100
	Horseshoe Bay	MEDU	NA	97.5	97.5
BC61	Red Rock	MCAL	87.5	NA	NA
	Red Rock	MEDU	90	NA	NA
BD15	Petaluma River	CGIG	98.6	NA	NA
	Petaluma River	MCAL	96.3	NA	NA
	Petaluma River	MEDU	91.3	NA	NA
BD20	San Pablo Bay	CGIG	88.9	NA	NA
	San Pablo Bay	MCAL	100	100	100
	San Pablo Bay	MEDU	97.5	92.5	100
BD30	Pinole Point	MCAL	98.8	100	NA
	Pinole Point	MEDU	86.3	100	NA
BD40	Davis Point	CGIG	29.2	NA	NA
	Davis Point	MCAL	90	NA	NA
	Davis Point	MEDU	100	NA	NA
BD50	Napa River	CGIG	25	NA	NA
	Napa River	MCAL	0	0	0
	Napa River	MEDU	88.8	87.5	95
BG20	Sacramento River	CFLU	NA	NA	NA
BG30	San Joaquin River	CFLU	NA	NA	NA

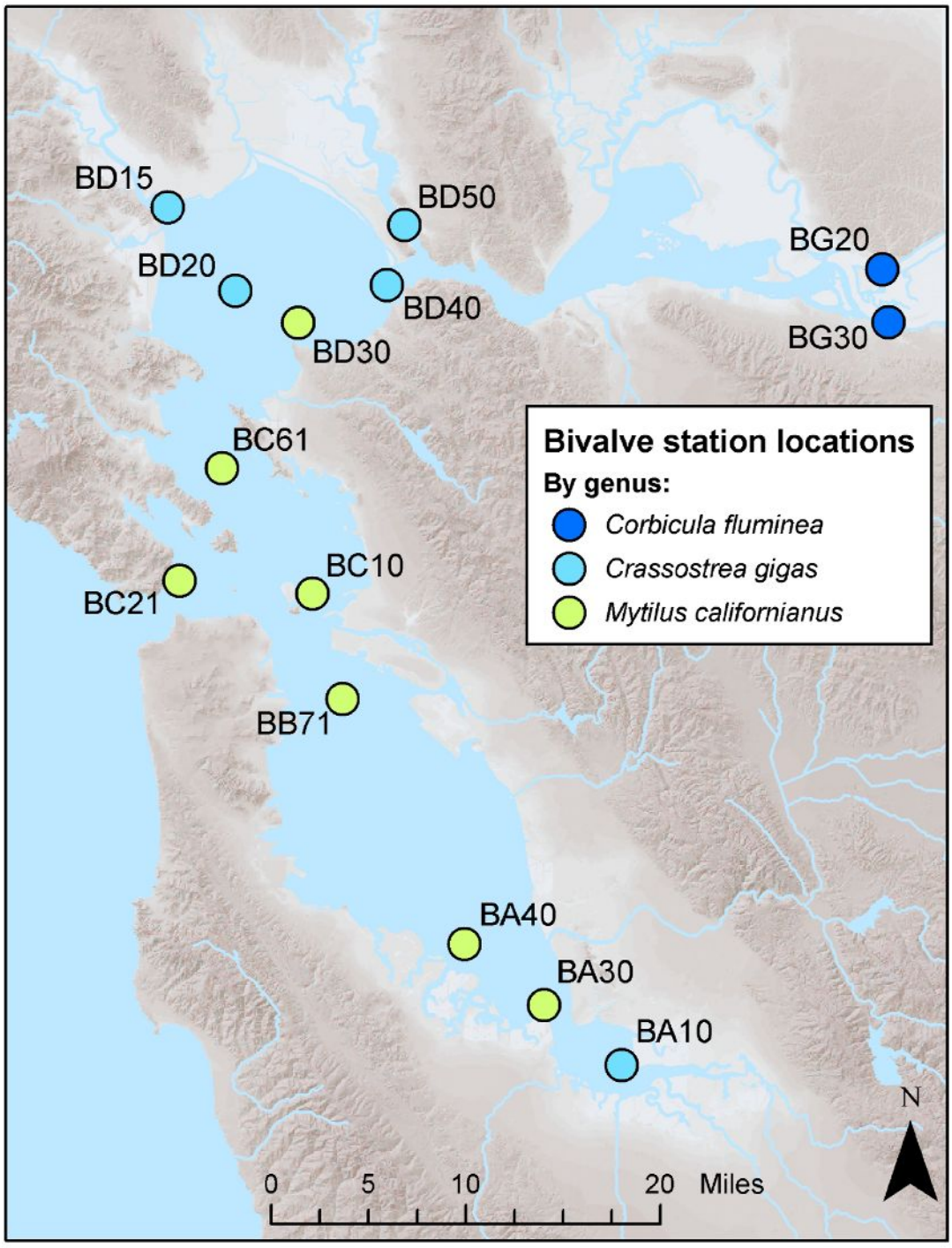

Figure 4.1. Map of the RMP Status and Trends bivalve deployment station locations in the San Francisco Estuary in 2002. 12 stations had bivalves deployed on moorings for three months (C*rassostrea* and *Mytilus*) and two locations were trawled for resident bivalves (C*orbicula*).

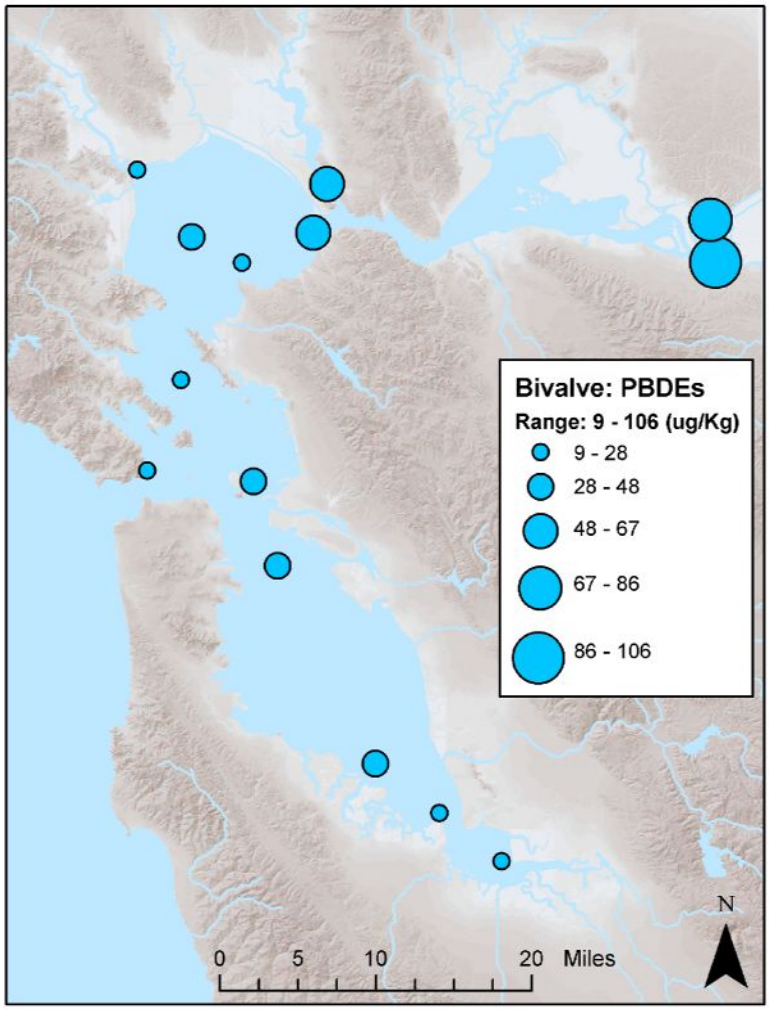

Figure 4.2 Bivalve tissue concentrations for Total PBDEs at 14 stations sampled in the San Francisco Estuary in 2002.

MONITORING NEW TRACE ORGANIC CONTAMINANTS IN 2002

>> Chapter 5

5.0 MONITORING NEW TRACE ORGANIC CONTAMINANTS IN 2002

Daniel R. Oros

5.1 Background

There are several classes of environmental organic contaminants that are currently not a focus of regulatory activity but are clearly drawing attention as potential threats to aquatic life in the San Francisco Estuary and elsewhere. These new organic contaminants of concern include a wide variety of persistent and non-persistent chemicals that either have potential to adversely affect natural endocrine system functions (e.g., development, growth, and reproduction) depending on exposure, induce toxicity depending on dosage and bioavailability, and/or bioaccumulate in marine biota (e.g., planktivorous fish, crabs, and bivalves) and biomagnify in higher food chain consumers (e.g., predatory fish, birds, marine mammals, and humans). Several examples of these emerging contaminants include personal care products (e.g., musk fragrance compounds), flame retardants (e.g., polybrominated diphenyl ethers), plasticizers (e.g., phthalates), and surfactants (e.g., p-nonylphenol). The major transport pathways of these synthetic chemical classes to the estuary are primarily through the discharge of treated wastewater effluents, and urban or agricultural runoff. Information provided by the San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP), among other sources, recently led to a ban on the sale and use of the polybrominated diphenyl ether flame retardants in California beginning in 2008 (Oros and David, 2002; Oros, 2003).

One of the most valuable services the RMP can provide to environmental managers is to identify potential problem contaminants and address them before they become the costly "legacy" pollutants of tomorrow. Thinking proactively, the RMP initiated a special study in 2001 with three objectives to conduct a comprehensive assessment of the identities, concentrations, distributions of previously unknown and unmonitored organic contaminants present in the Estuary, to link newly identified contaminants to known or suspected adverse impacts such as toxicity and bioaccumulation, and to identify potential problem contaminants for monitoring (Oros and David, 2002). As a result of this study, in 2002 the RMP added several new organic contaminants to the analyte list for monitoring in water, sediments, and bivalve tissues: polybrominated diphenyl ethers (PBDEs), phthalates (bis(2-ethylhexyl)phthalate, butylbenzylphthalate, and di-n-butylphthalate), p-nonylphenol, triphenylphosphate, musks (musk ketone, musk xylene, musk ambrette, musk moskene, Galaxolide, Tonalide, Versalide, and Celestolide). These new compounds were included for monitoring on a temporary basis only and their permanent inclusion in the RMP as regularly monitored trace organic analytes will depend on the outcome of at least 2 years of monitoring. A summary of the 2002 monitoring results for these new analytes follows.

5.2 Summary of Monitoring Results

5.2.1 Polybrominated Diphenyl Ethers

Polybrominated diphenyl ethers (PBDEs) are generally used as flame retardants in ready-made plastic products, polymers, resins and their substrates, electronic devices, building materials, and textiles. Municipal waste disposal is often the source of these compounds into the environment, along with incineration, leaching, and volatilization. The tendency of PBDEs to persist once released into the environment and bioaccumulate and biomagnify in biological tissues further increases concern over their occurrence in the environment. Their physical/chemical characteristics resemble those of restricted chlorinated hydrocarbons such as polychlorinated biphenyls (PCBs). PBDEs also have potential to disrupt normal endocrine system functions. PBDEs were analyzed in all matrices. The total PBDE (ΣPBDE) concentrations were calculated as the sum of the individual PBDE congeners detected in the samples, which the RMP identifies as target analytes (see Introduction Section, Table 1.4).

The ΣPBDEs concentrations in the water ranged from 1-513 pg/L (see Figure 2.39a&b in Section 2.0). The highest ΣPBDE concentration was found in the Lower South Bay (513 pg/L, LSB006W), followed by Sunnyvale (293 pg/L, C-1-3) and San Jose (238 pg/L, C-3-0). The estuary segment with the highest ΣPBDE concentrations was the Lower South Bay (range 103-513 pg/L, mean 206 pg/L), with the next highest segment being the South Bay (range 42-124 pg/L, mean 84 pg/L). Sunnyvale and San Jose stations are in the southern sloughs and are not considered Lower South Bay stations. The most abundant PBDE congeners were BDE-47, BDE-99, and BDE-209.

In sediments the ΣPBDE concentrations ranged from 0.2-212 µg/kg with the highest ΣPBDE concentration found at a South Bay station (SB005S)(see Figure 3.13a&b in Section 3.0). Only five PBDE congeners were detected in the sediment samples. BDE-47 (range 1-100 µg/kg) was the most abundant congener followed in decreasing order by BDE-99 (range 0.2-71 µg/kg), BDE-204 (range 2-19 µg/kg), BDE-205 (22 µg/kg), and BDE-183 (0.2 µg/kg).

The ΣPBDEs concentrations in all bivalves ranged from 9-106 µg/kg in all bivalves (see Figure 4.2 in Section 4.0). Only three PBDE congeners were detected in bivalve tissue samples: BDE-47, BDE-99, and BDE-100. For the individual bivalves, ΣPBDEs in oysters (*Crassostrea gigas*) ranged from 9-64 µg/kg dry wt (mean 40 µg/kg dry wt) with the highest ΣPBDE concentration found at Davis Point (BD40). The mean concentrations of the individual congeners in oysters were BDE-47 25 µg/kg dry wt, BDE-99 9 µg/kg dry wt, and BDE-100 6 µg/kg dry wt. In mussels (*Mytilus californianus*), the ΣPBDE concentrations ranged from 13-47 µg/kg dry wt (mean 29 µg/kg dry wt) with the highest ΣPBDE concentration found at Alameda (BB71). The mean concentrations of the individual congeners were BDE-47 17 µg/kg dry wt, BDE-99 8 µg/kg dry wt, and BDE-100 4 µg/kg dry wt. In clams (*Corbicula fluminea*), the ΣPBDE concentrations ranged from 85-106 µg/kg dry wt (mean 95 µg/kg dry wt) with the highest ΣPBDE concentration found at San Joaquin River (BG30). The mean

concentrations of the individual congeners were BDE-47 54 µg/kg dry wt, BDE-100 27 µg/kg dry wt, and BDE-99 15 µg/kg dry wt.

5.2.2 Phthalates

Phthalates are a class of widely used industrial compounds that are generally applied as plasticizers in industrial products such as nitrocellulose, polyvinyl acetate, polyvinyl chloride, adhesives, and coatings. They add flexibility to synthetic organic polymers. Furthermore, these compounds are found in personal care products such as hair spray, fingernail polish, and cosmetics. They are ubiquitous in environmental samples due to their release during manufacture, use, and disposal of industrial and consumer products. The phthalates that were analyzed in all matrices included bis(2-ethylhexyl)phthalate (DEHP), butylbenzylphthalate (BBP), and di-n-butylphthalate (DBP). Phthalates have been reported to cause disruption of normal endocrine system functions and even cancer in humans and animals.

The reportable concentrations of phthalates in water samples were the following: DEHP 372 ng/L and BBP range 5-11 ng/L. There were no reportable concentrations for DBP in the water samples. In sediments the phthalate concentrations were the following: DEHP range 208-605 µg/kg dry wt, BBP range 28-323 µg/kg dry wt, and DBP range 22-94 µg/kg dry wt. In bivalves, DEHP was the most abundant phthalate in oysters (range 84-558 µg/kg dry wt) and clams (257-350 µg/kg dry wt), while BBP was the most abundant phthalate in mussels (29-98 µg/kg dry wt). Overall, DEHP was the most abundant phthalate in almost all the matrices.

5.2.3 p-Nonylphenol

p-Nonylphenol (NP) is primarily used as a precursor in the manufacture of non-ionic surfactants. It is also a degradation product of alkylphenol ethoxylate surfactants that are used in household detergents and pesticide formulations. The ability of NP to bioaccumulate and potential to disrupt normal endocrine system functions further increase concern over its occurrence in the aquatic environment. NP was analyzed in all matrices. It was detected in water and one bivalve tissue sample, but not detected (<5 µg/kg) in sediments. In water the NP concentration ranged from 5-73 ng/L, with the highest concentration found at a Central Bay (CB002W) station. NP was detected in only one oyster sample (22 µg/kg dry wt) that was transplanted at the Petaluma River (BD15). NP was not detected (<5 µg/kg dry wt) in mussels or clams.

5.2.4 Triphenylphosphate

Triphenylphosphate (TPP) is a widely used flame retardant in video monitors and a plasticizer in some pesticide formulations, gasoline additives, synthetic motor oils, and in roofing paper. Its major transport pathway into the aquatic environment has been shown to occur primarily through urban runoff from hydraulic fluid leakage, leaching from vinyl plastics, and from manufacturing processes. TPP can bioaccumulate and biomagnify in biological tissues and it also has potential to disrupt normal endocrine system functions.

TPP was analyzed in transplanted bivalve tissues only and not in water or sediments. It was detected in mussels (range 24-378 µg/kg dry wt) with the highest concentration found at Pinole Point (BD30). In oysters TPP ranged from 20-22 µg/kg dry wt, with the highest concentration found at Coyote Creek (BA10). TPP was not detected (<5 µg/kg dry wt) in resident clams.

5.2.5 Nitro and polycyclic musks

The nitro and polycyclic musks are used as fragrances in laundry detergents, cosmetics, perfumes, and personal care products. The major source of the musk compounds is municipal wastewater effluent that is discharged directly in receiving waters. The ability of these compounds to bioaccumulate and induce toxicity increases concern over their occurrence in the environment. Nitro and polycyclic musks were analyzed in bivalve tissue only and not in water or sediment. The nitro musks included musk ketone, musk xylene, musk ambrette, and musk moskene, while the polycyclic musks included Galaxolide, Versalide, Tonalide, and Celestolide.

Nitro musks were not detected (<5.0 µg/kg dry wt) in bivalve tissue samples, while the polycyclic musks were detected. The concentrations of the detected polycyclic musks in mussels were the following: Galaxolide (range 79-305 µg/kg dry wt), Tonalide (range 92-275 µg/kg dry wt), and Celestolide (range 32-93 µg/kg dry wt). In oysters the concentrations were distributed as the following: Galaxolide (range 116-855 µg/kg dry wt), Tonalide (range 105-516 µg/kg dry wt), Versalide (range 20-25 µg/kg dry wt), and Celestolide (57 µg/kg dry wt). The concentrations in clams were the following: Galaxolide (range 243-249 µg/kg dry wt), Versalide (56 µg/kg dry wt), and Celestolide (range 23-26 µg/kg dry wt). Galaxolide was the most abundant polycyclic musk compound in bivalves with the highest concentrations found in oysters at Davis Point (BD40, 855 µg/kg), in mussels at Alameda (BB71, 305 µg/kg), and in clams at San Joaquin River (BG30, 249 µg/kg).

5.3 Conclusions

The first year of monitoring provided excellent field data on the concentrations and distributions of the new trace organic analytes. The RMP and its contract laboratories put much effort into developing the new analytical methods for detecting these new trace organics in each of the monitored matrices. Future efforts will include one more year of monitoring of these compounds in their respective matrices. Thereafter, the RMP will determine whether to keep monitoring for these compounds or not.

5.4 References

Oros, D.R., and N. David. 2002. Identification and evaluation of unidentified organic contaminants in the San Francisco Estuary. RMP Technical Report: SFEI Contribution 45. San Francisco Estuary Institute, Oakland, CA.

Oros, Daniel. 2003. Identification and evaluation of previously unknown organic contaminants in the San Francisco Estuary (1999-2001). RMP Technical Report: SFEI Contribution 75. San Francisco Estuary Institute, Oakland, CA.

>> Chapter 05

DESCRIPTION OF METHODS

6.0 DESCRIPTION OF METHODS

Nicole David, Daniel Oros, Sarah Lowe, Cristina Grosso, and John Ross

The purpose of this chapter is to provide brief descriptions on the sample collection and analytical methods used in Status and Trends Monitoring component of the Regional Monitoring Program for Trace Substances (RMP) and to highlight any changes that may occur each year. Water, sediment and bivalve tissue samples are collected and analyzed for trace elements, trace organics, and conventional water and sediment quality parameters, and tested for aquatic and sediment toxicity. Information on sampling methods and analytical procedures for RMP pilot and special studies and fish contamination monitoring are provided in separate technical reports available on the RMP Reports and Publications page at http://www.sfei.org/rmp/reports.htm, or by contacting the RMP Managers.

Other resources related to the RMP field and analytical methods include:

1. *Field Sampling Manual for the Regional Monitoring Program for Trace Substances* provides standard operating procedures for sampling of water, sediment, and bivalve tissue (http://www.sfei.org/rmp/documentation/fom/FOM2001.pdf).
2. *Quality Assurance Project Plan for the Regional Monitoring Program for Trace Substances* describes the quality assurance and quality control (QA/QC) protocols and requirements for RMP field sampling and laboratory analyses (http://www.sfei.org/rmp/reports/2001_QAPP/2001_QAPP_v2.PDF).
3. Standard Operating Procedures for each analytical laboratory are on file at SFEI.

6.1 Field Sampling Methods

Logistical planning and field sampling for the RMP is implemented by Applied Marine Sciences Inc. who have systematically improved the field sampling logistics and sampling methods each year since the inception of the program in 1993. Cruise plans and reports produced by Applied Marine Sciences are available on their website under RMP Information at http://www.amarine.com/.

6.1.1 Water Sampling

One of the RMP objectives is to evaluate if water quality guidelines are being met in the Estuary. Therefore, the sampling and analytical methods must be able to detect and, when analytically possible, quantify substances below guideline levels. In order to attain the low detection limits used in the RMP, ultra-clean sampling methods are used in all trace metal and organic sampling procedures (Flegal and Stukas, 1987; U.S. EPA, 1995).

Water samples are collected approximately one meter below the water surface using peristaltic and gear-driven pumps. The sampling intake ports for both the trace organic and trace element samplers are attached to aluminum poles that are oriented up-current from the vessel and upwind from equipment and personnel. The vessel is anchored and the engines turned off before the sampling begins. Total and dissolved fractions of

Estuary water are collected for trace element analyses. Particulate and dissolved fractions are collected for trace organics analyses.

Collection of Samples for Trace Organics

Background

The RMP used a polyurethane foam plug sampler to collect water for trace organics analyses during the first four years of the Program (Risebrough *et al.,* 1976; de Lappe *et al.,* 1980, 1983) and phased in a new, modified, commercially available resin extraction sampler in 1996, beginning with side-by-side comparisons of both sampling systems. XAD resins have been used throughout the world to measure synthetic organic contaminants in both water and air (Infante *et al.,* 1993). The sampler comparisons were continued in 1997, and results from both years are presented in the RMP 1997 Annual Report (SFEI, 1999).

Since 1997, an Axys Infiltrex system (Axys Environmental Systems, Ltd., Sidney, B.C.) has been used to collect all RMP water samples for analysis of trace organic contaminants. It consists of a constant-flow, gear-driven positive displacement pump, 1/2 inch Teflon® tubing, 1 µm glass fiber cartridge particulate filter, and two parallel Teflon® columns filled with XAD-2 resin with a particle size range of 300-900 µm. Amberlite XAD-2 resin is a macroreticular, styrene-divinyl benzene copolymer, nonionic bead, and each bead is an agglomeration of microspheres. This sponge-like structure offers excellent physical and chemical stability. The discrete pores allow rapid mass transfer of analytes, and the mesh size ensures very little, if any, back pressure during use. The hydrophobic nature of the resin leads to excellent capability of concentrating hydrophobic contaminants.

Collection of Particulate and Dissolved Fractions

To remove large debris that may interfere with sample collection, the sample water is first passed through a coarse screen before the Teflon® intake line. Particles greater than 140 µm are removed by a second inline pre-filter. The water then passes through the pump head and a pressure gauge, before it goes through a four-inch diameter, wound glass fiber filter (1 µm). Flow may be redirected without interruption to a second installed filter if the first filter becomes clogged. Material retained on the glass fiber filter (or filters) is designated the particulate fraction. After passing through the filter, the water is split and routed through two Teflon® columns, packed with 75 mL of XAD-2 resin. Two filters are used simultaneously to increase the flow to approximately 1.3 L/min. The compounds adsorbed to the XAD-2 resin are designated as the dissolved fraction. Lastly, the water passes through a flow meter and out the exit tube, where the extracted water volume (100 L per sample) is verified by filling five calibrated 20 L carboys.

Collection of Field Blanks for Trace Organics

Field blanks are taken for both the resin columns and the glass fiber filters. The two column blanks are collected by leaving both ends of a column open while the filled sample columns are being loaded into the sampler. Similarly, the two glass fiber filter blanks are collected by exposing a filter to the air while loading the sample filters into the

cartridges. The field blanks receive the same analytical treatment in the laboratory as the field samples.

Collection of Samples for Trace Metals

Collection of Total and Dissolved Fractions

For trace metals, water samples are collected using a peristaltic pump system equipped with C-Flex tubing in the pump head. Sample containers are filled on deck on the windward side of the ship to minimize contamination from shipboard sources (Flegal and Stukas, 1987). Filtered (dissolved fraction) water samples are obtained by placing an acid-cleaned polypropylene filter cartridge (Micron Separations, Inc., 0.45 µm pore size) on the outlet of the pumping system. Unfiltered (total) water samples are pumped directly into acid-cleaned containers. Prior to collecting water, several liters of water are pumped through the system, and sample bottles are rinsed five times with site water before filling. The bottles are always handled with polyethylene-gloved "clean hands". The sample tubing and fittings are acid-cleaned polyethylene or Teflon®, and the inlets and outlets are kept covered except during actual sampling. Samples are acidified within two weeks in a Class 100 trace metal clean laboratory.

Collection of Field Blanks for Trace Metals

During the collection of one sample, a pre-cleaned bottle filled with a diluted acid is opened and exposed to the air. Field blanks are collected during the sampling of both the total (unfiltered) and dissolved (filtered) fractions and receive the same analytical treatment in the laboratory as the field samples.

Collection of Water Quality Samples

Samples for conventional water quality parameters are collected using the same apparatus as for trace metals. However, containers are rinsed only three times, and the "clean hands" procedure is unnecessary.

Collection of Aquatic Bioassay Samples

Water samples are collected for toxicity tests using the same pumping apparatus as for the collection of the trace organic samples, however, they are not filtered. Five gallons of water are collected and placed in ice chests for transfer at the end of each cruise day to the testing laboratory. Two field blanks are collected each cruise by filtering (0.45 µm) water known to be non-toxic from the Bodega Marine Laboratory.

6.1.2 Sediment Sampling

Sediment sampling is conducted using a Young-modified Van Veen grab with a surface area of 0.1 m2. The grab is made of stainless steel, and the jaws and doors are coated with Dykon® (formerly known as Kynar®) to achieve chemical inertness. All scoops, buckets, and stirrers used to collect and homogenize sediments are also constructed of Teflon® or stainless steel coated with Dykon®. Sediment sampling equipment is thoroughly cleaned at each sampling location prior to each sampling event. In order to further minimize sample contamination, personnel handling samples wear gloves.

If the sediments at a station are considerably fine, plastic floats may be attached to the grab frame and secured so they do not interfere with grab operation. Likewise, if the sediments are considerably coarse, weights are added to the grab frame to assist penetration of the sediments. To ensure the quality of the sediment samples, each grab must satisfy several criteria in order to be accepted: complete closure, no evidence of sediment washout through the doors, even distribution of sediment in the grab, minimum disturbance of the sediment surface, and minimum overall sediment depth appropriate for the sediment type.

Collection of Sediment Samples

Two grabs are taken at each site, and sediment sub-samples are removed for toxicity tests and pore water analysis. Overlying water is drained off an accepted grab, and using pre-cleaned glass cores, three 5 cm deep cores are taken from each side of the grab. Cores collected for analysis of pore water are centrifuged on-board the vessel. Part of the supernatant is then used for analysis of ammonia and pH, which is conducted on-board the vessel, and part is preserved for analysis of sulfides in the laboratory.

The remaining top 5 cm of sediment is scooped from each of two replicate grabs and mixed in a compositing bucket to provide a single composite sample for each site. Between sample grabs, the compositing bucket is covered with aluminum foil to prevent airborne contamination. After two sediment samples have been placed into the compositing bucket, the bucket is taken into the ship's cabin and thoroughly mixed to obtain a uniform, homogeneous mixture. Aliquots are subsequently split into appropriate containers for sediment quality, trace metal, trace organics, and toxicity analyses for archive samples.

Collection of Intact Sediment Cores for Toxicity Sampling

Intact sediment cores were collected for Sediment-Water Interface Cores (SWICs) toxicity testing from the grab sampler by pressing polycarbonate core tubes 5 cm into the sediment, sealing the bottom of the cores for removal from the sampler with a gloved hand, and removing the cores. Cores were quickly capped, the polyethylene caps were dried, tightly sealed with Parafilm® to prevent leakage, then stored upright on ice for transport. Intact samples were stored for less than 4 days prior to initiation of the experiments (Anderson *et al.,* 2001).

6.1.3 Bivalve Tissue Sampling

Bivalve Collection

Bioaccumulation is evaluated by collecting oysters (*Crassostrea gigas*) and mussels (*Mytilus californianus*) from uncontaminated "background" sites of known chemistry and deploying these bivalves at 12 locations in the Estuary for approximately 100 days. Resident clams (*Corbicula fluminea*) are also collected from one site on the Sacramento River and another site on the San Joaquin River. Bivalves are deployed once each year during the dry season, usually in June. Since the RMP sites encompass a range of salinities, the species of bivalves used at each site depends on the expected salinities in the area and the known tolerances of the organisms.

Mussels (*Mytilus californianus*) are collected from Bodega Head and stored in running seawater at the Bodega Marine Laboratory until deployment at stations in San Pablo Bay, Central Bay, South Bay, and Lower South Bay, which are expected to have the highest salinities. *Mytilus californianus* will survive short-term exposure to salinities as low as 5 ppt (Bayne, 1976).

Oysters (*Crassostrea gigas*) are obtained from Tomales Bay Oyster Company (Marshall, California) and deployed at moderate-salinity sites in San Pablo Bay and in the extreme South Bay. *Crassostrea gigas* tolerates salinities as low as 2 ppt. To minimize the effects of high, short-term flows of freshwater on the transplanted bivalves, bivalves are deployed near the bottom, where density gradients tend to maintain higher salinities. All bivalves are kept on ice after collection and deployed within 24-48 hours. There are no shell length limits for clams.

Resident freshwater clams are now collected from near the historical deployment sites in the Sacramento River and San Joaquin Rivers. Resident clams are collected using a clam dredge approximately two feet wide by three feet long and 50 pounds in weight. The dredge is deployed from a boat and is dragged along the bottom. When brought to the surface, the clams are placed into a clean plastic container and packaged for analysis.

Deployment of Transplanted Bivalves

Depending on the salinity at a site, oysters or mussels (150 and 160, respectively) are randomly allocated and placed into nylon mesh bags (five for oysters and four for mussels) for deployment. Within each species, animals of approximately the same shell length are used (49-81 mm for mussels and 71-149 mm for oysters). The same number is also used for the reference (time zero) samples, which are analyzed for tissue condition before deployment.

Starting in 2001, a second set of caged bivalves was deployed in an effort to develop a more predator resistant housing for the bivalves. The new cages were fairly similar to the originals with rigid plastic mesh around sections of PVC. The mesh overlapped around itself to keep predators from slipping through any gaps between the edges. After the cages are built they are soaked in water for at least a day to remove any potential signal associated with the adhesives used for the construction.

At each site, a line runs from the bottom of the fixed structure out to the bivalve mooring, which consists of a large screw (earth anchor) that is threaded into the bottom and is associated with pilings or other permanent structures. A large subsurface buoy is attached to the earth anchor by a 1-2 meter line. The bivalves are in enclosures (mesh bags or cages) attached to the buoy line, which keeps the bivalves off the bottom to prevent smothering. In one hundred and fifty individual deployments, loss of a mooring has occurred on only two occasions, probably due to being ripped out by a vessel anchor. Mooring installation, bivalve deployment, maintenance, and retrieval are all accomplished by SCUBA divers.

Maintenance of Transplanted Bivalves

The deployed samples are checked approximately 50 days after deployment to ensure consistent exposure. Moorings and enclosures are checked for damage and repaired if necessary, and fouling organisms are removed.

Retrieval of Transplanted Bivalves

Upon retrieval, the bivalve enclosures are placed into polyethylene bags and taken to the surface. On the vessel, the number of dead organisms is recorded. Twenty percent of the live organisms are allocated for condition measurement, and the remainder is equally split for analyses of trace metal and organic compounds. Bivalves used for trace organic analyses are rinsed with reagent grade water to remove extraneous material, shucked using a stainless steel knife (acid-rinsed), and homogenized (until liquefied) in a combusted mason jar using a Tissumizer® or Polytron® blender. Bivalves used in trace element analyses are shucked with stainless steel knives, and the gonads are removed. The remaining tissue is rinsed with ultrapure water and placed in acid-cleaned, plastic coated, glass jars. The sample is then homogenized (until liquefied) using a Brinkmann homogenizer equipped with a titanium blade.

Based on findings by Stephenson (1992) during the RMP Pilot Program, bivalve guts are not depurated before homogenization for tissue analyses, although the gonads are removed from organisms for trace metal analyses. With the exception of lead and selenium, no significant differences exist in trace metal concentrations between mussels depurated for 48 hours in clean Granite Canyon seawater before homogenization and undepurated mussels. However, sediment in bivalve guts may contribute to the total tissue concentration for trace organic contaminants.

6.2 Analytical Methods

For a list of analytes measured in 2002 please refer to the Table 1.4 in the Introduction.

6.2.1 Analysis of Water and Sediment Quality

No significant changes were made to the analytical methods in 2002 for water or sediment quality.

Conventional Water Quality Parameters

In 2002 conventional water quality parameters were measured by the University of California Santa Cruz, Department of Environmental Toxicology (UCSCDET) and by Applied Marine Sciences (AMS). Hardness was measured by the Union Sanitary District, which is part of the Bay Area Clean Water Agencies (BACWA).

Dissolved nutrients in samples are analyzed using the Lachat QuikChem 800 System Nutrient Autoanalyzer (Ranger and Diamond, 1994). The QuickChem methods used are: 31-114-27-1 for silicates, 31-107-06-1 for ammonia, 31-107-04-1 for nitrate/nitrite, and 31-115-01-3 for phosphate. Chlorophyll and phaeophytin are measured using a fluorometric technique with filtered material from 200 mL samples (Parsons *et al.,* 1984). Shipboard measurements for temperature, salinity, pH, and dissolved oxygen content are made using a hand-held Solomat 520 C multi-functional chemistry and water quality

monitor. Dissolved organic carbon (DOC) is measured using high-temperature catalytic oxidation with a platinum catalyst (Fitzwater and Martin, 1993). Total suspended solids (TSS) are determined using method 2540D in Standard Methods for the Examination of Water and Wastewater (APHA, 1992).

Sediment Quality Parameters

UCSCDET measured sediment quality parameters in 2002 and UC Davis - Marine Pollution Studies Laboratories (UCD-MPSL) measured sediment quality parameters in porewater.

Sediment size fractions are determined with a grain-size analyzer based on x-ray transmission (Sedigraph 5100). Total organic carbon is analyzed according to the standard method for the Coulometrics CM 150 Analyzer made by UIC Inc., which determines light transmitted through a cell containing the carbon dioxide evolved from a combusted sample. Sulfide analysis in sediment porewater is determined using a combination of the methylene blue and iodimetric methods from Fonselius (1985) and Standard Methods (APHA, 1998).

Conductivity, Temperature, and Depth (CTD) Casts

CTD casts are taken by AMS at each site during water, sediment, and tissue sampling. A Sea-Bird SBE19 CTD probe is used to measure water quality parameters at depths throughout the water column. At each site, the CTD is lowered to approximately one meter below the water surface and allowed to equilibrate to ambient temperature for 3 minutes. Following the sampling, the CTD is then lowered to the bottom at approximately 0.15 meters per second and raised. However, only data from the down cast are kept. Data are downloaded onboard the ship and processed in the laboratory using Sea-Bird software.

The CTD probe measures temperature, conductivity, pressure, dissolved oxygen, and backscatter at a sampling rate of two scans per second. These data are compiled and averaged into 0.25 m depth bins during processing. At this time, salinity (based on conductivity measurements), and depth (based on pressure) are also calculated. Although the CTD data are not included in the 2001 RMP Monitoring Results, SFEI maintains these data in its database.

6.2.2 Trace Elements

Starting in 2001/2002 UCSCDET's analytical methods for water trace metals has changed as described below. Tissue trace metals were not analyzed in 2002 as the Redesign Workgroup decided to reduce analyses to every five years.

Analysis of Water Samples

As in previous years, trace metals analyses were conducted by the UCSCDET and Brooks Rand Ltd. (BRL). UCSCDET has changed their extraction methods for the analyses of aluminum, cadmium, cobalt, copper, iron, lead, manganese, nickel, silver, and zinc starting with 2001 samples.

The labor-intensive liquid-liquid organic extraction and graphite furnace atomic absorption spectrometry (GFAAS) method that had been previously used since the beginning of the RMP has now been replaced with a new methodology. Because the RMP is performance based, the new analytical methods used by the contract laboratories followed the strict protocols of the RMP's Quality Assurance Project Plan (QAPP). A brief overview of the extraction and chemical analytical methods used for the trace metals are described below. The laboratory SOPs, which describe the chemical methods in more detail, are on file at SFEI.

In water, total and dissolved (0.45µm filtered) concentrations of cadmium, copper, cobalt, manganese, iron, nickel, lead, silver, and zinc are measured. The high variability of salinity and dissolved organic carbon in estuarine waters makes these analyses difficult. A new methodology uses a high resolution magnetic sector inductively coupled plasma mass spectrometer (ICP-MS) and an inductively coupled plasma optical emission spectrometer (ICP-OES). Acidified samples are oxidized by ultraviolet radiation to release specific trace metals (e.g., cobalt, copper, nickel, and zinc) from organometallic complexes (Ndungu *et al.,* 2003). These samples are then analyzed by flow injection inductively coupled plasma magnetic sector mass spectrometry (copper, cobalt, nickel, lead, silver, zinc), a method that also removes the salt matrix and pre-concentrates the sample. The samples are analyzed by inductively coupled plasma optical emission spectrometry for iron and manganese.

In some instances, reported dissolved metal concentrations are higher than total (ostensibly including dissolved and particulate fractions) metal concentrations. This is due to expected analytical variation, which is proportionally larger at concentrations near the detection limits. Such results should be interpreted as no difference between dissolved and total concentrations, or that the total fraction of metals is in the dissolved phase.

Arsenic and selenium are analyzed by BRL. The same methods as in the past are employed. Samples are analyzed by both U.S. EPA Method 200.9 Graphite Furnace Atomic Absorption (GFAA) and by Brooks Rand SOP BR-0020 Hydride Generation Atomic Absorption (HGAA). The U.S. EPA method includes the digestion of samples with nitric acid and hydrochloric acid and heating by U.S. EPA Method 200.2. Samples are analyzed by Stabilized Temperature Platform-Graphite Furnace Atomic Absorption (STP-GFAA) Spectrometry by U.S. EPA Method 200.9. The Brooks Rand method uses sample aliquots digested using an 80:20 HNO_3:$HClO_4$ acid mixture with heating. Analysis is performed using hydride generation with $NaBH_4$ addition, cryogenic trap precollection, H_2/Air flame quartz furnace decomposition, and Atomic Absorption (HGAAS) detection.

Analysis of Sediment Samples

In 2002, trace metals in sediment were analyzed by the City and County of San Francisco (CCSF), which is part of the Bay Area Clean Water Agencies (BACWA), and BRL. No changes were made in methodology compared to previous years. UCSCDET analyzed methylmercury and total mercury in sediment. A summary of methods is not available at this time.

Sediments are digested in nitric/hydrochloric acids to obtain "near-total" concentrations of trace metals. Extracts are analyzed for silver by GFAAS and for aluminum, cadmium, copper, iron, manganese, nickel, lead, and zinc by inductively coupled plasma atomic emission spectrometry (ICP-AES) with cyclonic nebulization. The method chosen for RMP sediment analysis is comparable to U.S. EPA Standard Methods (Tetra Tech, 1986) but does not decompose the silicate matrix of the sediment. Because of this, any element that is tightly bound as a naturally occurring silicate may not be fully recovered.

Analysis of Bivalve Tissue Samples

In previous years trace metals in bivalve tissue samples were analyzed by CCSF and BRL. However, in 2002 trace metals in tissue were not analyzed since the analysis will be conducted every five years (next sampling period will be 2006). Analytical methods described here are for informational purposes for samples from prior years.

Bivalve tissue samples are homogenized and then digested with aqua regia to obtain near-total concentrations of trace elements. Digestion techniques are similar to the California State Mussel Watch Program (Flegal *et al.,* 1981; Smith *et al.,* 1986) and consistent with the RMP Pilot Program (Stephenson, 1992). Sample aliquots are extracted with dichloromethane using a Tissumizer®. Extracts are then concentrated and purified by various chromatographic techniques prior to instrumental analyses.

The trace metals are quantified by ICP-AES or ICP-MS. Selenium is quantified by hydride generation coupled with atomic absorption spectroscopy. Arsenic is analyzed by U.S. EPA Method 200.9 (stabilized temperature platform graphite furnace atomic absorption spectrometry, STP- GFAA) (U.S. EPA, 1994a). Butyltins are measured following NOAA's National Status and Trends Mussel Watch Project methods (NOAA, 1993). This technique involves extracting the sample with hexane and the chelating agent tropolone and then measuring the butyltin residues by capillary gas chromatography. Concentrations are expressed in total tin per gram of tissue dry weight.

6.2.3 Trace Organics

A new laboratory AXYS Analytical Services, Ltd. (AXYS) analyzed 2002 water samples for trace organics with the exception of diazinon and chlorpyrifos, which were analyzed by the California Department of Fish and Game – Water Pollution Control Laboratory (CDFG-WPCL). CDFG-WPCL also analyzed the tissue organics for the first time in 2002. New analytes were also added to the RMP analyte list. The new analytical methods are summarized below.

Analysis of Water Samples

In 2002 trace organics analyses of water samples was conducted by AXYS. Because the RMP is performance based, the analytical methods used by AXYS followed the strict protocols of the RMP's Quality Assurance Project Plan (QAPP). A brief overview of the extraction and chemical analytical methods used for the target trace organics are described below. The laboratory SOPs that describe the chemical methods in more detail are on file at SFEI.

Two parallel XAD-2 resin columns and one glass fiber filter contain the organic compounds extracted from 100 L of water at each site. The XAD columns and the filter samples were analyzed separately. Each XAD-2 column and filter sample was spiked with labeled quantification standards and Soxhlet extracted in solvent. The resulting extract was split into five portions for multiple instrumental analyses. Target concentrations were determined by isotope dilution or internal standard quantification against the labeled surrogate compounds added at the beginning of the analysis, a procedure that yields recovery corrected results. The recoveries of the labeled surrogates were determined against the labeled internal standards and were used as general indictors of data quality.

PCBs Extraction and Analyses: A 1/5th portion of the extract was cleaned up using gel permeation and then separated into two fractions (fraction E1 and fraction E2) using a Florisil chromatographic column. The E1 fraction, containing the PCBs was further split into two unequal portions and 4/5th of the extract was used for PCB analysis. The PCB extract was further cleaned up using layered acid/base silica and alumina chromatographic columns, reduced in volume and spiked with labeled internal standards prior to instrumental analysis. The final extract volume was adjusted to 22 ml, and 1 ml was injected into the instrument. The analytical procedure was in accordance with U.S. EPA Method 1668, Revision A. Analysis was performed using a Micromass Ultima high resolution MS equipped with a Hewlett Packard 6890 GC and a CTC autosampler. Chromatographic separation was achieved using an SPB-Octyl column (30 m, 0.25 mm i.d., 0.25 μm film thickness); a split/splitless injection sequence was used. The MS was operated at a mass resolution of 10000 (static) in the electron ionization (EI) mode using multiple ion detection (MID), acquiring at least two ions for each target and surrogate compound. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 6 standard solutions containing labeled and native WHO "toxic" PCB congeners (native concentrations ranged from 0.2 to 2000 ng/ml). The validity of these calibrations factors was verified by analysis of the mid-level calibration standard every 12 hours. Relative response factors for PCB congeners other than the WHO "toxic" congeners were established by analysis every 12 hours of a single calibration solution containing labeled PCBs and all 209 native PCB congeners.

Chlorinated Pesticides Extraction and Analyses: A 1/5th portion of the original extract was cleaned up using gel permeation and then separated into two fractions (fraction E1 and fraction E2) using a Florisil chromatographic column. The E1 fraction, containing the less polar pesticides, was further split into two unequal portions and a 1/5th portion was used for E1 fraction pesticide analysis. High resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) analysis was conducted using a VG 70 VSE HRMS equipped with a HP 5890 gas chromatograph, a CTC autosampler, and operated using manufacturer's software. A DB-5 (60 m, 0.25 mm i.d., 0.1 μm film thickness) chromatography column was coupled directly to the MS source. The MS was operated at 8000 (static) mass resolution in the EI mode using MID, acquiring at least two ions for each target and surrogate compound. Average relative response factors used

for sample quantification were established by initial multipoint calibration using a series of 5 standard solutions containing labeled and native pesticide compounds (native concentrations ranged from 8 to 4000 ng/ml). The validity of these calibrations factors was verified by analysis of the mid-level calibration standard every 12 hours.

Polycyclic Aromatic Hydrocarbons (PAH) Extraction and Analyses: A 1/5th portion of the original extract was cleaned up on silica, reduced in volume, spiked with additional labeled internal standards and analyzed by high resolution gas chromatography/low resolution mass spectrometry (HRGC/LCMS) using an Agilent 6890N GC equipped with an Agilent 5973 MSD, an Agilent 7683 Series Autosampler, and a HP Chemstation. A Restek Rtx-5 chromatography column (30 m, 0.25 mm i.d., 0.25 μm film thickness) was coupled directly to the MS source. The MS was operated at a unit mass resolution in the EI mode using MID, acquiring two characterization ions for each target analyte and labeled standard. A split/splitless injection sequence was used. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 5 standard solutions containing labeled and native PAH compounds (native concentrations ranged from 50 to 5000 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours.

Polybrominated Diphenyl Ethers (PBDE) Extraction and Analyses: A 1/5th portion of the extract was cleaned up using gel permeation and then separated into two fractions (fraction E1 and fraction E2) using a Florisil chromatographic column. The E1 fraction, containing the PCBs and the PBDEs, was further split into two unequal portions and 4/5th of the extract was used for PCB/PBDE analysis. The extract was further cleaned up using layered acid/base silica and alumina chromatographic columns, reduced in volume and spiked with labeled internal standard and analyzed for PCBs. Analysis for PBDEs began after completion of the PCB analysis of all the filter and XAD samples. The samples were spiked with PBDE quantification surrogates just prior to PBDE cleanup procedures. The extraction and cleanup procedures were in general accordance with U.S. EPA Method 1668 Revision A, followed by instrumental analysis in accordance with AXYS Method MLA-025. Samples were analyzed by HRGC/HRMS on an AUTOSPEC ULTIMA high resolution MS equipped with an HP 6890 gas chromatograph, a CTC autosampler, and an Alpha data system running Micromass software. A DB-5HT (30 m, 0.25 mm i.d., 0.1 μm film thickness) chromatography column was coupled directly to the MS source. The MS was operated at a mass resolution of 5000 (static) in the EI mode using MID, acquiring at least two ions for each target and labeled compound. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 5 standard solutions containing labeled and native PBDE compounds (native concentrations ranged from 25 to 15750 ng/ml). The validity of these calibrations factors was verified by analysis of the mid-level calibration standard every 12 hours. Target concentrations were determined by isotope dilution or internal standard quantification against the labeled PBDE surrogates; because these surrogates were added after completion of the PCB analyses final concentrations are not corrected for any losses that occurred during the PCB work-up procedure.

Phthalate Esters Extraction and Analyses: The phthalate ester analyses were conducted using the same 1/5th portion of the original extract that was used for PAH analyses. Each XAD column and filter sample was spiked with labeled quantification standards and Soxhlet extracted in solvent. The extract was cleaned up on silica, reduced in volume, spiked with additional labeled internal standards and analyzed by HRGC/LRMS using either: an Agilent 5973 MSD equipped with an Agilent 6890N GC, an Agilent 7683 autosampler and a HP Chemstation; or a Finnigan Incos 50 MS equipped with a Varian 3400 GC, a CTC autosampler, and a HP Chemstation. A Restek Rtx-5 chromatography column (30 m, 0.25 mm i.d., 0.25 μm film thickness) was coupled directly to the MS source. The MS was operated at a unit mass resolution in the EI mode using MID, acquiring two characterization ions for each target analyte and labeled standard. A split/splitless injection sequence was used. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 5 standard solutions containing labeled and native phthalate compounds (native concentrations ranged from 540 to 24,000 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours.

p-Nonylphenol Extraction and Analyses: A 1/5th portion of the original extract was reserved for p-nonylphenol analysis. From each sampling site, one half of the raw XAD extract and one half of the raw filter extract (equivalent to one tenth of each of the original extracts) were combined for p-nonylphenol analysis. The extracts were reduced to dryness and underwent non-aqueous acetylation using pyridine and acetic anhydride. Sample extracts were then loaded onto prepared 5% deactivated silica for chromatographic cleanup. The p-nonylphenols (there are a number of p-nonylphenol isomers) were eluted from the column with 10% ethylacetate:hexane. The extracts were reduced in volume and spiked with labeled internal standard and prepared for instrumental analysis. Instrumental analysis was conducted by HRGC/LRMS using an Agilent 5973 mass spectrometer equipped with an Agilent 5890 gas chromatograph, a CTC autosampler, and an Agilent Chemstation data system. The chromatographic separation was carried out using a Restek Rtx-5 capillary column (30 m, 0.25 mm i.d., 0.25 μm film thickness). The mass spectrometer was operated in the EI mode using MID, acquiring two characteristic ions for each target analyte and surrogate standard. A split/splitless injection sequence was used. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 5 standard solutions containing labeled and native compounds (native concentrations ranged from 303 to 12,120 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours or less.

Analysis of Sediment Samples

In 2002 trace organics analyses of sediment samples was conducted by the East Bay Municipal Utility District (EBMUD, Oakland, CA), which is a part of BACWA. Because the RMP is performance based, the analytical methods used by EBMUD followed the strict protocols of the RMP's Quality Assurance Project Plan (QAPP). A brief overview of the extraction procedures and analyses used for the target trace organics are described below. The laboratory SOPs, which describe the methods in detail, are on file at SFEI.

Sediment samples are generally analyzed based on the methods followed by NOAA's National Status and Trends Program.

Sediment Extraction: As a first step prior to solvent extraction, standing water in the sample containers was drained and discarded. The sample was then homogenized and a 20 g subsample was weighed for extraction. An additional subsample was taken for % solids determination. Surrogate recovery standards were added to the 20 g sample aliquot and the sample was then mixed with pelletized diatomaceous earth, until a dry, flee-flowing mixture was obtained. This mixture was then extracted using U.S. EPA Method 3545 (Accelerated Solvent Extraction, ASE). For extraction, sample was placed in the ASE extractor and extracted with dichloromethane (DCM) at elevated temperature (100ºC) and pressure (1500-2000 psi). Total extraction time was 30 minutes. The sample extracts were then dried with anhydrous granular Na_2SO_4 and a Labconco Rapid Vap system was used to reduce the extract volume to approximately 3 ml in DCM. Extracts were cleanup up with an alumina/copper column and concentrated to 1 ml in DCM. This extraction and concentration procedure is applicable to the extraction of all trace organic compounds of interest in the sediment samples.

Organochlorine Pesticides and PCB Analyses: Just prior to analysis the sample extracts were exchanged to hexane and then spiked with the internal standard tetrachloro-m-xylene. Organochlorine pesticides and PCBs were then analyzed using U.S. EPA Method 8080 (Organochlorine Pesticides and Polychlorinated Biphenyls by Gas Chromatography), which includes dual column gas chromatography with electron capture detection (GC-ECD). The GC was a Thermoquest Trace 2000 equipped with a CTC autosampler and two silicon-coated fused-silica capillary columns (Restek Rtx-5MS and J&W Scientific DB-17MS each 60 m, 0.25 mm i.d., 0.25 μm film thickness). A split/splitless injector was used. Two capillary columns were connected to the injector via a Y union and then directly to the dual ECDs. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 6 standard solutions (concentrations ranged from 5 to 200 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours. Internal standard quantification was used to calculate all concentrations, which were also adjusted for surrogate standard (PCBs 103 and 198) recoveries.

Polycyclic Aromatic Hydrocarbons (PAH) Analyses: Just prior to analysis the sample extracts were spiked with deuterated internal standards (fluorine-d10 and benzo[a]pyrene-d12). PAH were then analyzed using U.S. EPA Method 8270 (Semi-volatile Organic Compounds by Gas Chromatography), which was slightly modified to provide sufficient sensitivity for PAH in sediments. Briefly, PAH were analyzed using a Clarus 500 or Varian 2000 GC-MS equipped with guard column (deactivated fused silica: 6 m, 0.32 mm i.d.) coupled to a DB-5MS fused silica capillary column (30 m, 0.25 mm i.d., 0.25 μm film thickness; J&W Scientific). The MS was operated in the EI mode using MID, acquiring two characterization ions for each target analyte and labeled standard. A Grob-type splitless injection sequence was used. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 9 standard solutions containing labeled and unlabeled PAH compounds

(concentrations ranged from 0.02 to 4.0 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours. Internal standard quantification was used to calculate all concentrations, which were also adjusted for surrogate standard recoveries.

PBDEs, Phthalates, and p-Nonylphenol Analyses: The organochlorines extract was used without any additional cleanup for this analysis. PBDEs, phthalates, and p-nonylphenol were analyzed using a GC-MS equipped with a DB5-MS fused silica capillary column (15 m length, 0.25 mm i.d., 0.25 μm film thickness, J&W Scientific). The MS was operated in the EI mode using selected ion monitoring (SIM). Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 8 standard solutions (concentrations ranged from 5 to 1000 ng/ml). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours. Internal standard quantification was used to calculate all concentrations.

Analysis of Bivalve Tissue Samples

In 2002 trace organics analyses of bivalve tissue samples was conducted by CDFG-WPCL. Because the RMP is performance based, the analytical methods used by the CDFG-WPCL followed the strict protocols of the RMP's Quality Assurance Project Plan (QAPP). A brief overview of the extraction and analyses used for the target trace organics are described below. The laboratory SOPs that describe the methods in more detail are on file at SFEI.

Tissue Extraction: Prior to extraction, bivalve tissue samples were homogenized using a Büchi B-400 homogenizer. A 1-5 g (tissue homogenate) sample was weighed into a pre-weighed aluminum planchet and placed in a 70°C oven for 48 h to determine moisture content. A 10 g sample was mixed with approximately 7 g of pre-extracted Hydromatrix® until the mixture was free flowing. The mixture was then extracted using U.S. EPA Method 3545 (Pressurized Fluid Extraction). The mixture was poured into a 33 ml stainless steel Dionex Accelerated Solvent Extractor (ASE 200) cell and packed by tamping the mixture. A solution containing pesticide and PCB or PAH surrogate compounds was added to the cell. The extractor cells (24 maximum) were placed on the ASE 200 autosampler rack and the samples were extracted with a 1:1 mixture of acetone:dichloromethane (DCM) using heat (100°C) and pressure (1500 psi) for a total extraction time of 15 min. The extracts were collected in 60 ml VOA vials. The samples were extracted a second time using the same conditions. The extracts were evaporated to approximately 0.5 ml using a K-D apparatus and 3-ball Snyder column and micro-Snyder column. The extract was then diluted to 10 ml with DCM and mixed. Two ml of the extract was removed for % lipid determination. The remainder of the extract was filtered through a 0.45 μm syringe filter. All sample extracts were cleaned-up using a J2 Scientific GPC (Autoinject 110, AccuPrep 170, DFW-20 Fixed Wavelength Detector, 1" i.d. glass column with 70 g Bio-Beads SX-3 in 100% DCM). For pesticides, PCBs, and PBDEs the GPC purified extracts were then fractionated into 4 separate fractions using Florisil and petroleum ether (F1), 6% diethyl ether/petroleum ether (F2), 15% diethyl ether/petroleum ether (F3), and 50% diethyl ether/petroleum ether (F4). For PAHs the

GPC purified extracts were further cleaned-up with silica/alumina column chromatography using DCM:pentane (1:1) as the solvent.

Organochlorine Pesticides and PCBs Analyses: Organochlorine pesticides and PCBs in tissue samples are quantified via high-resolution capillary gas chromatography using GC/ECD with dual-column confirmation. An Agilent 6890plus GC equipped with two ^{63}Ni micro-electron capture detectors with EPC and autosampler was used. A 5 m length DB-5 pre-column was connected to a press fit "Y" union which split the column effluent into two fused silica capillary columns of different polarity, a DB-5 and a DB-17 (each column 60 m length, 0.25 mm i.d., 0.25 μm film thickness, J&W Scientific). The injector was a split-splitless injector with EPC. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 7 standard solutions containing pesticide compounds (concentrations ranged from 0.25 to 200 μg/L) and PCB congeners (concentrations ranged from 0.5 to 50 μg/L). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours. External standard quantification was used to calculate all concentrations, which were also adjusted for surrogate standard recoveries. The surrogates in the mixed surrogate solution are: PCB 207 (F1), deuterated p,p'-DDD (F2) and DBCE.

Polybrominated Diphenyl Ethers (PBDE) Analyses: The PBDEs in tissue samples are quantified using the same conditions described for the organochlorine pesticides and PCBs. Average relative response factors used for sample quantification were established by initial multipoint calibration using a series of 7 standard solutions containing PBDE compounds (concentrations ranged from 0.5 to 50 μg/L). The validity of these calibration factors was verified by analysis of the mid-level calibration standard every 12 hours. External standard quantification was used to calculate all concentrations, which were also adjusted for surrogate standard recoveries. PBDE 77 (F2) is the surrogate used to adjust the PBDE concentrations.

Polycyclic Aromatic Hydrocarbons (PAH) Analyses: PAHs and their alkylated homologues in tissue extracts are analyzed by GC-MS in the selected ion monitoring (SIM) mode. An Agilent 6890N GC equipped with an EPC, 5973N MSD, 7683 autosampler, and HP Chemstation was used for analysis and data reduction. The column used is a DB-5MS fused silica capillary column (60 m, 0.25 mm i.d., 0.25 μm film thickness, J&W Scientific.). Extracts were introduced to the system using a 2 mL pulsed splitless injection. Data was collected in the SIM mode using a primary ion for quantitation and a secondary ion for qualification for each compound. Samples are quantified using a multipoint calibration table using a series of 9 standard solutions containing labeled and target PAH compounds (concentrations ranged from 10 to 1000 μg/L). Nine labeled surrogates are used to correct the final results for the target compounds.

Phthalates Analyses: Phthalates were analyzed by liquid chromatography-mass spectrometry (LC-MS) using API-electrospray (+ mode) with sodium acetate buffer used to form the sodium adduct of the individual phthalates. The quantitation ion used was the

phthalate molecular weight plus sodium. Details of the analyses were not available at time of publication.

Nitro and Polycyclic Musks Analyses: The musks were analyzed by GC-MS using negative chemical ionization. Details of the analyses were not available at time of publication.

p-Nonylphenol Analyses: p-Nonylphenol was analyzed by liquid chromatography-mass spectrometry (LC-MS) using API-electrospray (- mode). Details of the analyses were not available at time of publication.

6.2.4 Toxicity Testing

Aquatic Bioassays

Aquatic toxicity testing was conducted by Pacific Eco-Risk Laboratories (PERL) in 2002, similar to previous years.

Water column toxicity is evaluated using a seven-day growth test, based on U.S. EPA test method 1007, with the estuarine mysid *Americamysis bahia*. The mysid survival test consists of exposing 7-day old juveniles to different concentrations of Estuary water in a static system during the period of egg development. Salinity adjustments are made for Estuary water from sampling stations with salinities below the test species' optimal ranges. Reference toxicant tests with potassium dichromate are performed for mysid tests. These tests are used to determine if the responses of the test organisms are relatively consistent over time.

The salinities of the ambient samples and the control/diluent (Evian spring water) are adjusted to 5 ppt using artificial sea salts (Tropic Marin). The test concentrations are 100%, 50%, and control, each with eight replicates and 20 larvae per replicate. Waste, dead larvae, excess food, and 80% of the test water are siphoned from the test chambers daily, and general water chemistry parameters of dissolved oxygen, pH, and salinity are recorded before and after each water change.

Sediment Bioassays

In 2002 sediment toxicity was tested by UC Davis - Marine Pollution Studies Laboratories (UCD-MPSL), similar to previous years.

The RMP uses three sediment bioassays: (1) a ten-day acute mortality test, where the estuarine amphipod *Eohaustorius estuarius* is exposed to whole sediment using ASTM method E 1367 (ASTM 1992), (2) a sediment elutriate test, where larval bivalves (*Mytilus spp*.) are exposed to the material dissolved from whole sediment in a water extract using ASTM method E 724-89 (ASTM 1991) and percent normally developed larvae measured as the endpoint, and (3) sediment-water interface core (SWIC) test, where *Mytilus galloprovincialis* larvae are exposed to SWI for 48 hours and percent normally developed larvae measured as the endpoint.

Solid-phase samples were prepared as described in the amphipod protocol (U.S. EPA, 1994b). Sediment was re-homogenized in the sample jar with a polypropylene spoon and then distributed to form a layer 2 cm deep in each of five one-liter replicate beakers. Overlying water was added to the test containers, and sediment and overlying water were allowed to equilibrate overnight before the amphipods were added.

Elutriate solutions are prepared by adding 50 g of sediment to 200 mL of Granite Canyon seawater or freshwater in a clean 250 mL borosilicate glass jar with a Teflon-lined lid (1:4 volume to volume ratio; U.S. EPA and ACOE, 1991). The elutriate mixture was shaken vigorously for 10 seconds and allowed to settle for 24 hours (Tetra Tech, 1986) before being transferred into replicate containers for testing.

The SWIC exposures were conducted with intact sediment core samples taken with minimal disturbance from the Van Veen grab sampler. Test containers consisted of a polycarbonate tube with a 25 µm screened bottom, which was placed within 1 cm of the surface of an intact sediment core (Anderson *et al.,* 1996). Overlying seawater was poured into the intact core tubes and allowed to equilibrate for 24 hours prior to initiation of the toxicity tests. Five replicate cores were tested per station, with a sixth core used for interstitial sulfide and ammonia measurements at the termination of the test. Screen tubes were gently added to the cores 2 hours prior to inoculation of embryos (Anderson *et al.,* 2001). After inserting the screen tube into the equilibrated cores, each tube was inoculated with approximately 134 bivalve embryos. The laboratory control consisted of Yaquina Bay amphipod home sediment from Northwestern Aquatic Sciences. SWI exposures were conducted simultaneously with elutriate exposures. The SWIC test was terminated by removing the screen from the core tube and rinsing larvae into a 20 mL scintillation vial for preservation with formalin.

6.2.5 Bivalve Growth and Survival

Applied Marine Sciences (AMS) conducted the bivalve health measure evaluations as in previous years but discontinued measuring the condition index.

Analysis of contaminant concentrations is conducted on a subset of the transplanted bivalves (composites contain 40-60 individual bivalves from each site) prior to deployment in Estuary locations (T-0) and after the 100-day deployment period. The differences between pre- and post-deployment concentrations allow determination of contaminant uptake during the period of deployment. A new batch of bivalves are also collected from the original T-0 transplanted bivalve collection sites at the end of the deployment period to obtain information on uptake variables that may have affected wild populations during the deployment period.

In 2001 AMS began calculating the growth mean in addition to the condition index (CI) for the RMP as an indicator of bivalve health. The CI interpretation of bivalve health can be confounding when ambient conditions (i.e., salinity) are more uniform such as during the summer deployment period. In 2002, the RMP discontinued the condition index measure in favor of the growth mean as the only health indicator. Because the CI is the ratio of dry tissue weight to shell cavity volume, it could be affected by changes in either

tissue weight or shell size. For example, either a decrease in tissue weight with stable shell size or an increase in shell size with stable tissue weight could be interpreted as a decrease in CI. Consequently, the interpretation of CI as an indicator of health can be problematic. The growth mean is a measure of growth of the composite of bivalves at a particular site in comparison to the T-0. The growth mean is determined by taking the dry weight of each individual and subtracting the mean dry weight of the T-0 for that species. This calculation is done for each individual bivalve. The mean of the difference of all the individuals at a particular site is then calculated to give the growth mean. The 2002 survival results include survival of both caged and bagged, maintained bivalves.

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Appendix A: Contaminant summary statistics for fixed historical RMP sites for water-column-total data. Only RMP target parameters are reported.
total samples= number of measures that passed QA/QC review, Count NDs = total number of measures below detection limit (ND)
Note that for organic contaminant results samples reported as ND were reported as "0". For trace metals data that were ND 1/2 the MDL was reported.
Regions: RIV=Rivers, SU=Suisun Bay, SPB= San Pablo Bay, CB=Central Bay, SB=South Bay, LSB=Lower South Bay, SS=Southern Sloughs

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
RIV	BG20	PAH	Acenaphthene	12	8	1996-07	2002-07	0	1900	223	0
RIV	BG20	PAH	Anthracene	20	15	1993-03	2002-07	0	197	20	0
RIV	BG20	PAH	Benz(a)anthracene	18	2	1993-03	2002-07	0	1100	477	539
RIV	BG20	PAH	Benzo(a)pyrene	22	16	1993-03	2002-07	0	547	51	0
RIV	BG20	PAH	Benzo(b)fluoranthene	22	1	1993-03	2002-07	0	1900	716	621
RIV	BG20	PAH	Benzo(k)fluoranthene	22	5	1993-03	2002-07	0	928	247	213
RIV	BG20	PAH	Chrysene	22		1993-03	2002-07	180	1060	587	607
RIV	BG20	PAH	Dibenz(a,h)anthracene	22	15	1993-03	2002-07	0	670	73	0
RIV	BG20	PAH	Fluoranthene	20		1993-03	2002-07	830	3000	1548	1224
RIV	BG20	PAH	Fluorene	13	2	1996-02	2002-07	0	720	353	400
RIV	BG20	PAH	Indeno(1,2,3-cd)pyrene	22	5	1993-03	2002-07	0	1317	364	200
RIV	BG20	PAH	Pyrene	20		1993-03	2002-07	470	3160	1483	1225
RIV	BG20	PAH	Total PAHs (SFEI)	19		1993-03	2002-07	3032	15124	8727	9500
RIV	BG20	PCB	Total PCBs (SFEI)	21		1993-03	2002-07	54	792	236	177
RIV	BG20	PEST	alpha-HCH	17	1	1993-03	2002-07	0	347	76	35
RIV	BG20	PEST	beta-HCH	17		1994-04	2002-07	6	118	28	18
RIV	BG20	PEST	Chlorpyrifos	19	1	1993-03	2002-07	0	950	321	321
RIV	BG20	PEST	Diazinon	18		1994-04	2002-07	520	37690	6291	2350
RIV	BG20	PEST	Dieldrin	17		1994-04	2002-07	2	380	127	89
RIV	BG20	PEST	Endrin	16	14	1994-08	2002-07	0	19	2	0
RIV	BG20	PEST	gamma-HCH	18		1993-03	2002-07	9	1003	210	94
RIV	BG20	PEST	Heptachlor	15	10	1994-04	2002-07	0	11	2	0
RIV	BG20	PEST	Heptachlor Epoxide	18		1994-04	2002-07	2	97	26	20
RIV	BG20	PEST	Mirex	19	18	1994-04	2002-07	0	54	3	0
RIV	BG20	PEST	p,p'-DDD	16		1993-03	2002-07	45	347	156	133
RIV	BG20	PEST	p,p'-DDE	21		1993-03	2002-07	96	920	365	304
RIV	BG20	PEST	p,p'-DDT	18		1993-03	2002-07	6	349	59	34
RIV	BG20	PEST	Total Chlordanes (SFEI)	18		1993-03	2002-07	25	302	130	111
RIV	BG20	PEST	Total DDTs (SFEI)	16		1993-03	2002-07	283	1769	657	602
RIV	BG20	TE	Ag	33	1	1993-03	2002-07	0	0.057	0.007	0.003
RIV	BG20	TE	As	26	1	1993-03	2002-07	0	3.7	2	2
RIV	BG20	TE	Cd	39		1993-03	2002-07	0.01	0.07	0.02	0.02
RIV	BG20	TE	Cr	34		1993-03	1999-07	0.1	80.4	6.8	4
RIV	BG20	TE	Cu	38		1993-03	2002-07	0.9	9.9	3.2	3.2
RIV	BG20	TE	Hg	29		1993-03	2002-07	0.001	0.038	0.008	0.006
RIV	BG20	TE	Ni	38		1993-03	2002-07	0.8	21.8	4.1	3.3
RIV	BG20	TE	Pb	40		1993-03	2002-07	0.04	2.3	0.6	0.5
RIV	BG20	TE	Se	26	2	1993-03	2002-07	0	0.3	0.1	0.1
RIV	BG20	TE	Zn	38		1993-03	2002-07	0.4	18	5	4
RIV	BG30	PAH	Acenaphthene	11	8	1996-07	2002-07	0	798	123	0
RIV	BG30	PAH	Anthracene	17	11	1993-03	2002-07	0	280	41	0
RIV	BG30	PAH	Benz(a)anthracene	16	3	1993-03	2002-07	0	1540	423	341
RIV	BG30	PAH	Benzo(a)pyrene	20	17	1993-03	2002-07	0	1100	96	0
RIV	BG30	PAH	Benzo(b)fluoranthene	20	1	1993-03	2002-07	0	1800	662	673
RIV	BG30	PAH	Benzo(k)fluoranthene	20	6	1993-03	2002-07	0	600	206	189
RIV	BG30	PAH	Chrysene	20	1	1993-03	2002-07	0	1160	538	460
RIV	BG30	PAH	Dibenz(a,h)anthracene	20	13	1993-03	2002-07	0	490	72	0
RIV	BG30	PAH	Fluoranthene	18		1993-03	2002-07	381	3100	1260	1059
RIV	BG30	PAH	Fluorene	11	4	1996-07	2002-07	0	850	281	267
RIV	BG30	PAH	Indeno(1,2,3-cd)pyrene	20	8	1993-03	2002-07	0	3700	383	147
RIV	BG30	PAH	Pyrene	17		1993-03	2002-07	430	3300	1332	1210
RIV	BG30	PAH	Total PAHs (SFEI)	17		1993-03	2002-07	2822	23085	7995	6100
RIV	BG30	PCB	Total PCBs (SFEI)	19		1993-03	2002-07	66	704	201	170
RIV	BG30	PEST	alpha-HCH	17		1993-03	2002-07	2	200	60	33
RIV	BG30	PEST	beta-HCH	17		1993-03	2002-07	2	292	44	34
RIV	BG30	PEST	Chlorpyrifos	16	1	1994-01	2002-07	0	789	327	332
RIV	BG30	PEST	Diazinon	16	1	1994-01	2002-07	0	35259	8634	2760
RIV	BG30	PEST	Dieldrin	20	3	1993-03	2002-07	0	327	95	76
RIV	BG30	PEST	Endrin	17	12	1994-08	2002-07	0	224	15	0

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
RIV	BG30	PEST	gamma-HCH	18	1	1993-03	2002-07	0	617	163	123
RIV	BG30	PEST	Heptachlor	15	12	1994-04	2002-07	0	16	2	0
RIV	BG30	PEST	Heptachlor Epoxide	18	1	1994-01	2002-07	0	170	29	15
RIV	BG30	PEST	Mirex	17	16	1994-04	2002-07	0	4	0	0
RIV	BG30	PEST	p,p'-DDD	17		1993-03	2002-07	36	368	116	99
RIV	BG30	PEST	p,p'-DDE	19		1993-03	2002-07	97	570	242	236
RIV	BG30	PEST	p,p'-DDT	16	2	1993-03	2002-07	0	310	57	21
RIV	BG30	PEST	Total Chlordanes (SFEI)	17		1993-03	2002-07	26	254	126	114
RIV	BG30	PEST	Total DDTs (SFEI)	17		1993-03	2002-07	175	1049	442	366
RIV	BG30	TE	Ag	33	2	1993-03	2002-07	0	0.044	0.006	0.003
RIV	BG30	TE	As	26		1993-03	2002-07	1.3	2.6	2	2
RIV	BG30	TE	Cd	38		1993-03	2002-07	0.01	0.03	0.02	0.02
RIV	BG30	TE	Cr	33		1993-03	1999-07	0.1	51.1	4.5	2.7
RIV	BG30	TE	Cu	40		1993-03	2002-07	1.2	5.3	2.9	2.9
RIV	BG30	TE	Hg	29		1993-03	2002-07	0.002	0.016	0.007	0.007
RIV	BG30	TE	Ni	38		1993-03	2002-07	0.7	6.7	2.9	2.6
RIV	BG30	TE	Pb	40		1993-03	2002-07	0.01	1.4	0.5	0.5
RIV	BG30	TE	Se	26		1993-03	2002-07	0.1	0.4	0.2	0.2
RIV	BG30	TE	Zn	43		1993-03	2002-07	0.2	9	3	4
SU	BF10	TE	Ag	33		1993-03	2001-08	0.001	0.037	0.008	0.007
SU	BF10	TE	As	25		1993-03	2001-08	1.4	3.7	2.5	2.6
SU	BF10	TE	Cd	37		1993-03	2001-08	0.01	0.12	0.04	0.04
SU	BF10	TE	Cr	35		1993-03	1999-07	0.1	122.2	10.2	6
SU	BF10	TE	Cu	40		1993-03	2001-08	1.2	8.2	4.4	4.3
SU	BF10	TE	Hg	28		1993-03	2001-08	0.003	0.033	0.015	0.013
SU	BF10	TE	Ni	39		1993-03	2001-08	1	16.6	5.7	5.2
SU	BF10	TE	Pb	39		1993-03	2001-08	0.01	3.9	1.2	1.2
SU	BF10	TE	Se	25	1	1993-03	2001-08	0	0.3	0.2	0.2
SU	BF10	TE	Zn	41		1993-03	2001-08	0.2	22	8	6
SU	BF20	PAH	Acenaphthene	10	5	1996-07	2001-08	0	470	151	80
SU	BF20	PAH	Anthracene	17	5	1993-03	2001-08	0	1300	277	240
SU	BF20	PAH	Benz(a)anthracene	16	2	1993-03	2001-08	0	8120	2055	1122
SU	BF20	PAH	Benzo(a)pyrene	20	13	1993-03	2001-08	0	5923	463	0
SU	BF20	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	556	12000	3561	2490
SU	BF20	PAH	Benzo(k)fluoranthene	20	1	1993-03	2001-08	0	3500	1205	1020
SU	BF20	PAH	Chrysene	20	1	1993-03	2001-08	0	7000	1942	1350
SU	BF20	PAH	Dibenz(a,h)anthracene	20	4	1993-03	2001-08	0	2500	427	195
SU	BF20	PAH	Fluoranthene	19		1993-03	2001-08	703	16200	4768	3920
SU	BF20	PAH	Fluorene	12		1996-02	2001-08	180	2790	957	540
SU	BF20	PAH	Indeno(1,2,3-cd)pyrene	20	1	1993-03	2001-08	0	9400	2413	1146
SU	BF20	PAH	Pyrene	17		1993-03	2001-08	506	14100	5172	5300
SU	BF20	PAH	Total PAHs (SFEI)	17		1993-03	2001-08	5840	96817	29959	24106
SU	BF20	PCB	Total PCBs (SFEI)	20		1993-03	2001-08	80	2311	507	296
SU	BF20	PEST	alpha-HCH	16		1993-03	2001-08	2	512	107	41
SU	BF20	PEST	beta-HCH	18		1993-03	2001-08	8	345	66	34
SU	BF20	PEST	Chlorpyrifos	19	1	1993-03	2001-08	0	481	214	197
SU	BF20	PEST	Diazinon	17		1994-01	2001-08	540	58350	7764	2700
SU	BF20	PEST	Dieldrin	21	2	1993-03	2001-08	0	280	83	65
SU	BF20	PEST	Endrin	18	10	1994-08	2001-08	0	84	7	0
SU	BF20	PEST	gamma-HCH	18		1993-03	2001-08	3	922	196	117
SU	BF20	PEST	Heptachlor	17	10	1994-04	2001-08	0	18	3	0
SU	BF20	PEST	Heptachlor Epoxide	18	2	1994-01	2001-08	0	182	28	16
SU	BF20	PEST	Mirex	19	13	1994-04	2001-08	0	3	0	0
SU	BF20	PEST	p,p'-DDD	18		1993-03	2001-08	100	1100	278	197
SU	BF20	PEST	p,p'-DDE	21		1993-03	2001-08	169	1455	485	370
SU	BF20	PEST	p,p'-DDT	19	1	1993-03	2001-08	0	516	106	33
SU	BF20	PEST	Total Chlordanes (SFEI)	19		1993-03	2001-08	8	254	134	139
SU	BF20	PEST	Total DDTs (SFEI)	18		1993-03	2001-08	341	3071	971	737
SU	BF20	TE	Ag	33		1993-03	2001-08	0.001	0.119	0.014	0.01
SU	BF20	TE	As	25		1993-03	2001-08	1.6	7.4	2.8	2.5
SU	BF20	TE	Cd	40		1993-03	2001-08	0	0.11	0.04	0.04
SU	BF20	TE	Cr	35		1993-03	1999-07	0.1	148.7	12.6	6.3
SU	BF20	TE	Cu	40		1993-03	2001-08	1.3	15.3	5.2	4.7

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SU	BF20	TE	Hg	28		1993-03	2001-08	0.003	0.084	0.02	0.014
SU	BF20	TE	Ni	39		1993-03	2001-08	1	24.1	7.1	5.2
SU	BF20	TE	Pb	37		1993-03	2001-08	0	5.8	1.5	1.3
SU	BF20	TE	Se	25		1993-03	2001-08	0	0.3	0.2	0.2
SU	BF20	TE	Zn	40		1993-03	2001-08	0.2	94	10	9
SU	BF40	TE	Ag	30	1	1994-01	2001-08	0	0.024	0.006	0.006
SU	BF40	TE	As	22		1994-01	2001-08	1.2	4.4	2.6	2.5
SU	BF40	TE	Cd	35		1994-01	2001-08	0	0.07	0.03	0.03
SU	BF40	TE	Cr	31		1994-01	1999-07	0.1	201.1	22.6	5.9
SU	BF40	TE	Cu	38		1994-01	2001-08	1.2	10.9	4.2	3.6
SU	BF40	TE	Hg	24		1994-01	2001-08	0.004	0.046	0.018	0.017
SU	BF40	TE	Ni	37		1994-01	2001-08	0.9	28.5	5.8	4.4
SU	BF40	TE	Pb	38		1994-01	2001-08	0	3.4	1	0.9
SU	BF40	TE	Se	22		1994-01	2001-08	0.1	0.3	0.2	0.2
SU	BF40	TE	Zn	41		1994-01	2001-08	0.2	28	8	7
CAR	BD50	PAH	Acenaphthene	10	2	1996-02	2000-07	0	1556	750	788
CAR	BD50	PAH	Anthracene	17	3	1993-03	2001-08	0	930	308	197
CAR	BD50	PAH	Benz(a)anthracene	16		1993-03	2001-08	401	16610	3242	2071
CAR	BD50	PAH	Benzo(a)pyrene	19	11	1993-03	2001-08	0	700	98	0
CAR	BD50	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	820	8370	3879	3745
CAR	BD50	PAH	Benzo(k)fluoranthene	20		1993-03	2001-08	202	2600	1223	1195
CAR	BD50	PAH	Chrysene	20		1993-03	2001-08	516	7780	2403	1990
CAR	BD50	PAH	Dibenz(a,h)anthracene	19	4	1993-03	2001-08	0	2760	485	370
CAR	BD50	PAH	Fluoranthene	20		1993-03	2001-08	1860	13100	7024	5310
CAR	BD50	PAH	Fluorene	11		1996-02	2001-08	270	2643	1472	1400
CAR	BD50	PAH	Indeno(1,2,3-cd)pyrene	19		1993-03	2001-08	410	5040	2746	2821
CAR	BD50	PAH	Pyrene	18		1993-03	2001-08	2120	15500	6607	5769
CAR	BD50	PAH	Total PAHs (SFEI)	17		1993-03	2001-08	14812	96250	36321	32505
CAR	BD50	PCB	Total PCBs (SFEI)	19		1993-03	2001-08	217	1784	541	481
CAR	BD50	PEST	alpha-HCH	18	1	1993-03	2001-08	0	502	182	183
CAR	BD50	PEST	beta-HCH	19	1	1993-03	2001-08	0	294	86	75
CAR	BD50	PEST	Chlorpyrifos	19		1993-03	2001-08	9	715	230	123
CAR	BD50	PEST	Diazinon	19		1994-01	2001-08	320	39300	6077	4600
CAR	BD50	PEST	Dieldrin	21	1	1993-03	2001-08	0	289	76	53
CAR	BD50	PEST	Endrin	17	10	1994-08	2001-08	0	73	10	0
CAR	BD50	PEST	gamma-HCH	19	1	1993-03	2001-08	0	577	220	191
CAR	BD50	PEST	Heptachlor	16	8	1994-04	2001-08	0	26	4	1
CAR	BD50	PEST	Heptachlor Epoxide	19		1994-01	2001-08	6	128	40	23
CAR	BD50	PEST	Mirex	18	15	1994-04	2001-08	0	3	0	0
CAR	BD50	PEST	p,p'-DDD	19		1993-03	2001-08	61	508	278	276
CAR	BD50	PEST	p,p'-DDE	20		1993-03	2001-08	97	1570	464	349
CAR	BD50	PEST	p,p'-DDT	18		1993-03	2000-07	3	580	126	69
CAR	BD50	PEST	Total Chlordanes (SFEI)	20		1993-03	2001-08	56	702	223	179
CAR	BD50	PEST	Total DDTs (SFEI)	18		1993-03	2001-08	195	2753	895	722
CAR	BD50	TE	Ag	35		1993-03	2001-08	0	0.126	0.014	0.008
CAR	BD50	TE	As	25		1993-03	2001-08	1.6	5.6	2.8	2.6
CAR	BD50	TE	Cd	39		1993-03	2001-08	0	0.16	0.06	0.06
CAR	BD50	TE	Cr	33		1993-03	1999-07	0.1	54	7.8	4.9
CAR	BD50	TE	Cu	42		1993-03	2001-08	0.6	14.5	4.7	3.9
CAR	BD50	TE	Hg	28		1993-03	2001-08	0.003	0.071	0.023	0.016
CAR	BD50	TE	Ni	40		1993-03	2001-08	1.2	37.8	6.9	5.1
CAR	BD50	TE	Pb	41		1993-03	2001-08	0.01	6.4	1.4	1.1
CAR	BD50	TE	Se	24		1993-03	2001-08	0.1	0.3	0.2	0.2
CAR	BD50	TE	Zn	43		1993-03	2001-08	0.2	38	10	7
SPB	BD15	PAH	Acenaphthene	11	3	1996-02	2001-08	0	13300	1572	440
SPB	BD15	PAH	Anthracene	16	1	1994-01	2001-08	0	2248	758	459
SPB	BD15	PAH	Benz(a)anthracene	14		1994-01	2001-08	910	27130	6657	4464
SPB	BD15	PAH	Benzo(a)pyrene	18	6	1994-01	2001-08	0	51000	8055	1144
SPB	BD15	PAH	Benzo(b)fluoranthene	18		1994-01	2001-08	540	68000	15864	11425
SPB	BD15	PAH	Benzo(k)fluoranthene	18	1	1994-01	2001-08	0	22000	5064	4125
SPB	BD15	PAH	Chrysene	18		1994-01	2001-08	480	20000	5633	4735
SPB	BD15	PAH	Dibenz(a,h)anthracene	19	1	1994-01	2001-08	0	8200	1638	1133
SPB	BD15	PAH	Fluoranthene	17		1994-01	2001-08	2090	67420	12774	7000

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SPB	BD15	PAH	Fluorene	10		1996-02	2001-08	510	1960	1039	1075
SPB	BD15	PAH	Indeno(1,2,3-cd)pyrene	19		1994-01	2001-08	240	75000	13470	8535
SPB	BD15	PAH	Pyrene	17		1994-01	2001-08	1740	90000	18814	10580
SPB	BD15	PAH	Total PAHs (SFEI)	16		1994-01	2001-08	7750	476720	113377	66271
SPB	BD15	PCB	Total PCBs (SFEI)	19		1994-01	2001-08	174	6788	1593	908
SPB	BD15	PEST	alpha-HCH	17		1994-01	2001-08	34	648	255	233
SPB	BD15	PEST	beta-HCH	17		1994-01	2001-08	17	376	140	123
SPB	BD15	PEST	Chlorpyrifos	18	1	1994-01	2001-08	0	756	181	47
SPB	BD15	PEST	Diazinon	19	2	1994-01	2001-08	0	13924	4239	2500
SPB	BD15	PEST	Dieldrin	20	1	1994-01	2001-08	0	157	59	54
SPB	BD15	PEST	Endrin	18	12	1994-08	2001-08	0	197	18	0
SPB	BD15	PEST	gamma-HCH	18		1994-01	2001-08	7	602	215	175
SPB	BD15	PEST	Heptachlor	16	7	1994-04	2001-08	0	16	4	2
SPB	BD15	PEST	Heptachlor Epoxide	17		1994-01	2001-08	5	176	51	24
SPB	BD15	PEST	Mirex	18	12	1994-04	2001-08	0	11	1	0
SPB	BD15	PEST	p,p'-DDD	18		1994-01	2001-08	52	2630	449	278
SPB	BD15	PEST	p,p'-DDE	19		1994-01	2001-08	97	3178	684	471
SPB	BD15	PEST	p,p'-DDT	16		1994-01	1999-07	8	665	188	112
SPB	BD15	PEST	Total Chlordanes (SFEI)	19		1994-01	2001-08	37	781	242	233
SPB	BD15	PEST	Total DDTs (SFEI)	18		1994-01	2001-08	197	6828	1384	1082
SPB	BD15	TE	Ag	33		1994-01	2001-08	0.001	0.14	0.031	0.021
SPB	BD15	TE	As	22		1994-01	2001-08	2.1	7.7	4.4	4.4
SPB	BD15	TE	Cd	34		1994-01	2001-08	0.02	0.19	0.11	0.1
SPB	BD15	TE	Cr	32		1994-01	1999-07	0.1	63.9	18.5	11.8
SPB	BD15	TE	Cu	39		1994-01	2001-08	2.3	20.7	8.7	8.6
SPB	BD15	TE	Hg	26		1994-01	2001-08	0.006	0.126	0.049	0.042
SPB	BD15	TE	Ni	37		1994-01	2001-08	2	41.3	17.8	16.7
SPB	BD15	TE	Pb	36		1994-01	2001-08	0	8.7	2.9	2.3
SPB	BD15	TE	Se	22		1994-01	2001-08	0	0.4	0.2	0.2
SPB	BD15	TE	Zn	36		1994-01	2001-08	0.3	91	17	12
SPB	BD20	PAH	Acenaphthene	11	5	1996-02	2001-08	0	650	230	200
SPB	BD20	PAH	Anthracene	17	5	1993-03	2001-08	0	2300	298	63
SPB	BD20	PAH	Benz(a)anthracene	17		1993-03	2001-08	82	6400	2544	2159
SPB	BD20	PAH	Benzo(a)pyrene	20	11	1993-03	2001-08	0	9400	1525	0
SPB	BD20	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	880	18380	5447	4320
SPB	BD20	PAH	Benzo(k)fluoranthene	20		1993-03	2001-08	333	5100	1642	1127
SPB	BD20	PAH	Chrysene	20		1993-03	2001-08	550	8590	2269	1775
SPB	BD20	PAH	Dibenz(a,h)anthracene	20	3	1993-03	2001-08	0	2600	579	425
SPB	BD20	PAH	Fluoranthene	19		1993-03	2001-08	1100	21800	6158	5400
SPB	BD20	PAH	Fluorene	11		1996-02	2001-08	410	2070	750	610
SPB	BD20	PAH	Indeno(1,2,3-cd)pyrene	20	1	1993-03	2001-08	0	12034	3924	3300
SPB	BD20	PAH	Pyrene	18		1993-03	2001-08	601	29600	7488	5815
SPB	BD20	PAH	Total PAHs (SFEI)	17		1993-03	2001-08	6483	144730	41125	26960
SPB	BD20	PCB	Total PCBs (SFEI)	21		1993-03	2001-08	143	3344	705	425
SPB	BD20	PEST	alpha-HCH	18		1993-03	2001-08	43	802	280	230
SPB	BD20	PEST	beta-HCH	19	1	1993-03	2001-08	0	635	156	120
SPB	BD20	PEST	Chlorpyrifos	19		1993-03	2001-08	8	734	165	92
SPB	BD20	PEST	Diazinon	18	3	1994-01	2001-08	0	31190	5358	2913
SPB	BD20	PEST	Dieldrin	20	2	1993-03	2001-08	0	237	65	56
SPB	BD20	PEST	Endrin	17	11	1994-08	2001-08	0	180	16	0
SPB	BD20	PEST	gamma-HCH	19	1	1993-03	2001-08	0	791	233	180
SPB	BD20	PEST	Heptachlor	17	11	1994-04	2001-08	0	30	3	0
SPB	BD20	PEST	Heptachlor Epoxide	19	1	1994-01	2001-08	0	121	33	24
SPB	BD20	PEST	Mirex	19	17	1994-04	2001-08	0	5	0	0
SPB	BD20	PEST	p,p'-DDD	19		1993-03	2001-08	40	670	233	188
SPB	BD20	PEST	p,p'-DDE	21		1993-03	2001-08	81	1159	321	239
SPB	BD20	PEST	p,p'-DDT	18		1993-03	2001-08	3	416	93	43
SPB	BD20	PEST	Total Chlordanes (SFEI)	19		1993-03	2001-08	44	344	158	149
SPB	BD20	PEST	Total DDTs (SFEI)	19		1993-03	2001-08	237	2443	692	478
SPB	BD20	TE	Ag	32		1993-03	2001-08	0.001	0.059	0.015	0.008
SPB	BD20	TE	As	25		1993-03	2001-08	1.3	4.6	2.7	2.7
SPB	BD20	TE	Cd	38		1993-03	2001-08	0.01	0.23	0.07	0.06
SPB	BD20	TE	Cr	35		1993-03	1999-07	0.1	41.2	8.4	3.1

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SPB	BD20	TE	Cu	40		1993-03	2001-08	1.2	14.5	4.5	3
SPB	BD20	TE	Hg	28		1993-03	2001-08	0.003	0.099	0.022	0.016
SPB	BD20	TE	Ni	39		1993-03	2001-08	1.4	32.8	7.4	5.2
SPB	BD20	TE	Pb	39		1993-03	2001-08	0	6.5	1.7	0.8
SPB	BD20	TE	Se	25	1	1993-03	2001-08	0	0.3	0.2	0.2
SPB	BD20	TE	Zn	38		1993-03	2001-08	0.2	37	8	5
SPB	BD30	PAH	Acenaphthene	12	4	1996-02	2001-08	0	960	334	388
SPB	BD30	PAH	Anthracene	18	11	1993-03	2001-08	0	767	110	0
SPB	BD30	PAH	Benz(a)anthracene	18	2	1993-03	2001-08	0	3359	1253	1165
SPB	BD30	PAH	Benzo(a)pyrene	21	16	1993-03	2001-08	0	6457	463	0
SPB	BD30	PAH	Benzo(b)fluoranthene	21		1993-03	2001-08	436	9310	2792	1800
SPB	BD30	PAH	Benzo(k)fluoranthene	21	2	1993-03	2001-08	0	2979	916	650
SPB	BD30	PAH	Chrysene	21		1993-03	2001-08	480	5009	1335	905
SPB	BD30	PAH	Dibenz(a,h)anthracene	21	6	1993-03	2001-08	0	1361	316	210
SPB	BD30	PAH	Fluoranthene	19		1993-03	2001-08	1570	10812	3929	3100
SPB	BD30	PAH	Fluorene	12	2	1996-02	2001-08	0	1100	697	845
SPB	BD30	PAH	Indeno(1,2,3-cd)pyrene	21	1	1993-03	2001-08	0	7738	2073	1200
SPB	BD30	PAH	Pyrene	19		1993-03	2001-08	1009	13773	4031	2737
SPB	BD30	PAH	Total PAHs (SFEI)	18		1993-03	2001-08	6381	76902	24070	18340
SPB	BD30	PCB	Total PCBs (SFEI)	20		1993-03	2001-08	130	2804	584	317
SPB	BD30	PEST	alpha-HCH	18		1993-03	2001-08	8	494	206	221
SPB	BD30	PEST	beta-HCH	19	2	1993-03	2001-08	0	523	119	103
SPB	BD30	PEST	Chlorpyrifos	18		1993-03	2001-08	2	640	170	96
SPB	BD30	PEST	Diazinon	18		1994-01	2001-08	260	43958	9392	2865
SPB	BD30	PEST	Dieldrin	21		1993-03	2001-08	3	337	79	51
SPB	BD30	PEST	Endrin	18	12	1994-08	2001-08	0	56	8	0
SPB	BD30	PEST	gamma-HCH	19	1	1994-01	2001-08	0	476	197	182
SPB	BD30	PEST	Heptachlor	16	14	1994-04	2001-08	0	8	1	0
SPB	BD30	PEST	Heptachlor Epoxide	19	3	1994-01	2001-08	0	117	28	15
SPB	BD30	PEST	Mirex	18	16	1994-04	2001-08	0	20	1	0
SPB	BD30	PEST	p,p'-DDD	18		1993-03	2001-08	17	579	223	153
SPB	BD30	PEST	p,p'-DDE	20		1993-03	2001-08	79	990	275	194
SPB	BD30	PEST	p,p'-DDT	18	1	1993-03	1999-07	0	729	90	33
SPB	BD30	PEST	Total Chlordanes (SFEI)	19		1993-03	2001-08	34	478	149	130
SPB	BD30	PEST	Total DDTs (SFEI)	18		1993-03	2001-08	126	2293	651	513
SPB	BD30	TE	Ag	33		1993-03	2001-08	0.001	0.039	0.009	0.007
SPB	BD30	TE	As	25		1993-03	2001-08	1.4	4.4	2.3	2.2
SPB	BD30	TE	Cd	40		1993-03	2001-08	0.01	0.17	0.06	0.06
SPB	BD30	TE	Cr	33		1993-03	1999-07	0.1	39.9	5.3	2.2
SPB	BD30	TE	Cu	41		1993-03	2001-08	1.3	10.3	3	2.5
SPB	BD30	TE	Hg	27		1993-03	2001-08	0.001	0.046	0.011	0.007
SPB	BD30	TE	Ni	39		1993-03	2001-08	1.2	19.6	4.2	3.1
SPB	BD30	TE	Pb	41		1993-03	2001-08	0	3.2	0.7	0.5
SPB	BD30	TE	Se	25	1	1993-03	2001-08	0	0.4	0.2	0.2
SPB	BD30	TE	Zn	38		1993-03	2001-08	0.3	23	5	3
SPB	BD40	PAH	Acenaphthene	13	3	1996-02	2001-08	0	21000	2027	560
SPB	BD40	PAH	Anthracene	19	5	1993-03	2001-08	0	3170	433	145
SPB	BD40	PAH	Benz(a)anthracene	17		1993-03	2001-08	155	5320	2045	1441
SPB	BD40	PAH	Benzo(a)pyrene	21	13	1993-03	2001-08	0	7300	805	0
SPB	BD40	PAH	Benzo(b)fluoranthene	21		1993-03	2001-08	760	20300	4660	3151
SPB	BD40	PAH	Benzo(k)fluoranthene	21	1	1993-03	2001-08	0	6400	1488	1200
SPB	BD40	PAH	Chrysene	21		1993-03	2001-08	577	8500	2141	1610
SPB	BD40	PAH	Dibenz(a,h)anthracene	21	2	1993-03	2001-08	0	1200	441	330
SPB	BD40	PAH	Fluoranthene	21		1993-03	2001-08	1439	21600	6491	5010
SPB	BD40	PAH	Fluorene	12		1996-02	2001-08	270	1630	1058	1005
SPB	BD40	PAH	Indeno(1,2,3-cd)pyrene	21	1	1993-03	2001-08	0	17000	3359	2730
SPB	BD40	PAH	Pyrene	20		1993-03	2001-08	1444	28400	6945	4525
SPB	BD40	PAH	Total PAHs (SFEI)	18		1993-03	2001-08	10061	107870	33446	26920
SPB	BD40	PCB	Total PCBs (SFEI)	20		1993-03	2001-08	131	1827	656	426
SPB	BD40	PEST	alpha-HCH	18		1993-03	2001-08	24	613	214	163
SPB	BD40	PEST	beta-HCH	20	1	1993-03	2001-08	0	313	89	67
SPB	BD40	PEST	Chlorpyrifos	20		1993-03	2001-08	6	1253	265	173
SPB	BD40	PEST	Diazinon	19		1994-01	2001-08	450	44320	6673	2400

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SPB	BD40	PEST	Dieldrin	21		1993-03	2001-08	3	294	72	39
SPB	BD40	PEST	Endrin	17	11	1994-08	2001-08	0	79	9	0
SPB	BD40	PEST	gamma-HCH	20	1	1993-03	2001-08	0	572	209	163
SPB	BD40	PEST	Heptachlor	18	12	1994-04	2001-08	0	10	2	0
SPB	BD40	PEST	Heptachlor Epoxide	19		1994-01	2001-08	1	94	27	18
SPB	BD40	PEST	Mirex	19	15	1994-04	2001-08	0	4	0	0
SPB	BD40	PEST	p,p'-DDD	18		1993-03	2001-08	85	810	251	201
SPB	BD40	PEST	p,p'-DDE	21		1993-03	2001-08	52	1834	449	229
SPB	BD40	PEST	p,p'-DDT	20		1993-03	2001-08	3	500	128	58
SPB	BD40	PEST	Total Chlordanes (SFEI)	19		1993-03	2001-08	42	337	165	155
SPB	BD40	PEST	Total DDTs (SFEI)	18		1993-03	2001-08	197	2266	808	558
SPB	BD40	TE	Ag	32		1993-03	2001-08	0	0.1	0.017	0.011
SPB	BD40	TE	As	25		1993-03	2001-08	1.4	7.7	2.8	2.5
SPB	BD40	TE	Cd	38		1993-03	2001-08	0.01	0.16	0.07	0.07
SPB	BD40	TE	Cr	34		1993-03	1999-07	0.1	74.9	8.5	4.6
SPB	BD40	TE	Cu	40		1993-03	2001-08	1.3	20.2	4.7	3.8
SPB	BD40	TE	Hg	27		1993-03	2001-08	0.001	0.09	0.02	0.012
SPB	BD40	TE	Ni	39		1993-03	2001-08	1.2	36.3	7.3	5.2
SPB	BD40	TE	Pb	38		1993-03	2001-08	0	6.5	1.3	1.1
SPB	BD40	TE	Se	25		1993-03	2001-08	0.1	0.5	0.2	0.2
SPB	BD40	TE	Zn	38		1993-03	2001-08	0.3	50	9	7
CB	BB15	TE	Ag	29		1994-01	2001-08	0.001	0.023	0.009	0.01
CB	BB15	TE	As	22		1994-01	2001-08	1.4	3.6	2.4	2.1
CB	BB15	TE	Cd	34		1994-01	2001-08	0.02	0.2	0.08	0.08
CB	BB15	TE	Cr	33		1994-01	1999-07	0.1	4.9	1.2	1
CB	BB15	TE	Cu	37		1994-01	2001-08	1.3	4	2.3	2.1
CB	BB15	TE	Hg	25		1994-01	2001-08	0.002	0.016	0.006	0.004
CB	BB15	TE	Ni	36		1994-01	2001-08	1.3	6.2	2.6	2.2
CB	BB15	TE	Pb	35		1994-01	2001-08	0.01	1.6	0.3	0.2
CB	BB15	TE	Se	22	2	1994-01	2001-08	0	0.4	0.2	0.1
CB	BB15	TE	Zn	33		1994-01	2001-08	0.1	6	2	2
CB	BB30	TE	Ag	32		1993-03	2001-08	0.001	0.072	0.011	0.009
CB	BB30	TE	As	25		1993-03	2001-08	1.2	3	2	2.1
CB	BB30	TE	Cd	38		1993-03	2001-08	0.02	0.14	0.07	0.08
CB	BB30	TE	Cr	34	1	1993-03	1999-07	-0.1	5.6	1.1	0.6
CB	BB30	TE	Cu	44		1993-03	2001-08	0.9	3.4	1.9	1.7
CB	BB30	TE	Hg	28		1993-03	2001-08	0.001	0.029	0.006	0.004
CB	BB30	TE	Ni	43		1993-03	2001-08	1	8.5	2.4	1.9
CB	BB30	TE	Pb	38		1993-03	2001-08	0.01	1.4	0.3	0.2
CB	BB30	TE	Se	25	1	1993-03	2001-08	0	0.3	0.1	0.1
CB	BB30	TE	Zn	40		1993-03	2001-08	0.3	10	2	2
CB	BB70	PAH	Acenaphthene	12	6	1996-02	2001-08	0	2600	499	175
CB	BB70	PAH	Anthracene	16	8	1994-01	2001-08	0	1000	225	55
CB	BB70	PAH	Benz(a)anthracene	16	1	1994-01	2001-08	0	9905	2173	1275
CB	BB70	PAH	Benzo(a)pyrene	18	14	1994-01	2001-08	0	1564	93	0
CB	BB70	PAH	Benzo(b)fluoranthene	19		1994-01	2001-08	730	42154	5082	2650
CB	BB70	PAH	Benzo(k)fluoranthene	19	1	1994-01	2001-08	0	17386	1867	976
CB	BB70	PAH	Chrysene	19		1994-01	2001-08	350	25501	2567	1100
CB	BB70	PAH	Dibenz(a,h)anthracene	19	5	1994-01	2001-08	0	1313	371	340
CB	BB70	PAH	Fluoranthene	18		1994-01	2001-08	950	50964	6861	4095
CB	BB70	PAH	Fluorene	12		1996-02	2001-08	210	5500	1094	531
CB	BB70	PAH	Indeno(1,2,3-cd)pyrene	19	2	1994-01	2001-08	0	13025	2821	2100
CB	BB70	PAH	Pyrene	15		1994-01	2000-07	610	42409	7299	3540
CB	BB70	PAH	Total PAHs (SFEI)	17		1994-01	2001-08	5946	258691	39280	21576
CB	BB70	PCB	Total PCBs (SFEI)	19		1994-01	2001-08	130	1367	512	409
CB	BB70	PEST	alpha-HCH	18		1994-01	2001-08	22	494	218	185
CB	BB70	PEST	beta-HCH	19		1994-01	2001-08	29	428	169	137
CB	BB70	PEST	Chlorpyrifos	16		1994-01	2001-08	2	326	106	69
CB	BB70	PEST	Diazinon	17		1994-04	2001-08	52	9537	2753	1700
CB	BB70	PEST	Dieldrin	19	4	1994-01	2001-08	0	178	48	34
CB	BB70	PEST	Endrin	17	10	1994-08	2001-08	0	140	14	0
CB	BB70	PEST	gamma-HCH	20	1	1994-01	2001-08	0	727	200	156
CB	BB70	PEST	Heptachlor	19	11	1994-04	2001-08	0	14	3	0

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
CB	BB70	PEST	Heptachlor Epoxide	19	2	1994-01	2001-08	0	136	28	12
CB	BB70	PEST	Mirex	18	17	1994-04	2001-08	0	3	0	0
CB	BB70	PEST	p,p'-DDD	17		1994-01	2001-08	56	177	101	96
CB	BB70	PEST	p,p'-DDE	18		1994-01	2001-08	27	212	86	76
CB	BB70	PEST	p,p'-DDT	19	4	1994-01	2001-08	0	85	24	22
CB	BB70	PEST	Total Chlordanes (SFEI)	17		1994-01	2001-08	43	298	108	81
CB	BB70	PEST	Total DDTs (SFEI)	17		1994-01	2001-08	117	419	225	200
CB	BB70	TE	Ag	31	1	1994-01	2001-08	0	0.021	0.008	0.006
CB	BB70	TE	As	22		1994-01	2001-08	1.4	2.9	1.9	1.8
CB	BB70	TE	Cd	34		1994-01	2001-08	0.02	0.2	0.08	0.07
CB	BB70	TE	Cr	30		1994-01	1999-07	0.1	9	1.5	0.6
CB	BB70	TE	Cu	40		1994-01	2001-08	1	3.3	2	1.9
CB	BB70	TE	Hg	26		1994-01	2001-08	0.001	0.016	0.005	0.004
CB	BB70	TE	Ni	39		1994-01	2001-08	1	5.8	2.5	2.2
CB	BB70	TE	Pb	36		1994-01	2001-08	0.01	1.3	0.3	0.3
CB	BB70	TE	Se	22	3	1994-01	2001-08	0	0.8	0.2	0.1
CB	BB70	TE	Zn	35		1994-01	2001-08	0.2	7	2	1
CB	BC10	PAH	Acenaphthene	12	2	1996-02	2001-08	0	1500	773	825
CB	BC10	PAH	Anthracene	17	9	1993-03	2001-08	0	498	97	0
CB	BC10	PAH	Benz(a)anthracene	16		1993-03	2001-08	63	5315	1328	1160
CB	BC10	PAH	Benzo(a)pyrene	19	14	1993-03	2001-08	0	287	21	0
CB	BC10	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	800	4590	2000	1828
CB	BC10	PAH	Benzo(k)fluoranthene	20	1	1993-03	2001-08	0	1508	708	604
CB	BC10	PAH	Chrysene	20		1993-03	2001-08	410	2402	984	893
CB	BC10	PAH	Dibenz(a,h)anthracene	20	5	1993-03	2001-08	0	640	209	175
CB	BC10	PAH	Fluoranthene	19		1993-03	2001-08	2520	10855	4971	4033
CB	BC10	PAH	Fluorene	12		1996-02	2001-08	240	2078	1129	1100
CB	BC10	PAH	Indeno(1,2,3-cd)pyrene	20	2	1993-03	2001-08	0	3981	1350	785
CB	BC10	PAH	Pyrene	19		1993-03	2001-08	838	19380	3920	3290
CB	BC10	PAH	Total PAHs (SFEI)	18		1993-03	2001-08	8993	51449	21682	19443
CB	BC10	PCB	Total PCBs (SFEI)	19		1993-03	2001-08	203	1462	447	332
CB	BC10	PEST	alpha-HCH	19		1993-03	2001-08	81	496	242	223
CB	BC10	PEST	beta-HCH	19		1993-03	2001-08	16	413	148	130
CB	BC10	PEST	Chlorpyrifos	16	1	1993-03	2001-08	0	2185	301	136
CB	BC10	PEST	Diazinon	17	1	1994-04	2001-08	0	13000	2907	1700
CB	BC10	PEST	Dieldrin	20	3	1993-03	2001-08	0	264	65	46
CB	BC10	PEST	Endrin	16	9	1994-08	2001-08	0	40	7	0
CB	BC10	PEST	gamma-HCH	19	1	1993-03	2001-08	0	703	193	153
CB	BC10	PEST	Heptachlor	17	11	1994-04	2001-08	0	19	3	0
CB	BC10	PEST	Heptachlor Epoxide	17	2	1994-01	2001-08	0	94	23	16
CB	BC10	PEST	Mirex	17	17	1994-04	2001-08	0	0	0	0
CB	BC10	PEST	p,p'-DDD	17		1993-03	2001-08	12	313	118	95
CB	BC10	PEST	p,p'-DDE	19		1993-03	2001-08	32	693	112	76
CB	BC10	PEST	p,p'-DDT	18	4	1993-03	2001-08	0	167	31	26
CB	BC10	PEST	Total Chlordanes (SFEI)	18		1993-03	2001-08	38	180	101	102
CB	BC10	PEST	Total DDTs (SFEI)	17		1993-03	2001-08	106	546	251	221
CB	BC10	TE	Ag	33		1993-03	2001-08	0.001	0.052	0.007	0.005
CB	BC10	TE	As	25		1993-03	2001-08	1.1	2.5	1.9	1.9
CB	BC10	TE	Cd	39		1993-03	2001-08	0.02	0.16	0.07	0.07
CB	BC10	TE	Cr	33		1993-03	1999-07	0.1	4.4	1.1	0.8
CB	BC10	TE	Cu	40		1993-03	2001-08	0.7	2.5	1.6	1.6
CB	BC10	TE	Hg	27		1993-03	2001-08	0	0.009	0.004	0.004
CB	BC10	TE	Ni	38		1993-03	2001-08	1	3.7	2	2
CB	BC10	TE	Pb	38		1993-03	2001-08	0.01	0.8	0.3	0.3
CB	BC10	TE	Se	25	1	1993-03	2001-08	0	0.4	0.1	0.1
CB	BC10	TE	Zn	39		1993-03	2001-08	0.3	5	2	2
CB	BC30	TE	Ag	35		1993-03	2001-08	0	0.068	0.006	0.005
CB	BC30	TE	As	25		1993-03	2001-08	1.3	2.1	1.8	1.7
CB	BC30	TE	Cd	39		1993-03	2001-08	0.02	0.15	0.06	0.06
CB	BC30	TE	Cr	33		1993-03	1999-07	0.1	3.3	0.8	0.8
CB	BC30	TE	Cu	39		1993-03	2001-08	0.7	2.4	1.5	1.5
CB	BC30	TE	Hg	27		1993-03	2001-08	0.001	0.006	0.003	0.003
CB	BC30	TE	Ni	37		1993-03	2001-08	0.9	2.8	1.7	1.7

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
CB	BC30	TE	Pb	38		1993-03	2001-08	0.01	0.6	0.2	0.2
CB	BC30	TE	Se	25	1	1993-03	2001-08	0	0.4	0.1	0.1
CB	BC30	TE	Zn	37		1993-03	2001-08	0.4	5	2	2
CB	BC41	TE	Ag	33		1993-03	2001-08	0.001	0.072	0.009	0.006
CB	BC41	TE	As	25		1993-03	2001-08	1.2	2.7	2	2
CB	BC41	TE	Cd	37		1993-03	2001-08	0.02	0.15	0.06	0.06
CB	BC41	TE	Cr	34		1993-03	1999-07	0.1	9.4	1.6	0.9
CB	BC41	TE	Cu	40		1993-03	2001-08	0.9	4.2	1.8	1.6
CB	BC41	TE	Hg	29		1993-03	2001-08	0.001	0.021	0.006	0.004
CB	BC41	TE	Ni	38		1993-03	2001-08	1	7.3	2.4	2.1
CB	BC41	TE	Pb	39		1993-03	2001-08	0	1.9	0.4	0.3
CB	BC41	TE	Se	24		1993-03	2001-08	0	0.3	0.1	0.1
CB	BC41	TE	Zn	38		1993-03	2001-08	0.2	9	2	2
CB	BC60	PAH	Acenaphthene	14	6	1996-02	2001-08	0	1400	339	255
CB	BC60	PAH	Anthracene	17	13	1994-01	2001-08	0	530	50	0
CB	BC60	PAH	Benz(a)anthracene	18	1	1994-01	2001-08	0	2700	774	514
CB	BC60	PAH	Benzo(a)pyrene	19	14	1994-01	2001-08	0	390	23	0
CB	BC60	PAH	Benzo(b)fluoranthene	20		1994-01	2001-08	750	6650	1893	1600
CB	BC60	PAH	Benzo(k)fluoranthene	20		1994-01	2001-08	231	2200	695	580
CB	BC60	PAH	Chrysene	20		1994-01	2001-08	323	2700	868	729
CB	BC60	PAH	Dibenz(a,h)anthracene	20	4	1994-01	2001-08	0	480	164	135
CB	BC60	PAH	Fluoranthene	19		1994-01	2001-08	1260	29800	4259	2700
CB	BC60	PAH	Fluorene	13	2	1996-02	2001-08	0	1490	623	490
CB	BC60	PAH	Indeno(1,2,3-cd)pyrene	20	3	1994-01	2001-08	0	4800	1125	789
CB	BC60	PAH	Pyrene	16		1994-01	1999-07	236	7930	2054	1793
CB	BC60	PAH	Total PAHs (SFEI)	18		1994-01	2001-08	5528	49900	14857	12770
CB	BC60	PCB	Total PCBs (SFEI)	18		1994-01	2001-08	143	2451	401	254
CB	BC60	PEST	alpha-HCH	19		1994-01	2001-08	13	566	191	164
CB	BC60	PEST	beta-HCH	19		1994-01	2001-08	31	290	125	121
CB	BC60	PEST	Chlorpyrifos	18		1994-01	2001-08	3	231	69	39
CB	BC60	PEST	Diazinon	19	1	1994-04	2001-08	0	32000	3493	1500
CB	BC60	PEST	Dieldrin	20	3	1994-01	2001-08	0	202	47	28
CB	BC60	PEST	Endrin	17	11	1994-08	2001-08	0	75	11	0
CB	BC60	PEST	gamma-HCH	19	1	1994-01	2001-08	0	562	134	101
CB	BC60	PEST	Heptachlor	16	13	1994-04	2001-08	0	21	2	0
CB	BC60	PEST	Heptachlor Epoxide	19	2	1994-01	2001-08	0	127	23	10
CB	BC60	PEST	Mirex	18	18	1994-04	2001-08	0	0	0	0
CB	BC60	PEST	p,p'-DDD	16		1994-01	2001-08	38	254	106	86
CB	BC60	PEST	p,p'-DDE	19		1994-01	2001-08	27	314	111	91
CB	BC60	PEST	p,p'-DDT	16	4	1994-04	1999-07	0	174	28	16
CB	BC60	PEST	Total Chlordanes (SFEI)	17		1994-01	2000-07	41	357	98	73
CB	BC60	PEST	Total DDTs (SFEI)	16		1994-01	2001-08	76	754	253	225
CB	BC60	TE	Ag	30	1	1994-01	2001-08	0	0.015	0.005	0.005
CB	BC60	TE	As	22		1994-01	2001-08	0.9	2.6	1.8	1.8
CB	BC60	TE	Cd	36		1994-01	2001-08	0.02	0.13	0.06	0.06
CB	BC60	TE	Cr	29		1994-01	1999-07	0.1	5.2	1.5	0.7
CB	BC60	TE	Cu	39		1994-01	2001-08	0.6	3.6	1.7	1.5
CB	BC60	TE	Hg	24		1994-01	2001-08	0.001	0.012	0.006	0.005
CB	BC60	TE	Ni	37		1994-01	2001-08	0.8	5	2.4	1.9
CB	BC60	TE	Pb	36		1994-01	2001-08	0	1.1	0.3	0.2
CB	BC60	TE	Se	22	1	1994-01	2001-08	0	0.4	0.1	0.1
CB	BC60	TE	Zn	34		1994-01	2001-08	0.3	8	2	2
REF	BC20	PAH	Acenaphthene	13	3	1996-02	2002-07	0	870	302	304
REF	BC20	PAH	Anthracene	19	16	1993-03	2002-07	0	770	48	0
REF	BC20	PAH	Benz(a)anthracene	17	4	1993-03	2002-07	0	1600	266	76
REF	BC20	PAH	Benzo(a)pyrene	21	16	1993-03	2002-07	0	278	29	0
REF	BC20	PAH	Benzo(b)fluoranthene	21	1	1993-03	2002-07	0	1740	501	390
REF	BC20	PAH	Benzo(k)fluoranthene	21	4	1993-03	2002-07	0	730	178	130
REF	BC20	PAH	Chrysene	21	3	1993-03	2002-07	0	940	273	230
REF	BC20	PAH	Dibenz(a,h)anthracene	21	14	1993-03	2002-07	0	1050	72	0
REF	BC20	PAH	Fluoranthene	21		1993-03	2002-07	380	4560	1462	1160
REF	BC20	PAH	Fluorene	13	1	1996-02	2002-07	0	1850	493	415
REF	BC20	PAH	Indeno(1,2,3-cd)pyrene	21	10	1993-03	2002-07	0	1130	202	28

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
REF	BC20	PAH	Pyrene	16		1993-03	2002-07	28	2260	554	288
REF	BC20	PAH	Total PAHs (SFEI)	19		1993-03	2002-07	940	21279	6161	4729
REF	BC20	PCB	Total PCBs (SFEI)	19		1993-03	2002-07	37	2907	305	128
REF	BC20	PEST	alpha-HCH	18		1993-03	2002-07	62	601	319	302
REF	BC20	PEST	beta-HCH	18		1994-01	2002-07	23	352	182	172
REF	BC20	PEST	Chlorpyrifos	16	5	1993-03	2002-07	0	440	59	22
REF	BC20	PEST	Diazinon	18	6	1994-04	2002-07	0	5800	919	255
REF	BC20	PEST	Dieldrin	20	4	1993-03	2002-07	0	61	18	13
REF	BC20	PEST	Endrin	16	8	1995-02	2002-07	0	52	6	3
REF	BC20	PEST	gamma-HCH	19	1	1993-03	2002-07	0	280	117	105
REF	BC20	PEST	Heptachlor	15	8	1994-04	2000-07	0	33	5	0
REF	BC20	PEST	Heptachlor Epoxide	20	4	1994-01	2002-07	0	140	19	7
REF	BC20	PEST	Mirex	19	19	1994-04	2002-07	0	0	0	0
REF	BC20	PEST	p,p'-DDD	17		1993-03	2002-07	7	102	39	35
REF	BC20	PEST	p,p'-DDE	20		1993-03	2002-07	6	63	30	24
REF	BC20	PEST	p,p'-DDT	19	2	1993-03	2002-07	0	350	35	12
REF	BC20	PEST	Total Chlordanes (SFEI)	17		1993-03	2002-07	4	185	59	58
REF	BC20	PEST	Total DDTs (SFEI)	17		1993-03	2002-07	16	252	101	79
REF	BC20	TE	Ag	36	1	1993-03	2002-07	0	0.037	0.003	0.002
REF	BC20	TE	As	23		1993-03	2002-07	1.3	2.4	1.6	1.6
REF	BC20	TE	Cd	43		1993-03	2002-07	0.02	0.12	0.06	0.06
REF	BC20	TE	Cr	35	4	1993-03	1999-07	0	1.2	0.3	0.2
REF	BC20	TE	Cu	44		1993-03	2002-07	0.2	1.3	0.5	0.5
REF	BC20	TE	Hg	23	1	1993-03	2002-07	0	0.02	0.002	0.001
REF	BC20	TE	Ni	41		1993-03	2002-07	0.3	1.6	0.8	0.7
REF	BC20	TE	Pb	40		1993-03	2002-07	0	0.2	0.1	0
REF	BC20	TE	Se	21	2	1993-03	2002-07	0	0.3	0.1	0.1
REF	BC20	TE	Zn	42		1993-03	2002-07	0.1	2	1	0
SB	BA30	PAH	Acenaphthene	13	2	1996-02	2001-08	0	2640	659	560
SB	BA30	PAH	Anthracene	19	2	1993-03	2001-08	0	2300	491	250
SB	BA30	PAH	Benz(a)anthracene	16		1993-03	2001-08	467	11250	3826	2858
SB	BA30	PAH	Benzo(a)pyrene	20	11	1993-03	2001-08	0	45000	2695	0
SB	BA30	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	1727	57200	11068	8370
SB	BA30	PAH	Benzo(k)fluoranthene	20		1993-03	2001-08	553	21048	3903	2630
SB	BA30	PAH	Chrysene	20		1993-03	2001-08	1600	22062	4429	3135
SB	BA30	PAH	Dibenz(a,h)anthracene	21	1	1993-03	2001-08	0	8800	1354	730
SB	BA30	PAH	Fluoranthene	19		1993-03	2001-08	2180	38960	8886	7400
SB	BA30	PAH	Fluorene	12	1	1996-02	2001-08	0	5450	1368	1115
SB	BA30	PAH	Indeno(1,2,3-cd)pyrene	21		1993-03	2001-08	1398	78000	11025	7230
SB	BA30	PAH	Pyrene	19		1993-03	2001-08	1200	56031	10782	9230
SB	BA30	PAH	Total PAHs (SFEI)	18		1993-03	2001-08	16357	384331	77527	52731
SB	BA30	PCB	Total PCBs (SFEI)	20		1993-03	2001-08	370	4046	1125	831
SB	BA30	PEST	alpha-HCH	17		1993-03	2001-08	40	662	280	190
SB	BA30	PEST	beta-HCH	17		1994-01	2001-08	11	607	187	152
SB	BA30	PEST	Chlorpyrifos	17	1	1993-03	2001-08	0	1005	198	102
SB	BA30	PEST	Diazinon	17		1994-01	2001-08	610	18469	6227	5600
SB	BA30	PEST	Dieldrin	19	2	1993-03	2001-08	0	292	82	73
SB	BA30	PEST	Endrin	16	8	1994-08	2001-08	0	120	25	2
SB	BA30	PEST	gamma-HCH	19	1	1993-03	2001-08	0	1667	516	385
SB	BA30	PEST	Heptachlor	16	9	1994-04	2001-08	0	22	3	0
SB	BA30	PEST	Heptachlor Epoxide	17	2	1994-01	2001-08	0	174	46	31
SB	BA30	PEST	Mirex	18	15	1994-04	2001-08	0	2	0	0
SB	BA30	PEST	p,p'-DDD	18		1993-03	2001-08	4	770	185	141
SB	BA30	PEST	p,p'-DDE	19		1993-03	2001-08	67	678	199	168
SB	BA30	PEST	p,p'-DDT	16	2	1993-03	1999-07	0	202	62	43
SB	BA30	PEST	Total Chlordanes (SFEI)	18		1993-03	2001-08	79	574	245	213
SB	BA30	PEST	Total DDTs (SFEI)	18		1993-03	2001-08	109	1850	492	400
SB	BA30	TE	Ag	33		1993-03	2001-08	0.001	0.119	0.018	0.012
SB	BA30	TE	As	25		1993-03	2001-08	1.7	4.9	3.1	2.8
SB	BA30	TE	Cd	37		1993-03	2001-08	0.05	0.22	0.09	0.09
SB	BA30	TE	Cr	34		1993-03	1999-07	0.1	14.7	3.5	2.3
SB	BA30	TE	Cu	39		1993-03	2001-08	1.9	8.6	3.9	3.6
SB	BA30	TE	Hg	28		1993-03	2001-08	0.005	0.068	0.016	0.01

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SB	BA30	TE	Ni	37		1993-03	2001-08	2.3	15.8	5.2	4.4
SB	BA30	TE	Pb	38		1993-03	2001-08	0.02	4.2	0.9	0.6
SB	BA30	TE	Se	25		1993-03	2001-08	0.1	0.6	0.3	0.3
SB	BA30	TE	Zn	40		1993-03	2001-08	0.6	21	5	5
SB	BA40	PAH	Acenaphthene	12	5	1996-02	2001-08	0	840	262	230
SB	BA40	PAH	Anthracene	16	6	1993-03	2001-08	0	1730	293	109
SB	BA40	PAH	Benz(a)anthracene	16		1993-03	2001-08	307	22460	3592	2384
SB	BA40	PAH	Benzo(a)pyrene	19	12	1993-03	2001-08	0	4400	322	0
SB	BA40	PAH	Benzo(b)fluoranthene	20		1993-03	2001-08	3000	20000	7299	4919
SB	BA40	PAH	Benzo(k)fluoranthene	20		1993-03	2001-08	940	6000	2496	1622
SB	BA40	PAH	Chrysene	20		1993-03	2001-08	990	8700	3010	2280
SB	BA40	PAH	Dibenz(a,h)anthracene	20	3	1993-03	2001-08	0	1760	754	635
SB	BA40	PAH	Fluoranthene	19		1993-03	2001-08	3070	18600	7143	5364
SB	BA40	PAH	Fluorene	12	3	1996-02	2001-08	0	1120	557	685
SB	BA40	PAH	Indeno(1,2,3-cd)pyrene	20		1993-03	2001-08	1800	17000	6790	5150
SB	BA40	PAH	Pyrene	19		1993-03	2001-08	3189	28000	8328	5513
SB	BA40	PAH	Total PAHs (SFEI)	18		1993-03	2001-08	20020	140030	47003	38323
SB	BA40	PCB	Total PCBs (SFEI)	20		1993-03	2001-08	255	3069	871	630
SB	BA40	PEST	alpha-HCH	18		1993-03	2001-08	35	502	204	160
SB	BA40	PEST	beta-HCH	19		1993-03	2001-08	9	605	150	100
SB	BA40	PEST	Chlorpyrifos	18	1	1993-03	2001-08	0	458	128	93
SB	BA40	PEST	Diazinon	17	2	1994-04	2001-08	0	7133	3095	3400
SB	BA40	PEST	Dieldrin	19	2	1993-03	2001-08	0	169	65	41
SB	BA40	PEST	Endrin	17	12	1994-08	2001-08	0	81	12	0
SB	BA40	PEST	gamma-HCH	19	1	1993-03	2001-08	0	1000	322	224
SB	BA40	PEST	Heptachlor	15	11	1994-04	2001-08	0	5	1	0
SB	BA40	PEST	Heptachlor Epoxide	17	1	1994-04	2001-08	0	293	46	31
SB	BA40	PEST	Mirex	18	13	1994-04	2001-08	0	3	0	0
SB	BA40	PEST	p,p'-DDD	17		1993-03	2001-08	17	510	144	128
SB	BA40	PEST	p,p'-DDE	19		1993-03	2001-08	33	343	127	101
SB	BA40	PEST	p,p'-DDT	18	4	1993-03	2000-07	0	116	27	13
SB	BA40	PEST	Total Chlordanes (SFEI)	18		1993-03	2001-08	32	722	192	170
SB	BA40	PEST	Total DDTs (SFEI)	17		1993-03	2001-08	68	1043	333	268
SB	BA40	TE	Ag	33		1993-03	2001-08	0.001	0.081	0.015	0.012
SB	BA40	TE	As	25		1993-03	2001-08	1.4	4.4	2.6	2.4
SB	BA40	TE	Cd	41		1993-03	2001-08	0.02	0.18	0.08	0.08
SB	BA40	TE	Cr	34		1993-03	1999-07	0.1	8.7	2	1.2
SB	BA40	TE	Cu	39		1993-03	2001-08	1.4	8.6	2.9	2.7
SB	BA40	TE	Hg	28		1993-03	2001-08	0.001	0.025	0.008	0.006
SB	BA40	TE	Ni	37		1993-03	2001-08	1.8	15.5	4	3.1
SB	BA40	TE	Pb	39		1993-03	2001-08	0.02	4.6	0.6	0.4
SB	BA40	TE	Se	25	1	1993-03	2001-08	0	0.3	0.2	0.2
SB	BA40	TE	Zn	39		1993-03	2001-08	0.4	21	4	2
LSB	BA10	PAH	Acenaphthene	11	3	1996-02	2001-08	0	3650	779	370
LSB	BA10	PAH	Anthracene	16		1994-01	2001-08	52	2400	849	584
LSB	BA10	PAH	Benz(a)anthracene	15		1994-01	2001-08	1300	35450	9638	4273
LSB	BA10	PAH	Benzo(a)pyrene	17	4	1994-01	2001-08	0	54000	8077	3000
LSB	BA10	PAH	Benzo(b)fluoranthene	17		1994-01	2001-08	5535	66740	18370	10190
LSB	BA10	PAH	Benzo(k)fluoranthene	17		1994-01	2001-08	1755	25220	6129	3993
LSB	BA10	PAH	Chrysene	17		1994-01	2001-08	2520	22270	7140	4949
LSB	BA10	PAH	Dibenz(a,h)anthracene	17		1994-01	2001-08	520	11130	2106	1100
LSB	BA10	PAH	Fluoranthene	15		1994-01	2001-08	5500	40400	13493	8840
LSB	BA10	PAH	Fluorene	11	1	1996-02	2001-08	0	7400	1820	1240
LSB	BA10	PAH	Indeno(1,2,3-cd)pyrene	17		1994-01	2001-08	5843	95950	16594	9403
LSB	BA10	PAH	Pyrene	14		1994-01	2001-08	7900	57190	18906	14239
LSB	BA10	PAH	Total PAHs (SFEI)	16		1994-01	2001-08	55380	452477	128934	82317
LSB	BA10	PCB	Total PCBs (SFEI)	17		1994-01	2001-08	625	8707	2560	1573
LSB	BA10	PEST	alpha-HCH	14		1994-01	2001-08	80	591	206	183
LSB	BA10	PEST	beta-HCH	15	1	1994-01	2001-08	0	351	171	172
LSB	BA10	PEST	Chlorpyrifos	13	1	1994-01	2001-08	0	2054	349	191
LSB	BA10	PEST	Diazinon	17	1	1994-01	2001-08	0	98002	11067	6910
LSB	BA10	PEST	Dieldrin	18	4	1994-01	2001-08	0	225	78	86
LSB	BA10	PEST	Endrin	16	8	1994-08	2001-08	0	127	16	4

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
LSB	BA10	PEST	gamma-HCH	16		1994-01	2001-08	2	6601	968	514
LSB	BA10	PEST	Heptachlor	13	6	1994-04	2001-08	0	18	6	3
LSB	BA10	PEST	Heptachlor Epoxide	17		1994-01	2001-08	12	232	79	55
LSB	BA10	PEST	Mirex	16	9	1994-04	2001-08	0	9	2	0
LSB	BA10	PEST	p,p'-DDD	15		1994-01	2000-07	17	1370	376	258
LSB	BA10	PEST	p,p'-DDE	16		1994-01	2001-08	149	1597	618	377
LSB	BA10	PEST	p,p'-DDT	15		1994-01	1999-07	26	239	91	53
LSB	BA10	PEST	Total Chlordanes (SFEI)	17		1994-01	2001-08	163	1235	431	286
LSB	BA10	PEST	Total DDTs (SFEI)	15		1994-01	2000-07	223	3285	1222	948
LSB	BA10	TE	Ag	29		1994-01	2001-08	0.001	0.066	0.02	0.016
LSB	BA10	TE	As	22		1994-01	2001-08	1.8	5.9	3.5	3.1
LSB	BA10	TE	Cd	34		1994-01	2001-08	0.03	0.17	0.1	0.1
LSB	BA10	TE	Cr	30		1994-01	1999-07	0.1	31.5	6.4	5.1
LSB	BA10	TE	Cu	37		1994-01	2001-08	1.6	11.8	4.9	4.3
LSB	BA10	TE	Hg	24		1994-01	2001-08	0.003	0.105	0.022	0.016
LSB	BA10	TE	Ni	35		1994-01	2001-08	2.1	22.3	7.9	7.2
LSB	BA10	TE	Pb	35		1994-01	2001-08	0.03	7.7	1.4	1.2
LSB	BA10	TE	Se	22	1	1994-01	2001-08	0	1.2	0.4	0.4
LSB	BA10	TE	Zn	35		1994-01	2001-08	1.2	32	9	7
LSB	BA20	TE	Ag	32		1993-03	2001-08	0.001	0.142	0.02	0.015
LSB	BA20	TE	As	25		1993-03	2001-08	2	5.3	3.3	3.3
LSB	BA20	TE	Cd	37		1993-03	2001-08	0.04	0.2	0.1	0.1
LSB	BA20	TE	Cr	35		1993-03	1999-07	0.1	20.1	4.3	3.7
LSB	BA20	TE	Cu	39		1993-03	2001-08	1.8	8.6	4.3	4.2
LSB	BA20	TE	Hg	28		1993-03	2001-08	0.005	0.048	0.017	0.013
LSB	BA20	TE	Ni	37		1993-03	2001-08	2.4	17	6.1	5.2
LSB	BA20	TE	Pb	42		1993-03	2001-08	0.02	3.2	1	1
LSB	BA20	TE	Se	25		1993-03	2001-08	0	0.6	0.3	0.3
LSB	BA20	TE	Zn	43		1993-03	2001-08	0.7	18	7	6
SS	C-1-3	PAH	Acenaphthene	1		2002-07	2002-07	1970	1970	1970	1970
SS	C-1-3	PAH	Anthracene	1		2002-07	2002-07	2464	2464	2464	2464
SS	C-1-3	PAH	Benz(a)anthracene	1		2002-07	2002-07	11306	11306	11306	11306
SS	C-1-3	PAH	Benzo(a)pyrene	1		2002-07	2002-07	29369	29369	29369	29369
SS	C-1-3	PAH	Benzo(b)fluoranthene	1		2002-07	2002-07	25466	25466	25466	25466
SS	C-1-3	PAH	Benzo(k)fluoranthene	1		2002-07	2002-07	16973	16973	16973	16973
SS	C-1-3	PAH	Chrysene	1		2002-07	2002-07	18238	18238	18238	18238
SS	C-1-3	PAH	Dibenz(a,h)anthracene	1		2002-07	2002-07	2415	2415	2415	2415
SS	C-1-3	PAH	Fluoranthene	1		2002-07	2002-07	43340	43340	43340	43340
SS	C-1-3	PAH	Fluorene	1		2002-07	2002-07	3122	3122	3122	3122
SS	C-1-3	PAH	Indeno(1,2,3-cd)pyrene	1		2002-07	2002-07	22983	22983	22983	22983
SS	C-1-3	PAH	Pyrene	1		2002-07	2002-07	57540	57540	57540	57540
SS	C-1-3	PAH	Total PAHs (SFEI)	1		2002-07	2002-07	388665	388665	388665	388665
SS	C-1-3	PCB	Total PCBs (SFEI)	1		2002-07	2002-07	2635	2635	2635	2635
SS	C-1-3	PEST	alpha-HCH	1		2002-07	2002-07	57	57	57	57
SS	C-1-3	PEST	beta-HCH	1		2002-07	2002-07	220	220	220	220
SS	C-1-3	PEST	Chlorpyrifos	1	1	2002-07	2002-07	157	157	157	157
SS	C-1-3	PEST	Diazinon	1		2002-07	2002-07	2967	2967	2967	2967
SS	C-1-3	PEST	Dieldrin	1		2002-07	2002-07	100	100	100	100
SS	C-1-3	PEST	Endrin	1	1	2002-07	2002-07	8	8	8	8
SS	C-1-3	PEST	gamma-HCH	1		2002-07	2002-07	283	283	283	283
SS	C-1-3	PEST	Heptachlor	1	1	2002-07	2002-07	1	1	1	1
SS	C-1-3	PEST	Heptachlor Epoxide	1		2002-07	2002-07	15	15	15	15
SS	C-1-3	PEST	Mirex	1	1	2002-07	2002-07	1	1	1	1
SS	C-1-3	PEST	p,p'-DDD	1		2002-07	2002-07	547	547	547	547
SS	C-1-3	PEST	p,p'-DDE	1		2002-07	2002-07	486	486	486	486
SS	C-1-3	PEST	p,p'-DDT	1		2002-07	2002-07	26	26	26	26
SS	C-1-3	PEST	Total Chlordanes (SFEI)	1		2002-07	2002-07	337	337	337	337
SS	C-1-3	PEST	Total DDTs (SFEI)	1		2002-07	2002-07	1233	1233	1233	1233
SS	C-1-3	TE	Ag	31		1994-01	2002-07	0.001	0.231	0.059	0.034
SS	C-1-3	TE	As	23		1994-01	2002-07	1	8.2	4.6	4.4
SS	C-1-3	TE	Cd	35		1994-01	2002-07	0.01	0.16	0.07	0.06
SS	C-1-3	TE	Cr	35		1994-01	1999-07	0	72.8	20.6	9.5
SS	C-1-3	TE	Cu	41		1994-01	2002-07	1.4	31.8	8.8	5.6

Region	SITE CODE	PARAM TYPE	PARAMETER	Total Samples	Count NDs	First Sampled (yyyy-mm)	Last Sampled (yyyy-mm)	MIN	MAX	AVG	MEDIAN
SS	C-1-3	TE	Hg	26		1994-01	2002-07	0.007	0.157	0.046	0.028
SS	C-1-3	TE	Ni	38		1994-01	2002-07	1.6	82	17.9	10
SS	C-1-3	TE	Pb	46		1994-01	2002-07	0.03	14.8	4.8	3
SS	C-1-3	TE	Se	23		1994-01	2002-07	0.4	2.4	1.1	1
SS	C-1-3	TE	Zn	39		1994-01	2002-07	2.5	78	25	17
SS	C-3-0	PAH	Acenaphthene	13	2	1996-02	2002-07	0	3300	1273	1100
SS	C-3-0	PAH	Anthracene	15		1996-02	2002-07	320	4625	1986	1300
SS	C-3-0	PAH	Benz(a)anthracene	13		1996-02	2002-07	1910	100480	17510	11059
SS	C-3-0	PAH	Benzo(a)pyrene	15	2	1996-02	2002-07	0	28000	10399	6600
SS	C-3-0	PAH	Benzo(b)fluoranthene	15		1996-02	2002-07	6030	170350	29368	17420
SS	C-3-0	PAH	Benzo(k)fluoranthene	15		1996-02	2002-07	1930	37220	9657	6300
SS	C-3-0	PAH	Chrysene	15		1996-02	2002-07	2400	37460	10061	7180
SS	C-3-0	PAH	Dibenz(a,h)anthracene	15		1996-02	2002-07	550	16021	2866	1800
SS	C-3-0	PAH	Fluoranthene	15		1996-02	2002-07	5900	37825	19210	17700
SS	C-3-0	PAH	Fluorene	14		1996-02	2002-07	1020	5200	2622	2126
SS	C-3-0	PAH	Indeno(1,2,3-cd)pyrene	15		1996-02	2002-07	4200	95079	19982	12412
SS	C-3-0	PAH	Pyrene	14		1996-02	2002-07	7300	94200	27221	21326
SS	C-3-0	PAH	Total PAHs (SFEI)	13		1996-02	2002-07	54350	847025	211816	144487
SS	C-3-0	PCB	Total PCBs (SFEI)	11		1996-02	2002-07	1476	10373	3607	2588
SS	C-3-0	PEST	alpha-HCH	13		1996-02	2002-07	37	578	200	182
SS	C-3-0	PEST	beta-HCH	14		1996-02	2002-07	33	840	327	188
SS	C-3-0	PEST	Chlorpyrifos	13	1	1996-02	2002-07	0	11270	1718	701
SS	C-3-0	PEST	Diazinon	13		1996-02	2002-07	6500	36150	15859	14230
SS	C-3-0	PEST	Dieldrin	15	1	1996-02	2002-07	0	340	131	121
SS	C-3-0	PEST	Endrin	15	8	1996-02	2002-07	0	224	44	3
SS	C-3-0	PEST	gamma-HCH	15		1996-02	2002-07	66	4664	1791	1722
SS	C-3-0	PEST	Heptachlor	15	8	1996-02	2002-07	0	21	6	1
SS	C-3-0	PEST	Heptachlor Epoxide	15		1996-02	2002-07	8	390	107	78
SS	C-3-0	PEST	Mirex	14	3	1996-02	2002-07	0	13	4	3
SS	C-3-0	PEST	p,p'-DDD	13		1996-02	2002-07	130	2390	718	633
SS	C-3-0	PEST	p,p'-DDE	13		1996-02	2002-07	320	2110	1098	980
SS	C-3-0	PEST	p,p'-DDT	13		1996-02	2002-07	12	640	155	76
SS	C-3-0	PEST	Total Chlordanes (SFEI)	15		1996-02	2002-07	284	1429	685	635
SS	C-3-0	PEST	Total DDTs (SFEI)	12		1996-02	2002-07	644	3896	2165	1489
SS	C-3-0	TE	Ag	30		1994-01	2002-07	0.001	0.168	0.057	0.039
SS	C-3-0	TE	As	23		1994-01	2002-07	1.7	9.4	4.2	3.6
SS	C-3-0	TE	Cd	35		1994-01	2002-07	0.03	0.18	0.09	0.08
SS	C-3-0	TE	Cr	29		1994-01	1999-07	0.1	65	18.9	8.4
SS	C-3-0	TE	Cu	39		1994-01	2002-07	1.6	17.5	7.4	5.9
SS	C-3-0	TE	Hg	24		1994-01	2002-07	0.005	0.212	0.063	0.058
SS	C-3-0	TE	Ni	36		1994-01	2002-07	2.8	48.5	16.2	11.1
SS	C-3-0	TE	Pb	37		1994-01	2002-07	0.07	11.8	3.6	1.9
SS	C-3-0	TE	Se	23		1994-01	2002-07	0.4	1.5	1	1
SS	C-3-0	TE	Zn	37		1994-01	2002-07	4	99	29	27