REGIONAL MONITORING PROGRAM FOR TRACE SUBSTANCES

STATUS & TRENDS PROGRAM

Using a Spatially Balanced, Random Sampling Design to Assist Informed Management Decisions

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The RMP and How We Implement Adaptive Management into the Status & Trends Program

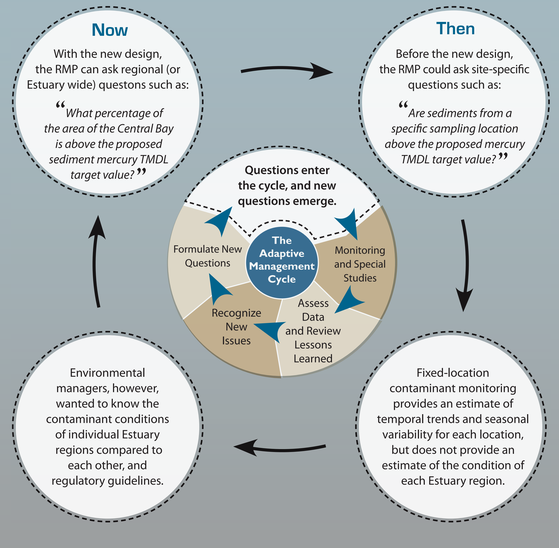
Introduction The San Francisco Estuary Regional Monitoring Program for Trace Substances (RMP) is a long-term monitoring program, started in 1993, which strives to provide water quality regulators the information they need to effectively manage the Estuary. The RMP is an innovative and collaborative effort between the San Francisco Estuary Institute (SFEI), the Regional Water Quality Control Board, and the regulated discharger community.

The RMP has two major program elements: 1) Status and Trends Monitoring, and 2) Pilot and Special Studies. The Status and Trends Program (S&T Program) includes long-term contaminant monitoring within the Estuary, while the Pilot and Special Studies component provides an avenue to develop and incorporate new monitoring measurements into the S&T Program, or to address specific scientific and management questions.

Adaptive Management Cycle In response to changes in the regulatory landscape, advances in scientific understanding of Estuary processes, development of new analytical methods, and a continual drive to keep the RMP relevant, the Program uses an adaptive management approach, or cycle, to respond to new management issues.

As a result of this adaptive management cycle, the S&T Program was redesigned in 2002 (see The Redesign Process) from a fixed-location sampling design to a spatially balanced, random sampling design in order to provide statistically defensible data to address a new set of more demanding management questions.

For example, the fixed-location sampling design (employed from 1993 to 2001) allowed us to evaluate contaminant conditions at specific sampling locations over time and make site-specific comparisons to regulatory guidelines. We could also compare concentrations between sampling locations throughout the Estuary, but had no way of knowing if these were representative samples. Now with the spatially balanced, random sampling design (2002 to present) we can better estimate what percentage of the Estuary (or an Estuary region) is above regulatory guidelines with some statistical confidence.

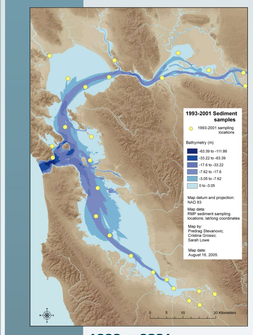


The Redesign Process

Beginning in 2000, a workgroup of scientists, environmental managers, and regulators was convened and they:

- Divided the Estuary into five hydrographic sampling regions using a weight-of-evidence approach employing statistical cluster analyses of available water and sediment quality data, and best professional judgment
- Determined the annual sample size for each region based on statistical power analyses and informational priorities set by the Regional Water Quality Control Board, and
- Used a Generalized Random Tessellation Stratified (GRTS) design to allocate samples into each region.

Don Stevens Jr. (Oregon State University, Corvallis, OR) and Anthony (Tony) R. Olsen (USEPA, Corvallis, OR) developed the GRTS sampling design for the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) to allow monitoring of the nation's aquatic resources. GRTS was used to allocate a fixed number of sampling locations into each Estuary region in a spatially balanced, randomly located manner, with spatially interpenetrating panels to give increased resolution over time.



1993 to 2001
Sediment-sampling, twice a year at fixed locations.

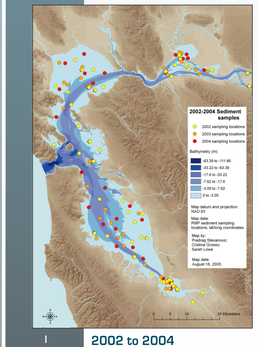
Before Redesign — 1993 to 2001

The RMP S&T Program had a fixed sampling design measuring "background" concentrations of contaminants along the deeper channel of the Estuary away from direct point sources, or at targeted locations, such as near the mouths of the larger streams and rivers.

Contaminant monitoring was conducted twice a year (wet and dry seasons) at the same 22 water and 26 sediment sites.

This design allowed interpretation of the data for:

- Seasonal variations—for example sediment mercury concentrations (mg/kg) at fixed historic RMP sampling locations
- Site-specific comparisons to regulatory guidelines and trends (blue line is the proposed sediment TMDL target of 0.2 mg/kg)
- Comparison of sites from different regions. However, data interpretation was not statistically defensible as the sites were not allocated randomly



2002 to 2004
Sediment-sampling locations (8 samples per region per year). Each year of sampling increases spatial resolution.

After Redesign — 2002 to 2004

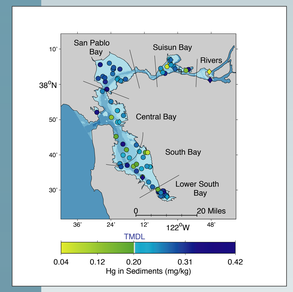
The RMP S&T Program is a spatially balanced random sampling design where randomly selected locations are sampled in sequential order, providing better spatial coverage of the Estuary over time.

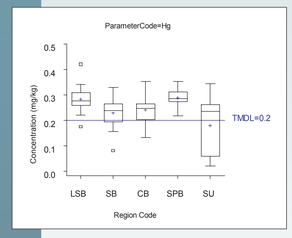
Contaminant monitoring is conducted during the dry season at 31 water and 47 sediment sites per year.

The new design allows interpretation of the data for:

- Site-specific and regional comparisons of contaminant concentrations to regulatory guidelines
- Regional trends over time with increased spatial coverage
- Comparison of contaminant concentrations for:
  - The Estuary as a whole
  - Among regions, and
  - Shallow areas vs. deep channels
- Improved statistical confidence in the information generated

New Design Data Interpretations: Sediment Mercury Example





Spatial Distribution

Map of mercury concentrations in sediments (mg/kg dry weight) in the six Estuary regions monitored. Eighty randomly allocated sites (based on the EMAP sample design) and seven historical RMP sites are represented for the period of 2002 and 2003. Only historic sites were sampled in the Rivers region.

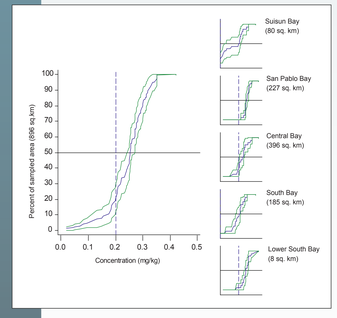
Number of Samples:
Random =16/region
Historic = 1/region *except* n=2 *for the Rivers region*

Random sites =
Historic sites =

Mean Regional Concentrations and Confidence Limits

Schematic Box Plot of sediment mercury concentrations in five Estuary regions (2002-2003). Blue line is the proposed sediment TMDL target for mercury.

Region Code:
LSB = Lower South Bay
SB = South Bay
CB = Central Bay
SPB = San Pablo Bay
Su = Suisun Bay



Percent of Area in Non-compliance with Regulatory Guidelines and Confidence Limits

Cumulative distribution function (CDF) plots for sediment mercury concentrations from the random samples in the five Estuary regions (2002-2003). n=16/region.

The large graph shows the percentage of the total area in the five Estuary regions (totaling 896 square kilometers) vs. sediment mercury concentrations.

The five small graphs show the same for each individual region (scales are identical to the large graph).

About 80% of the total area in the Estuary has sediment mercury concentrations above the proposed TMDL target of 0.2 mg/kg.

Possible Future Data Interpretations

- Composite estimation, that draws on prior years data to improve current years status estimate
- Trend analysis that uses the re-visit structure of the panel design
- Spatial-temporal models that use the correlation through space and time
- Hierarchical Bayesian models

For more information refer to the Regional Monitoring Program for Trace Substances 2003 Annual Monitoring Results available on the web at:
www.sfei.org/rmp/2003/2003_Annual_Results.htm

Details on the Regional Monitoring Program's Re-design process for the Status and Trends program are available on the web at:
www.sfei.org/rmp/Technical_Reports/RMP_2002_No109_RedesignProcess.pdf

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