San Francisco Estuary Regional Monitoring Program (RMP): Management Implications and Benefits of Redesign

Karen Taberski

San Francisco Bay Regional Water Quality Control Board
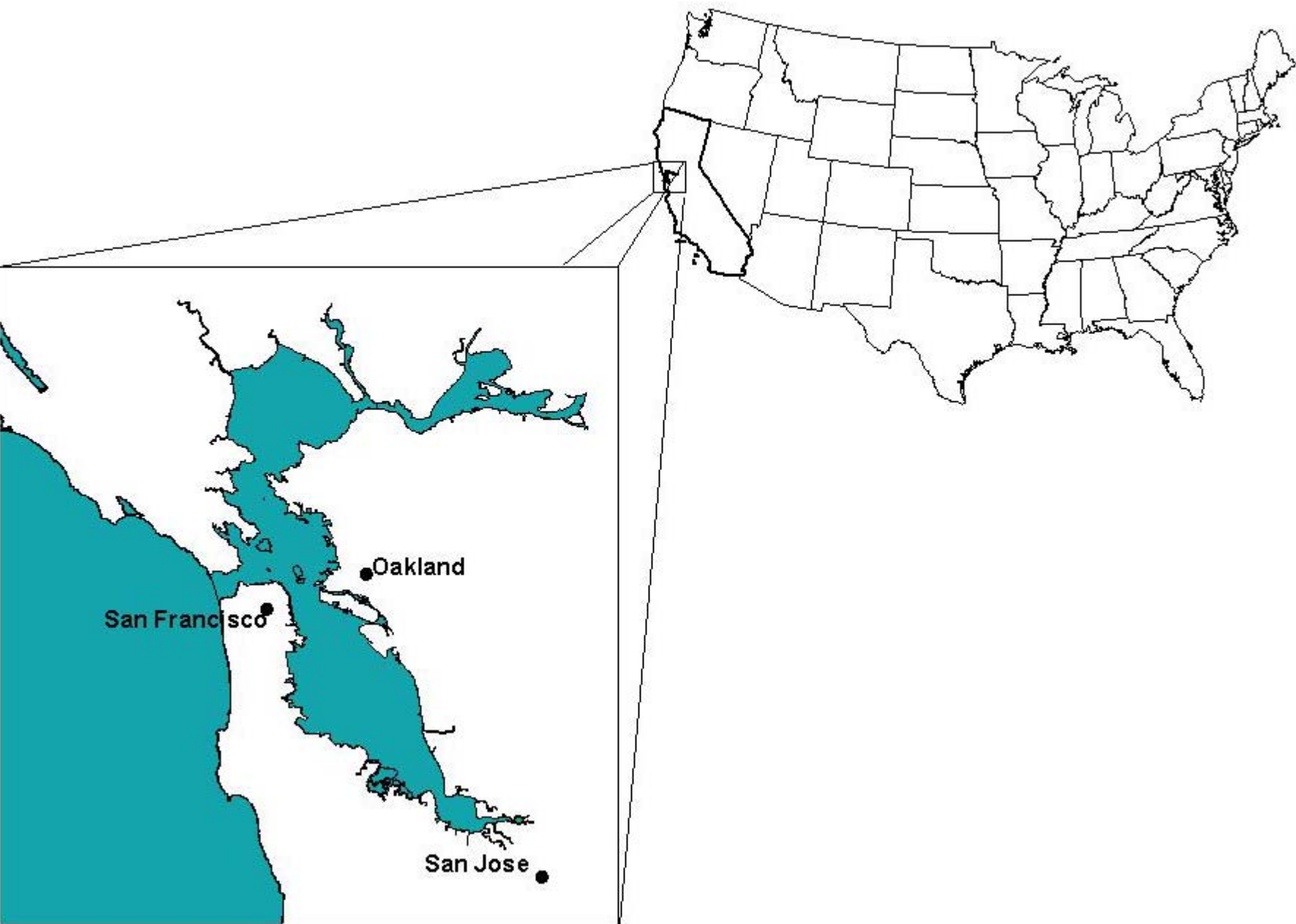
Acknowledgements

- Statisticians
  - Don Stevens (Oregon State University)
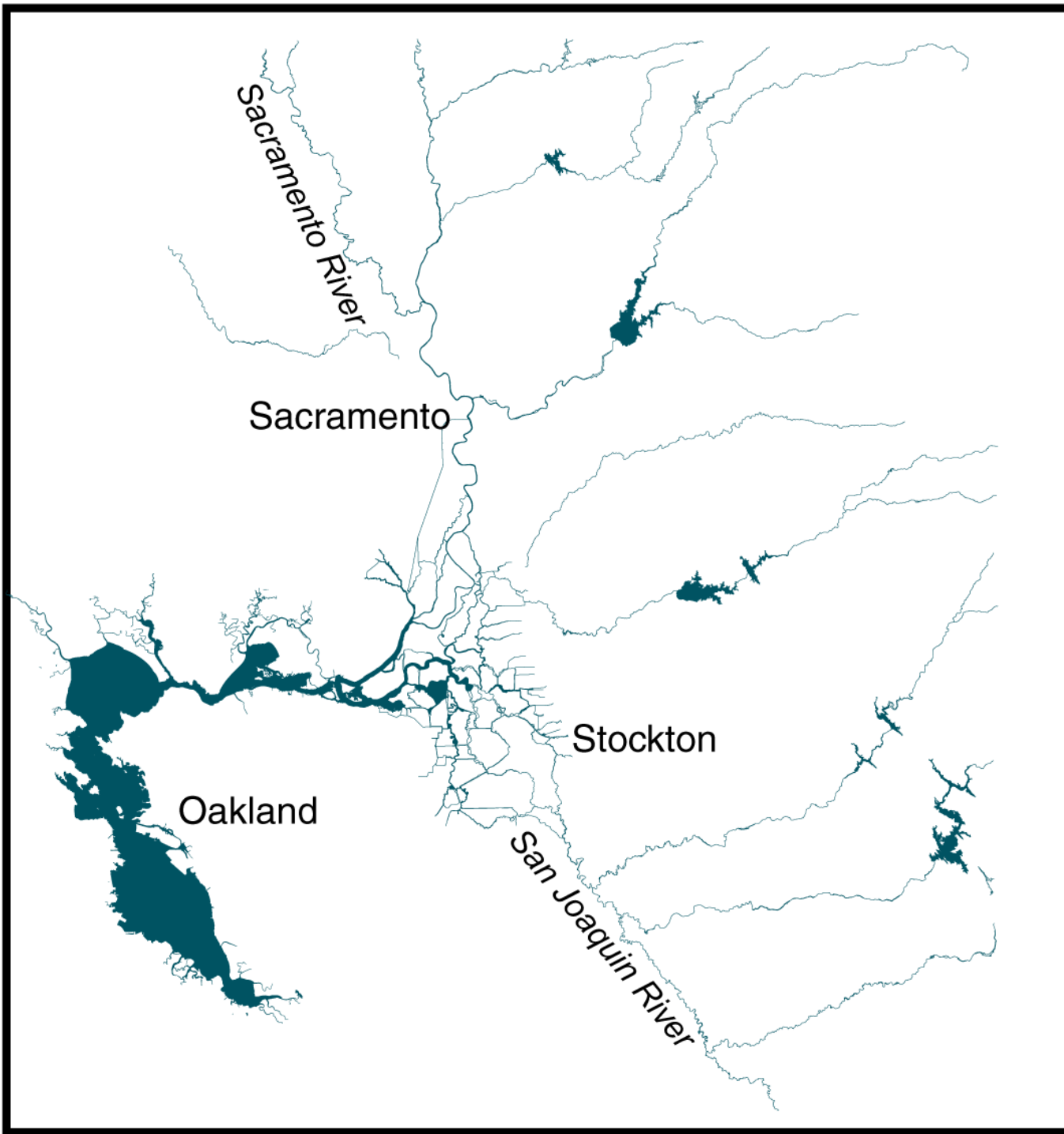 - Bob Smith
- San Francisco Estuary Institute
  - Sarah Lowe
  - Jay Davis
  - Bruce Thompson
  - Rainer Hoenicke (Ca. Resources Agency)

Outline of Presentation

- San Francisco Estuary
- SF Estuary Regional Monitoring Program (RMP)
- Benefits of RMP to Regulatory Agency (Regional Board)
- 5-year Review and Base Program Redesign
  - Segmentation of Estuary
  - Power analysis
  - Stratified random design with spatial balance
- Added benefits of the redesigned RMP

The State Water Project

California Department of Water Resources
STATE WATER PROJECT

Legend:
- ▲ Powerplants
- ● Pumping Plants
- ■ Pumping-Generating Plants

Redding

Antelope Lake
Frenchman Lake
Lake Davis
Lake Oroville

Hyatt Powerplant
Thermalito Diversion Dam Powerplant
Thermalito Pumping-Generating Plant
Thermalito Afterbay

North Bay Aqueduct — Sacramento

Barker Slough Pumping Plant
Cordelia Pumping Plant
Clifton Court Forebay
Bethany Reservoir
Banks Pumping Plant
South Bay Pumping Plant

San Francisco

South Bay Aqueduct

Del Valle Pumping Plant
Lake Del Valle

O'Neill Forebay
San Luis Reservoir
Gianelli Pumping-
Generating Plant
Los Banos Reservoir
Dos Amigos Pumping Plant

Fresno

Las Perillas Pumping Plant
Badger Hill Pumping Plant
Devils Den Pumping Plant
Bluestone Pumping Plant
Polonio Pass Pumping Plant

Alamo Powerplant

Coastal Branch

Buena Vista Pumping Plant

East Branch

Bakersfield

Teerink Pumping Plant

Chrisman Pumping Plant
Edmonston Pumping Plant
Oso Pumping Plant
West Branch
Warne Powerplant
Pyramid Lake
Castaic Pumping
Generating Plant (LADWP)
Castaic Lake

Los Angeles

Pearblossom Pumping Plant
Mojave Siphon Powerplant
Silverwood Lake
Devil Canyon Powerplant
Lake Perris

San Diego

Beneficial Uses

Impacts

What is the RMP ?

- Program to monitor and conduct special studies on contaminants in San Francisco Bay
- Purpose – To provide data to answer Regional Board regulatory and management questions
- RMP established in 1993
- Collaborative program
- Strong scientific base
- Adaptive management
  - External review every 5 years
  - 1997 Review & redesign

RMP Objectives

- Describe patterns and trends in contaminant concentration and distribution

- Describe general sources and loadings of contaminants to the Estuary

- Measure contaminant effects

- Compare monitoring data to water quality objectives and other guidelines

- 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

Roles of Involved Parties

- **Regional Board**
  - Regulatory context and motivation
  - Sets priorities and management questions
  - Links information with policy and management actions
- **Program Participants (discharger community)**
  - Provides funding and fiscal oversight
  - Helps evaluate technical aspects of program
- **San Francisco Estuary Institute (SFEI)**
  - Independent non-profit scientific research organization
  - Manages programs and contracts
  - Conducts data analysis, synthesis and interpretation
  - Create and distribute information

RMP Program

- Base program (status and trends monitoring)
- Pilot studies/Special studies

Base Program (Status and Trends)

- ■ Water Column
  - ◆ Chemistry
  - ◆ Ancillary measurements
- ■ Sediment
  - ◆ Chemistry
  - ◆ Toxicity
- ■ Bioaccumulation
  - ◆ Mussels
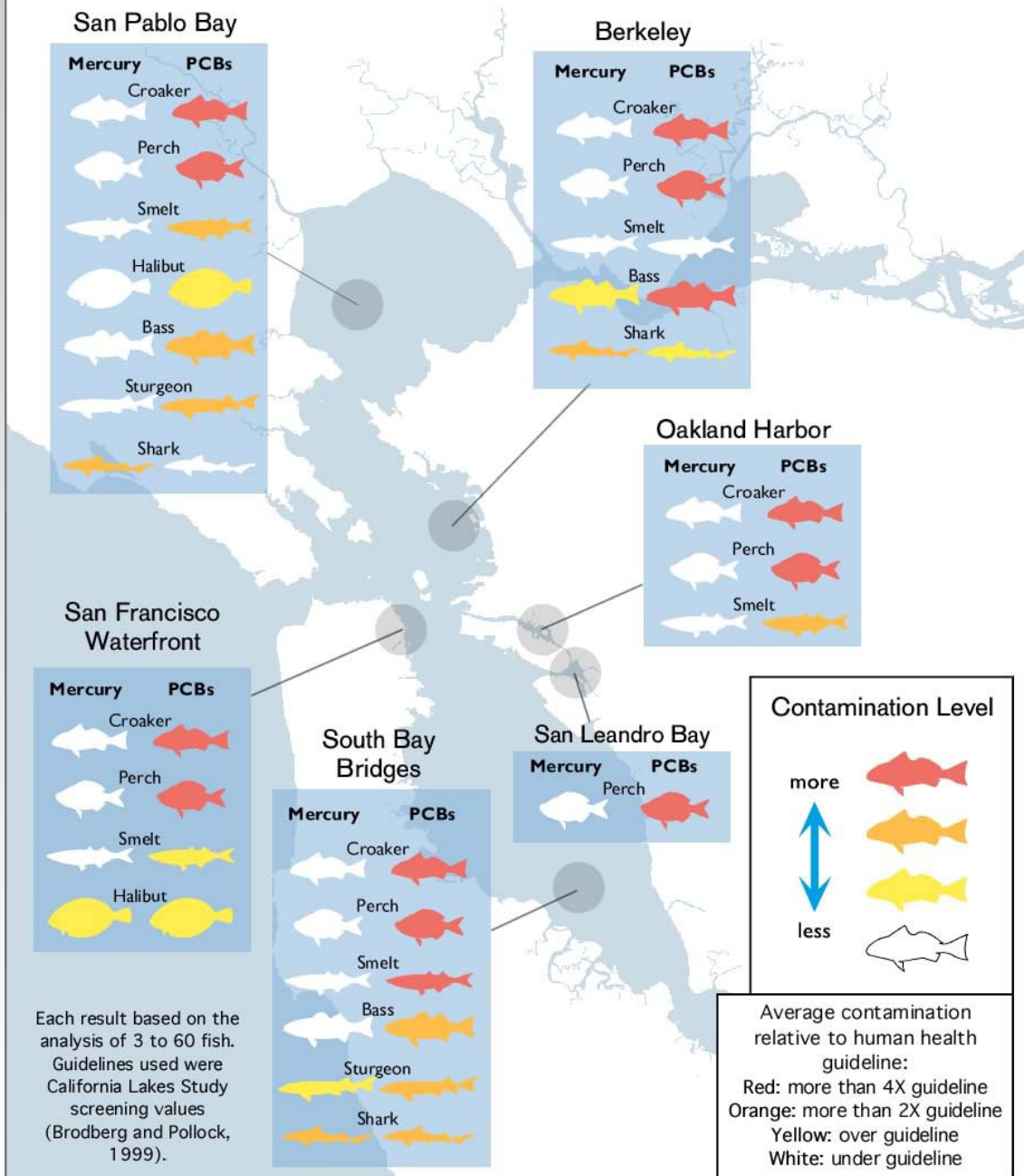 - ◆ Fish
- ■ Episodic Toxicity

RMP Sampling Locations
1999

Water sampling
Sediment sampling
Bivalve sampling
Air deposition sampling

Mercury in Water
1993–1999

0%   20   40   60   80   100

Percentage of samples
exceeding guideline

number of samples per site: 9 to 21

PCBs in Water
1993–1999

30%   40   50   60   70   80   90   100

Percentage of samples
exceeding human health
guidelines

number of samples per site: 9 to 19
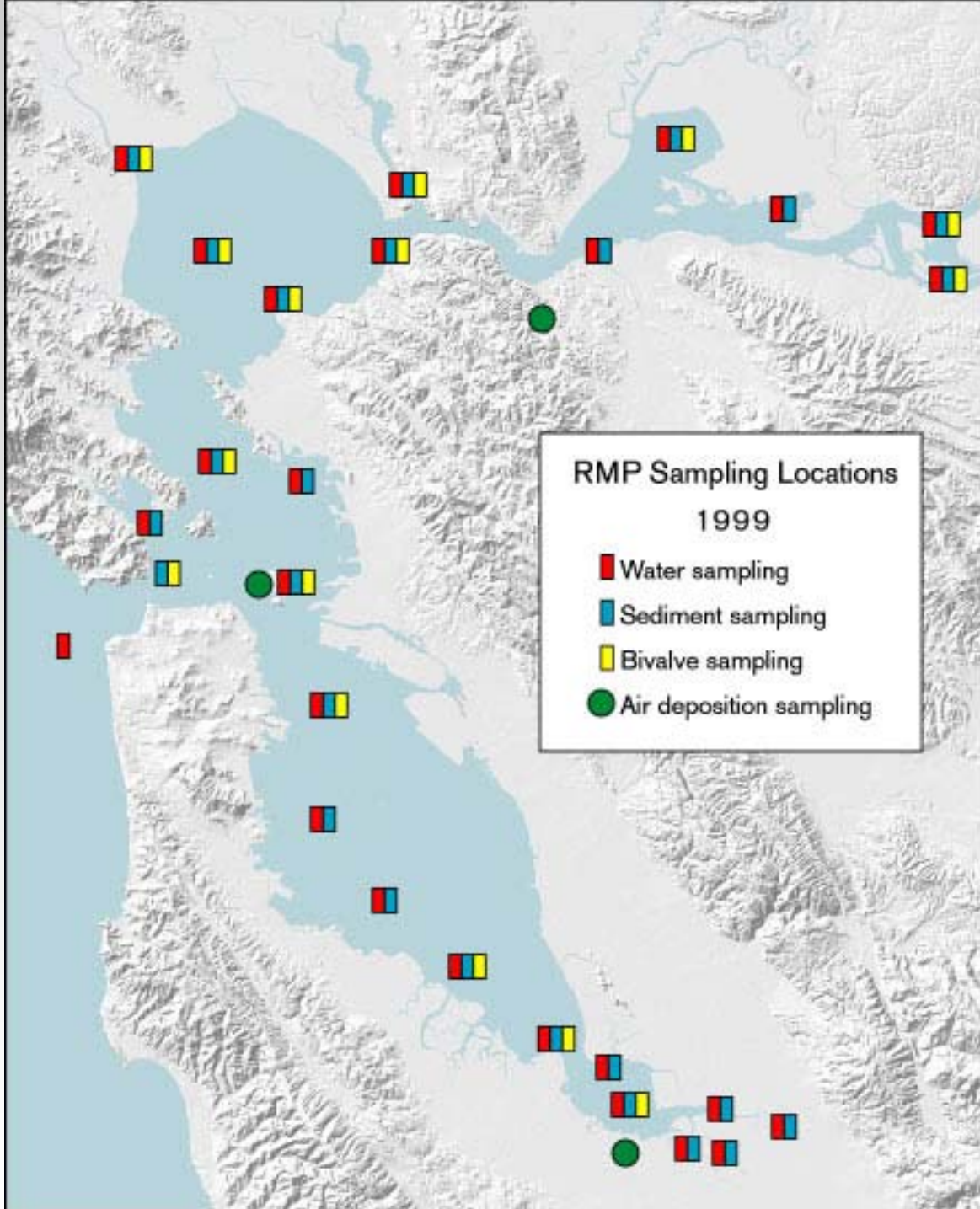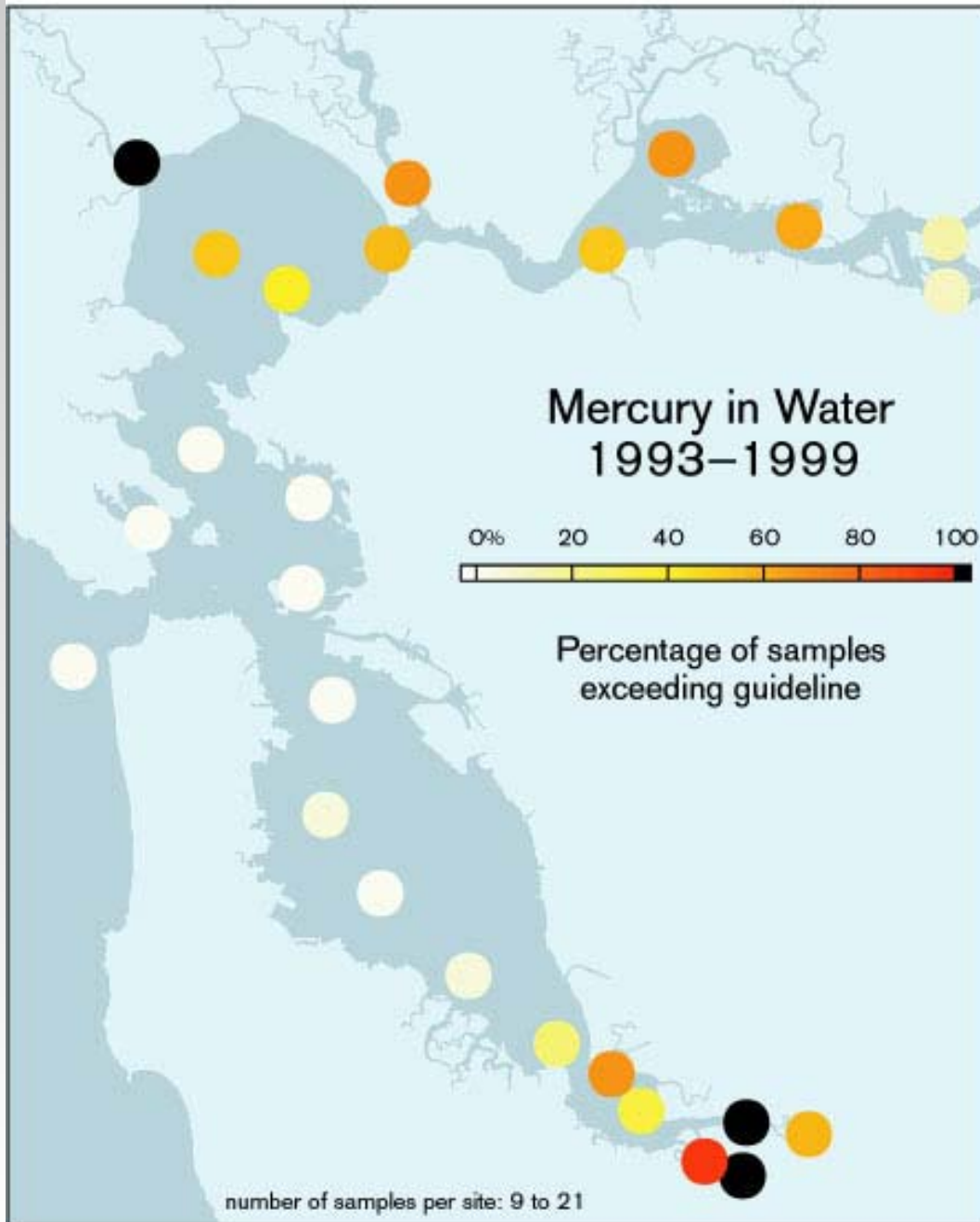
Fish Contamination 2000—PCBs and Mercury

San Pablo Bay

Mercury	PCBs
Croaker	
Perch	
Smelt	
Halibut	
Bass	
Sturgeon	
Shark	

Berkeley

Mercury	PCBs
Croaker	
Perch	
Smelt	
Bass	
Shark	

Oakland Harbor

Mercury	PCBs
Croaker	
Perch	
Smelt	

San Francisco Waterfront

Mercury	PCBs
Croaker	
Perch	
Smelt	
Halibut	

South Bay Bridges

Mercury	PCBs
Croaker	
Perch	
Smelt	
Bass	
Sturgeon	
Shark	

San Leandro Bay

Mercury	PCBs
	Perch

Contamination Level

more

less

Average contamination relative to human health guideline:
Red: more than 4X guideline
Orange: more than 2X guideline
Yellow: over guideline
White: under guideline

Each result based on the analysis of 3 to 60 fish. Guidelines used were California Lakes Study screening values (Brodberg and Pollock, 1999).

Pilot/Special Studies

- Fish Consumption Study
- Tidal Wetlands Contamination
- Bioaccumulation in birds, bird eggs, seals and their prey
- Biological effects studies tied to contaminants
- Air Deposition
- Measurements of pollutant loadings from rivers
- Evaluation of contaminants of concern for possible addition to analyte list

General Benefits to Regional Board

- Provides Focus
- Helps Develop Priorities
- Determine if Water Quality Standards Are Exceeded
- Determine if Beneficial Uses Are Being Protected

Specific Examples of Benefits to Regional Board

- Technical basis for "Impaired Waterbodies List" (303d list)
- Copper and nickel
- Fish Studies
  - **Contamination – PCBs & Hg, consumption advisory**
  - **Consumption – Public health education**
- Data and conceptual models provide technical basis for mercury and PCB TMDLs
- Track results of changes in pesticide usage (Episodic toxicity)
- Ambient Sediment Guidelines

5-Year Review

- Panel of nationally recognized experts
- Thorough scientific and programmatic review
- Review report (1998)
- Technical workgroups
- Integration of workgroup recommendations with Regional Board priorities
- Redesign development
    - base monitoring program
    - special/pilot studies
- Redesign implementation (2002)

New Base Program Status and Trends Design

- Redefines segments of the Estuary based on scientific data

- Used power analysis to evaluate the number of stations to monitor in each segment to obtain 80% confidence that mean concentrations were different than WQOs

- Developed a random stratified sampling design that provides spatial balance (Generalized Random Tesselation Stratified - GRTS)

Deterministic   Probabilistic

1993 – 2001   2002 – future

Existing Segments

Carquinez Bridge

Benicia Bridge

Chipps Island

Pt. San Pablo

Richmond Bridge

Golden Gate Bridge

Bay Bridge

San Mateo Bridge

Dumbarton Bridge

N

10   0   10   20 Kilometers

5   0   5   10   15 Miles

Professional Opinions

Zooplankton
Water density & circulation
Geographical constrictions
Water quality
Benthic community

Cluster Analysis Results

Water Cluster (Wet season)
Water Cluster (Dry season)

Temperature
salinity
DO
DOC
TSS
pH

Graphical Analysis Results

Temperature
salinity
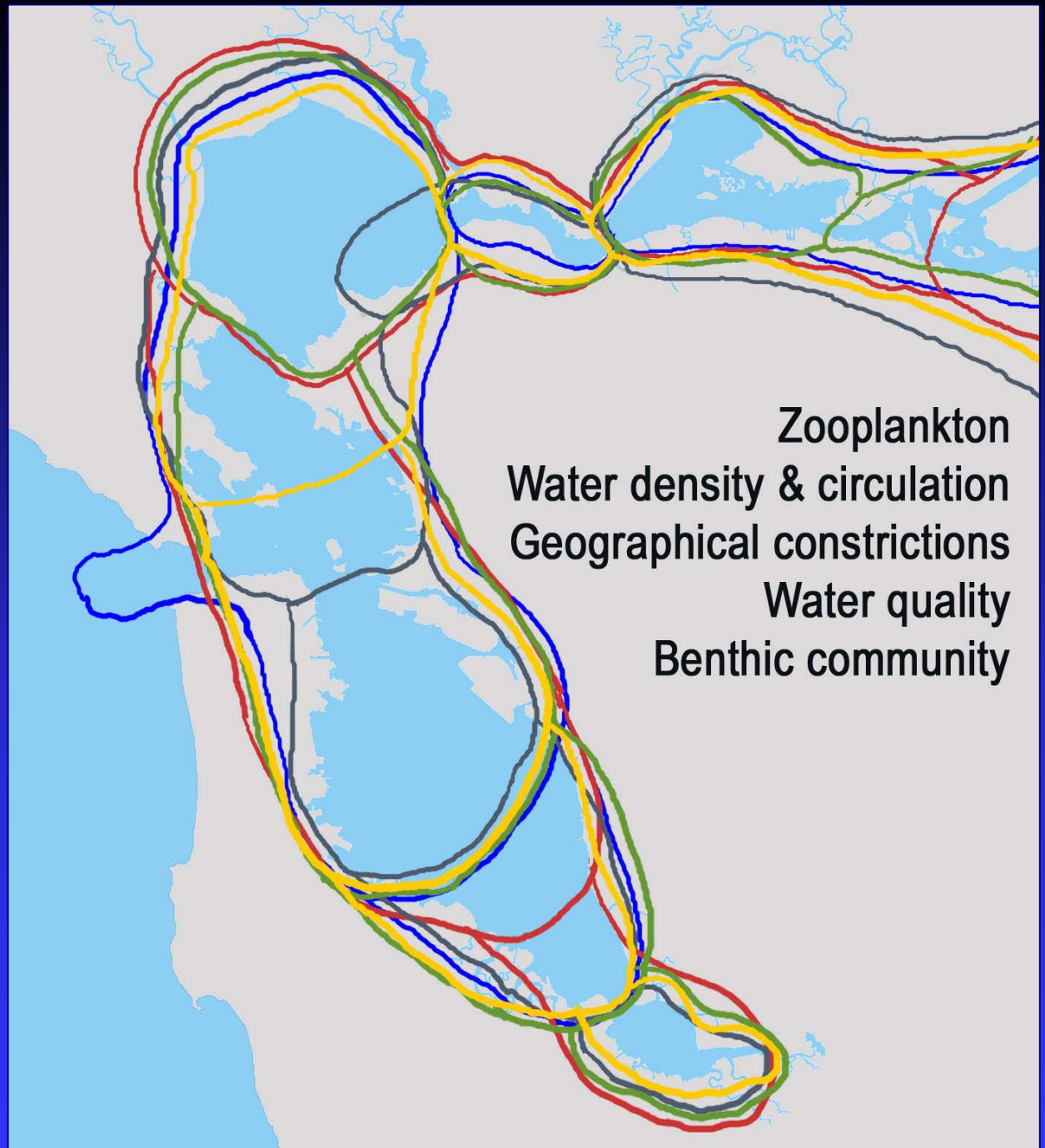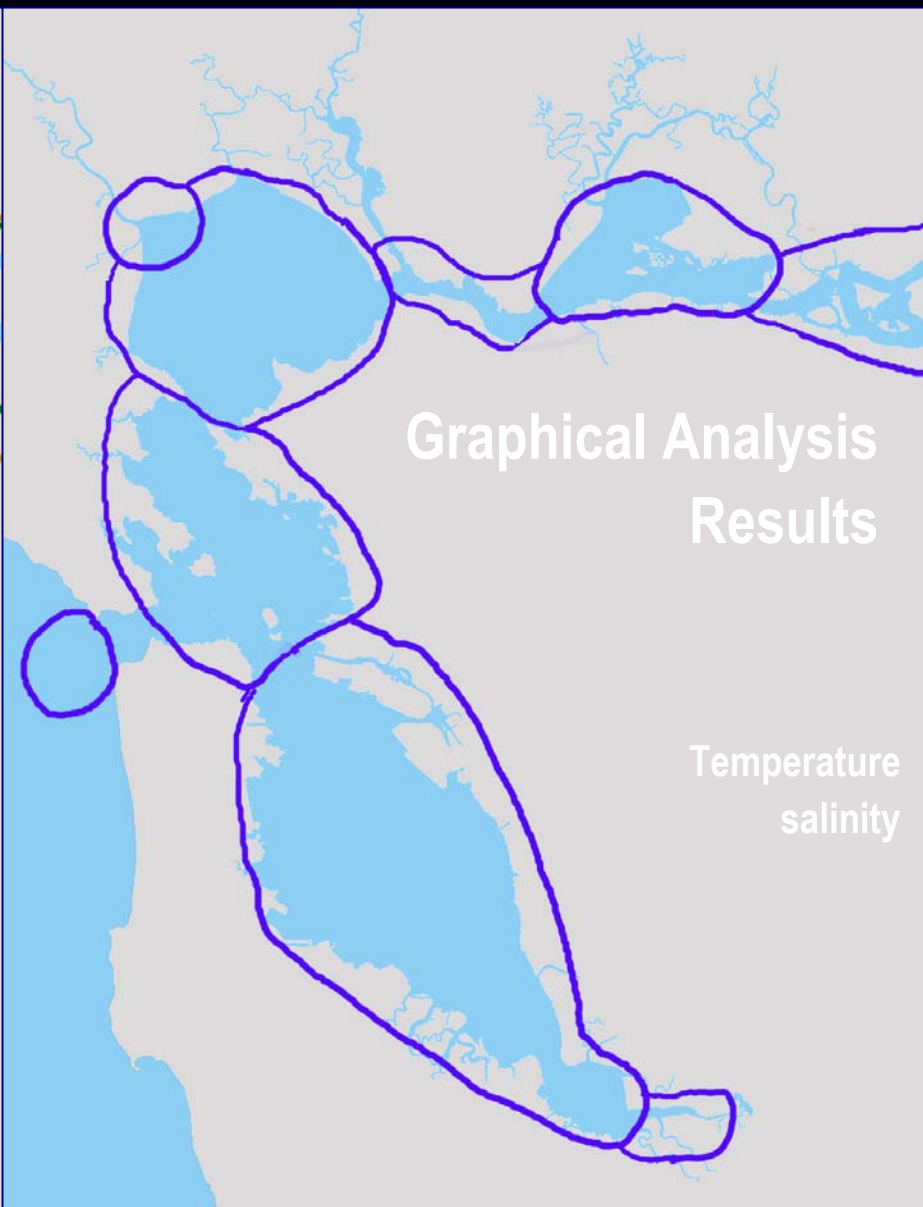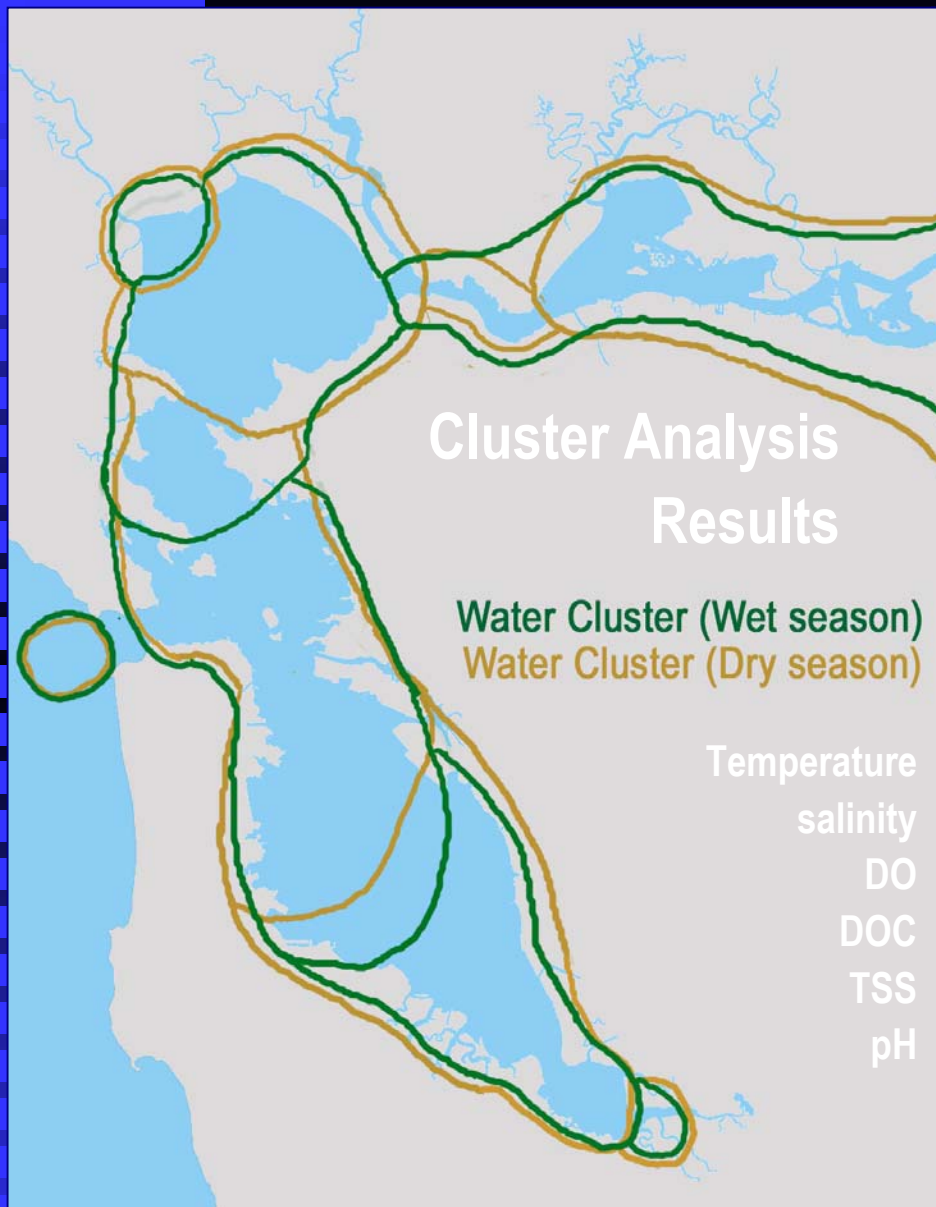
Water Quality data source: RMP and BPTCP (1989-1998)

Cluster Analysis Results

% Fine sediment
TOC

Graphical Analysis Results

% Fine sediment
TOC
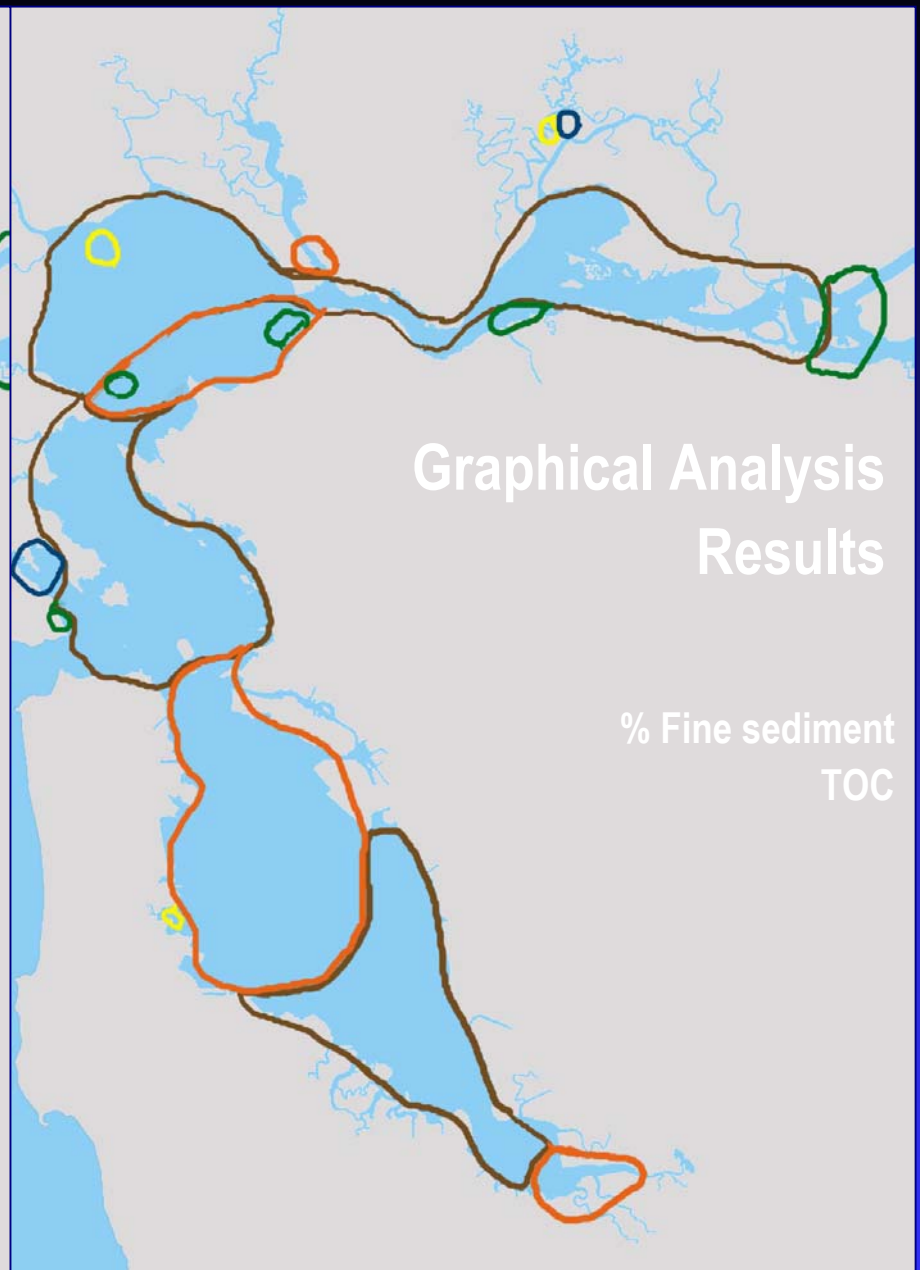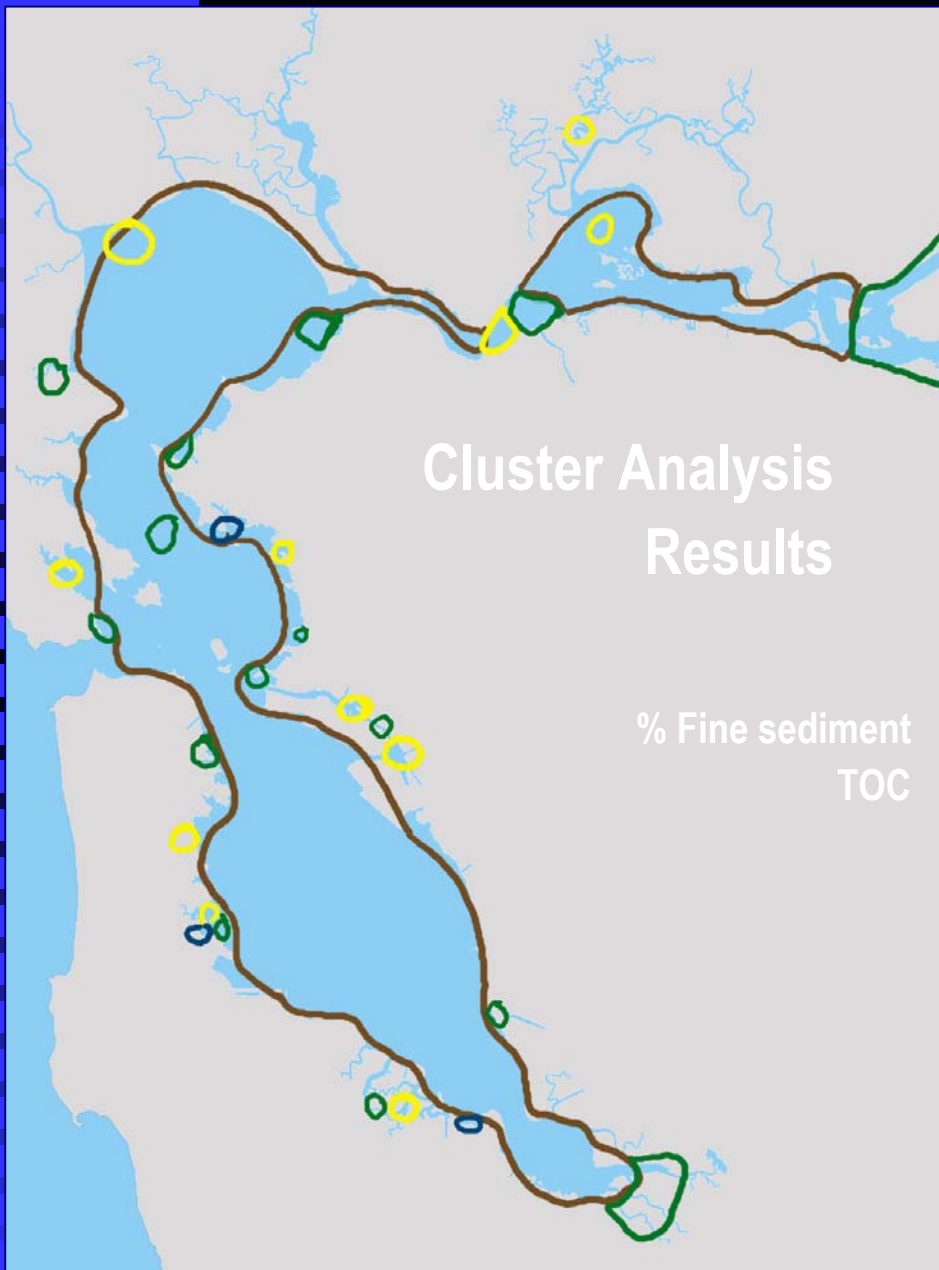
Sediment Quality data source: RMP, BPTCP & DWR (1991-1998)

Region Boundary	Expert Opinion	Water Cluster	Water Graphical	Sediment Graphical	Total	
Number of possible hits	5	2	1	1	9	
Chipps Island *	1	0	1	0	2	
Benicia Bridge*	5	1	1	0	7	✕
Carquinez Bridge*	0	1	0	0	1	
Carquinez Straight (west end)	3	1	1	1	6	✕
Pt. Pinole	1	0	0	0	1	
Pt. San Pablo	2	1	1	1	5	✕
Richmond Bridge*	0	0	0	0	0	
Angel Island	1	1	0	0	2	
Bay Bridge*	1	0	1	1	3	
San Bruno Shoal	4	2	0	1	7	✕
San Mateo Bridge*	1	0	0	0	1	
Dumbarton Bridge	4	0	0	0	4	✕
Sloughs	0	2	1	1	4	✕

The New Segmentation Scheme has Six Main Hydrographic Regions
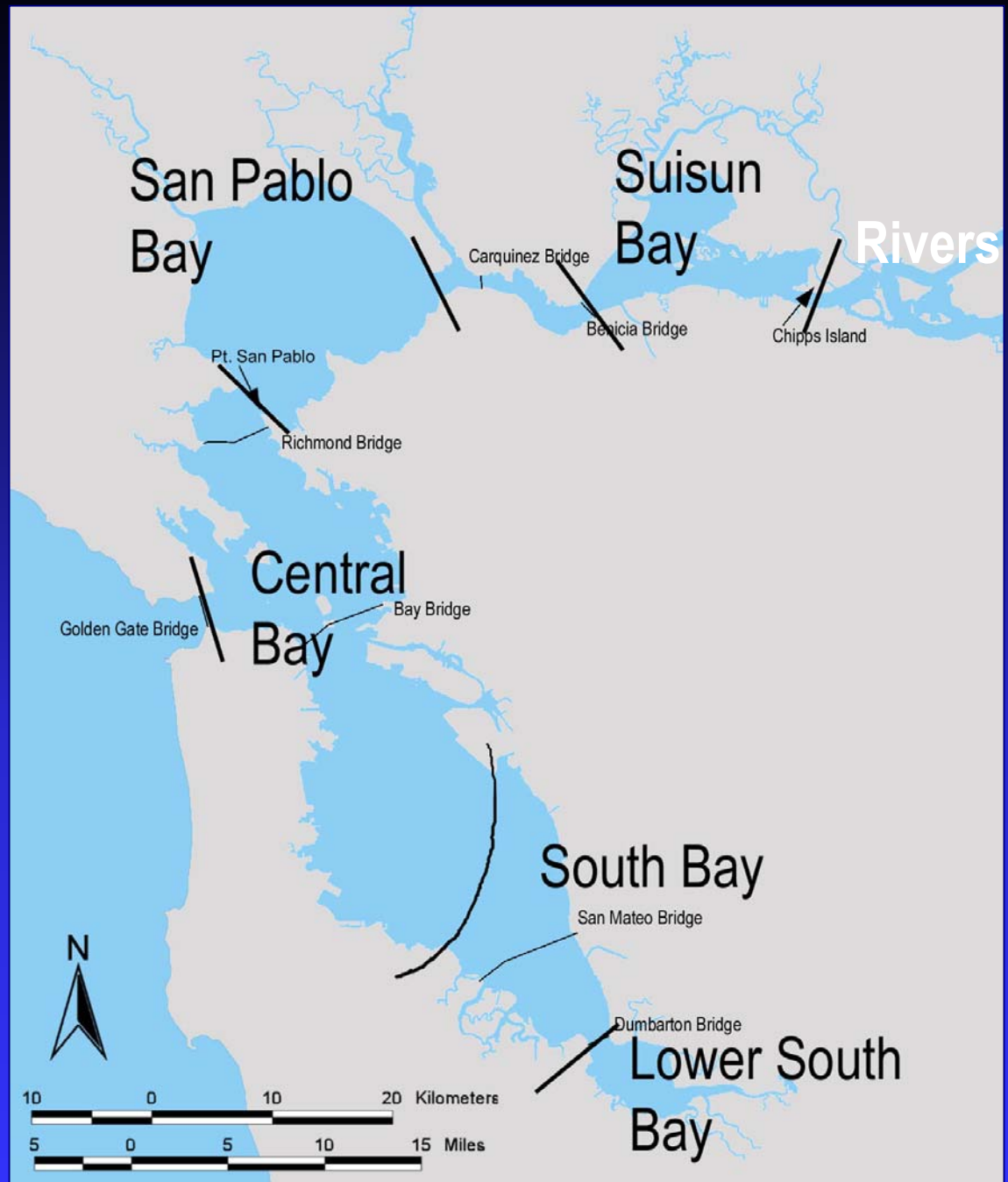
Power Analysis
Dissolved Copper

Hydrographic Region	Dry Season		% Power achieved with 2 to 10 samples								
	Mean	StDev	2	3	4	5	6	7	8	9	10
Rivers[1]	1.81	0.12	100								
Suisun Bay	2.06	0.20	64	99							
San Pablo Bay	2.02	0.56	29	60	81	92	97	99	100		
Central Bay	1.50	0.46	53	96	100						
South Bay	2.88	0.34	10	14	19	23	26	30	33	37	40
Lower South Bay	3.66	0.24	33	69	89	97	99				

[1] Rivers region was compared to the fresh water criterion.

WQO = **3.1**, freshwater = 9 (µg/L)

Type I error rate (a) = 0.05.   Dry Season: May-Oct

Number of Stations per Segment

- Determined by:
  - Statistical power analysis for key contaminants when compared to specific guidelines
  - Regional Board priorities
  - Funding

Number of SAMPLES per segment

San Pablo Bay

Suisun

Rivers

W=4
S=8

W=4
S=8

Water: 33 total
(28 random + 5 fixed)
Sediment: 49 total
(40 random + 9 fixed)

Central Bay

W=4
S=8

South Bay

W=10
S=8

Lower South Bay

W=6
S=8
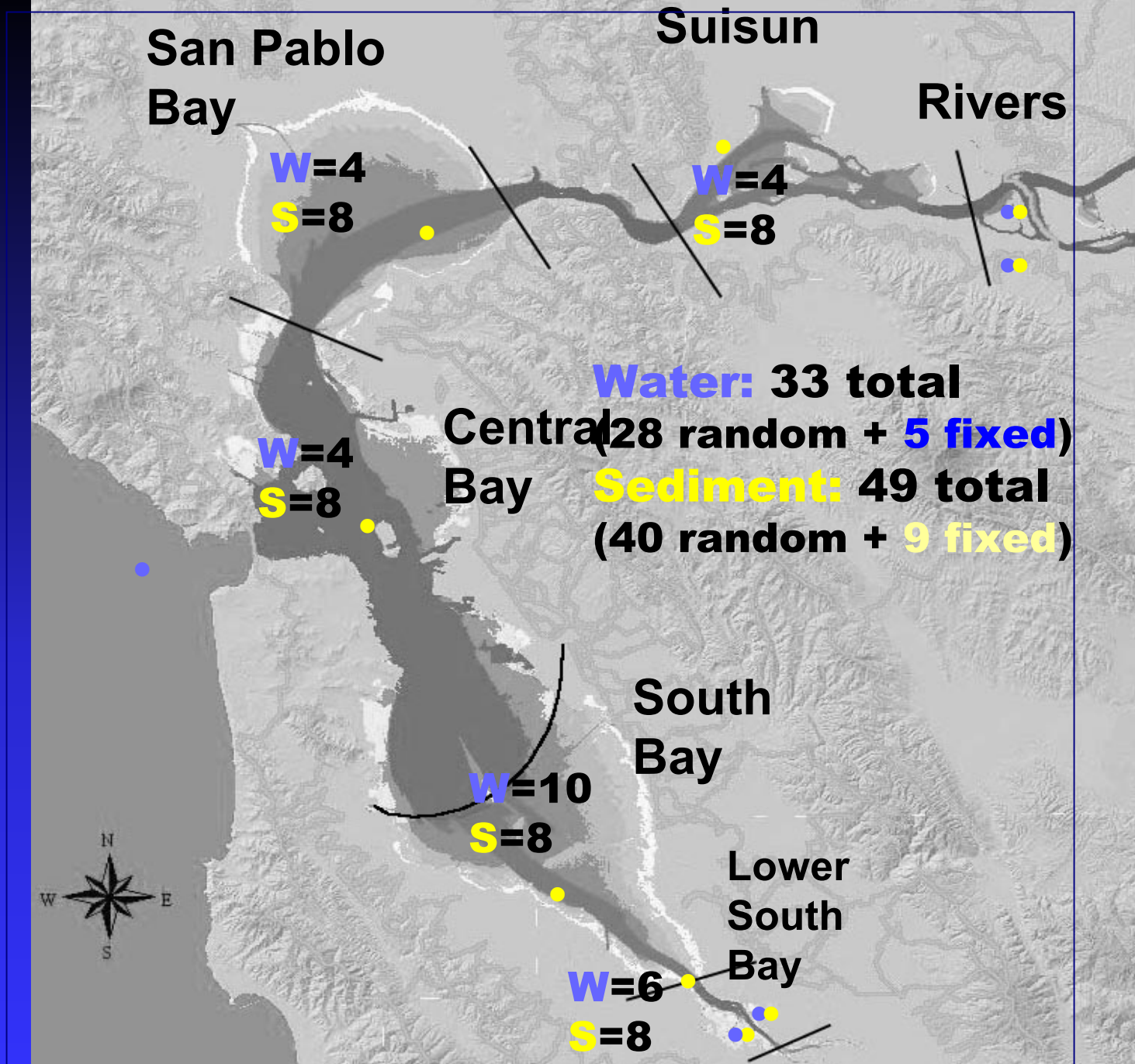
New Base Program Design
(Water and Sediment)

- Stratified random design with spatial balance (Generalized Random-tesselation Stratified Design – GRTS)
  - ◆ Spatially structured to avoid station patterns with voids and clusters
  - ◆ Used by U.S. EPA in Environmental Monitoring and Assessment Program (EMAP)
  - ◆ Peer reviewed
- For sediments, rotating panel design
  - ◆ Resampling of sediment sites on a rotating schedule of 2, 5, 10 and 20 years
- Maintains some fixed stations at historical stations including boundaries

Effects of Budgetary Limitations on Redesign

- Number of stations per segment
  - Insight into power of design
- Base monitoring limited to dry season
  - Episodic toxicity in wet season
  - Sources and loadings in wet season

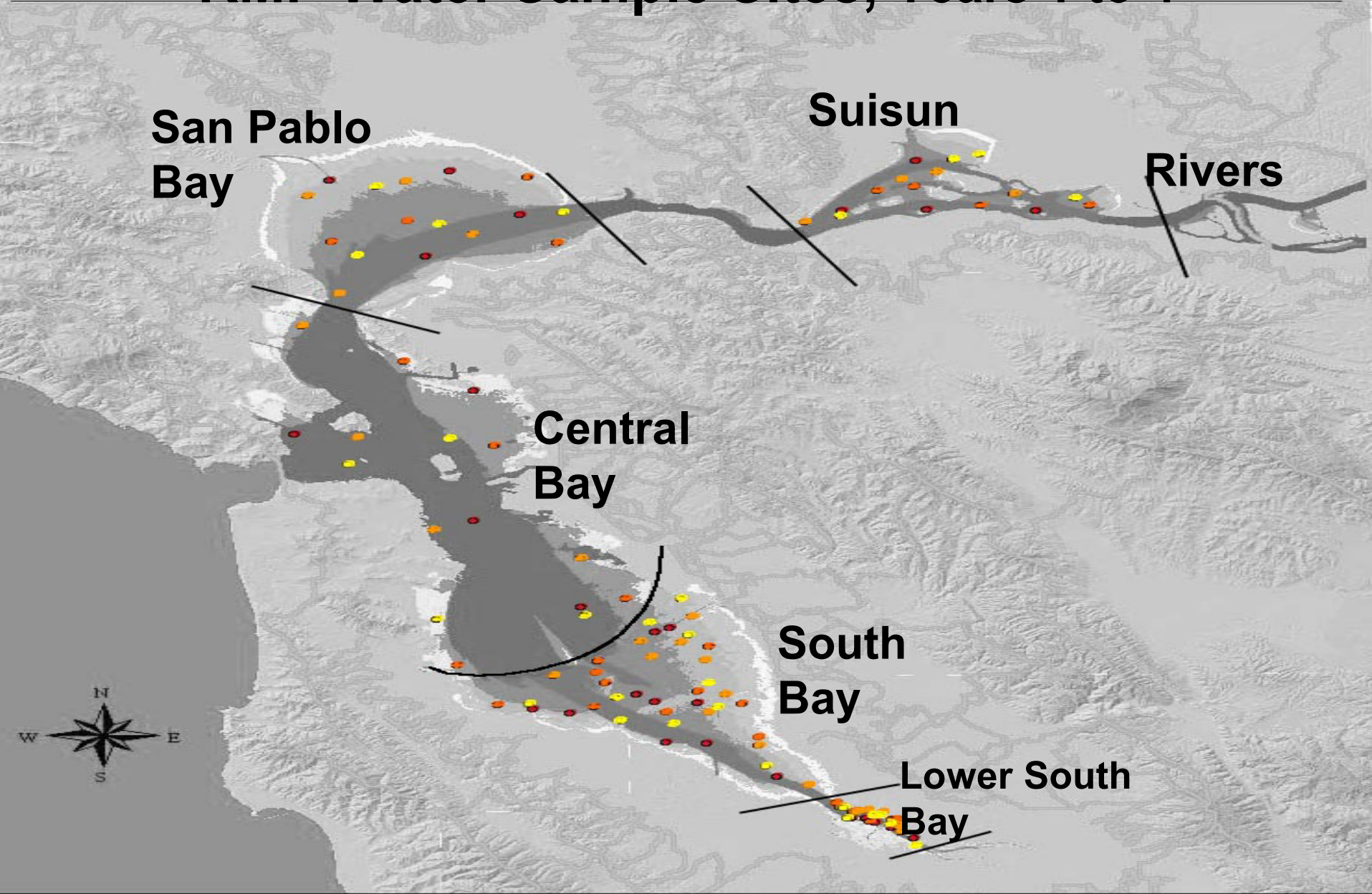# RMP Water Sample Sites, Year 1

San Pablo Bay

Suisun

Rivers

Central Bay

South Bay

Lower South Bay

RMP Water Sample Sites, Years 1 & 2

San Pablo Bay

Suisun

Rivers

Central Bay

South Bay

Lower South Bay
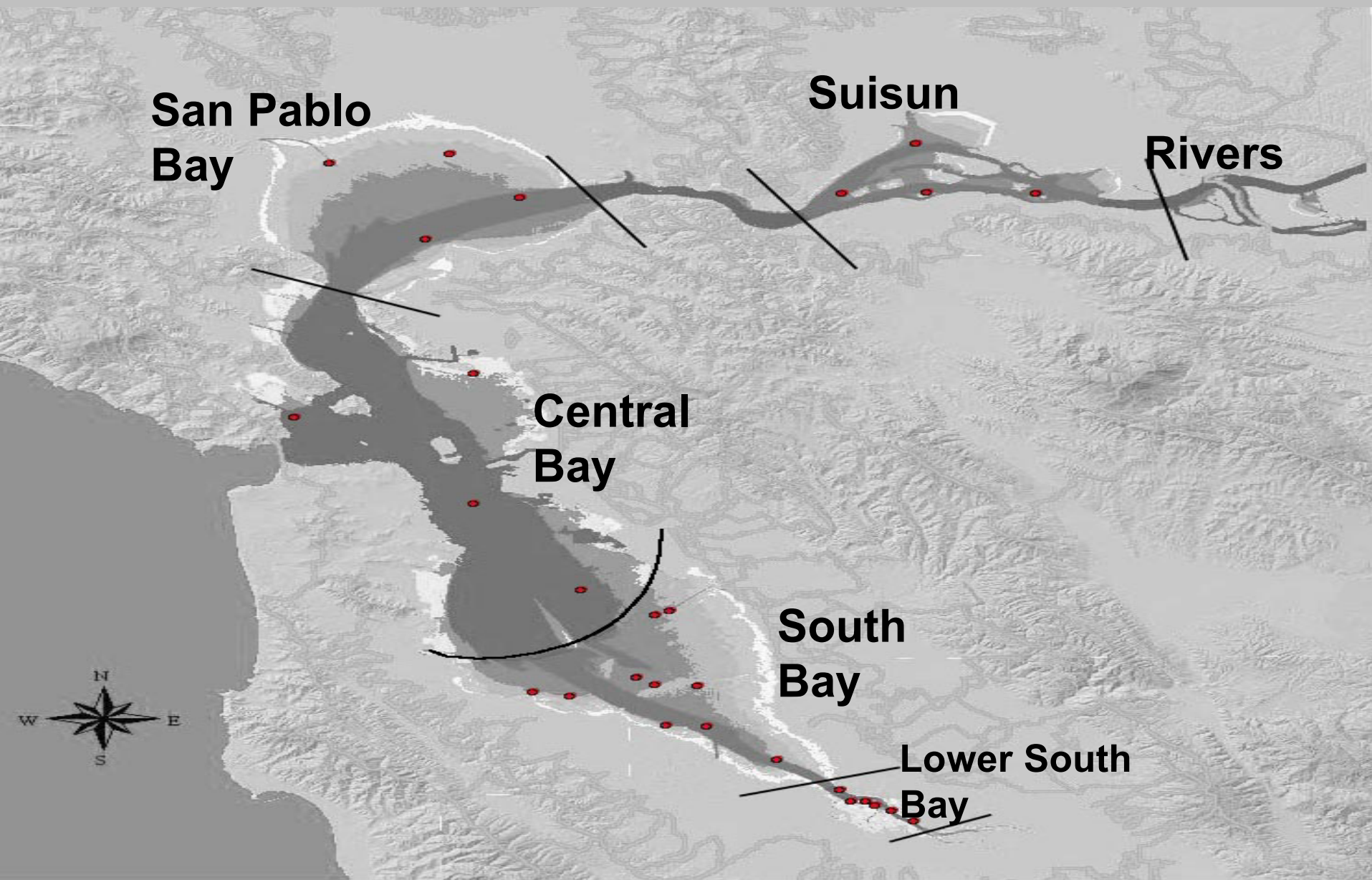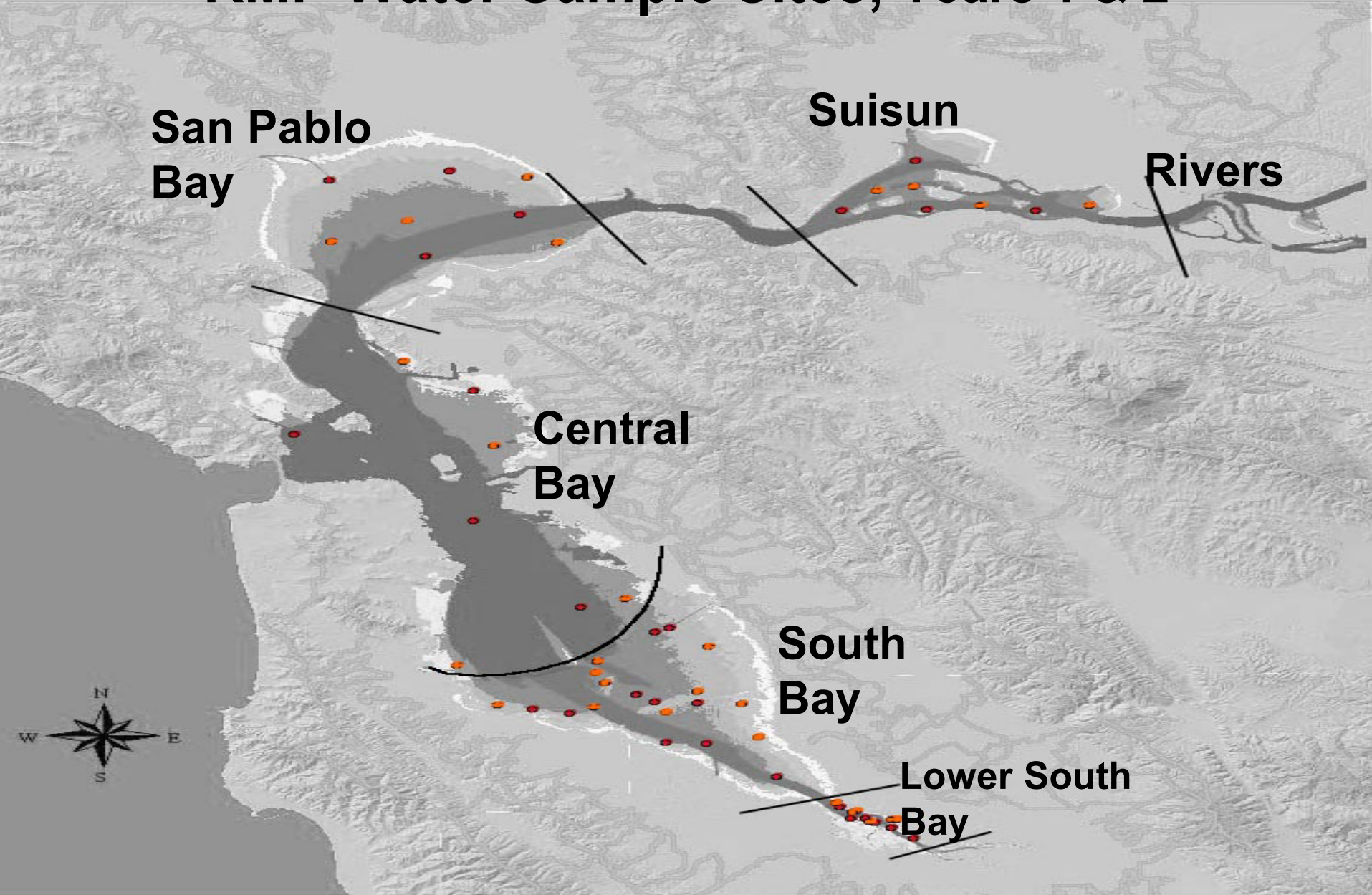
RMP Water Sample Sites, Years 1 to 3

RMP Water Sample Sites, Years 1 to 4

San Pablo Bay

Suisun

Rivers

Central Bay

South Bay

Lower South Bay

RMP Water Sample Sites, Years 1 to 5

San Pablo Bay

Suisun

Rivers

Central Bay

South Bay

Lower South Bay
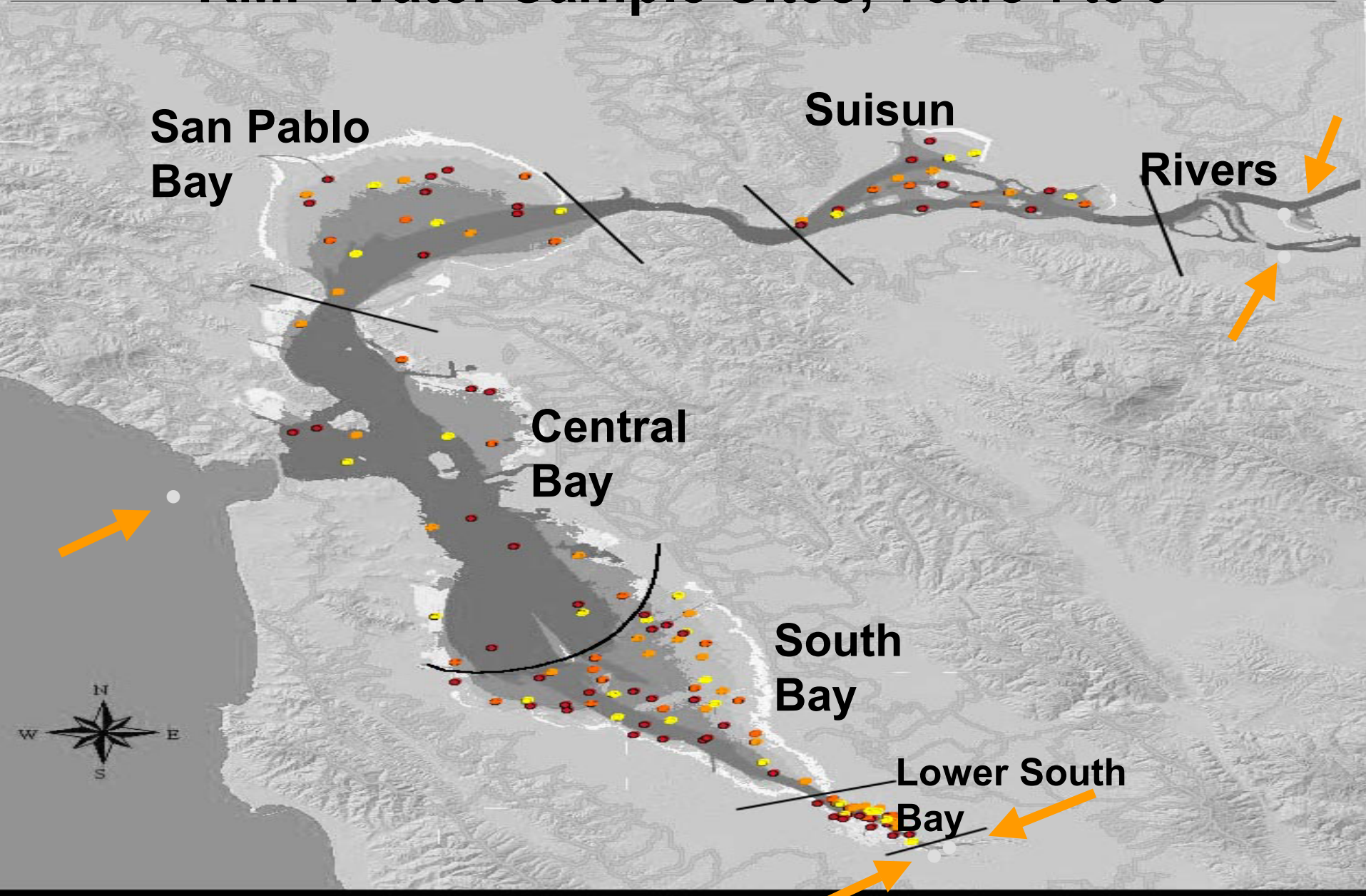
RMP Sediment Sample Sites, Year 1

Rotating Panel Design

8 samples per segment.

9 fixed historical RMP sites.

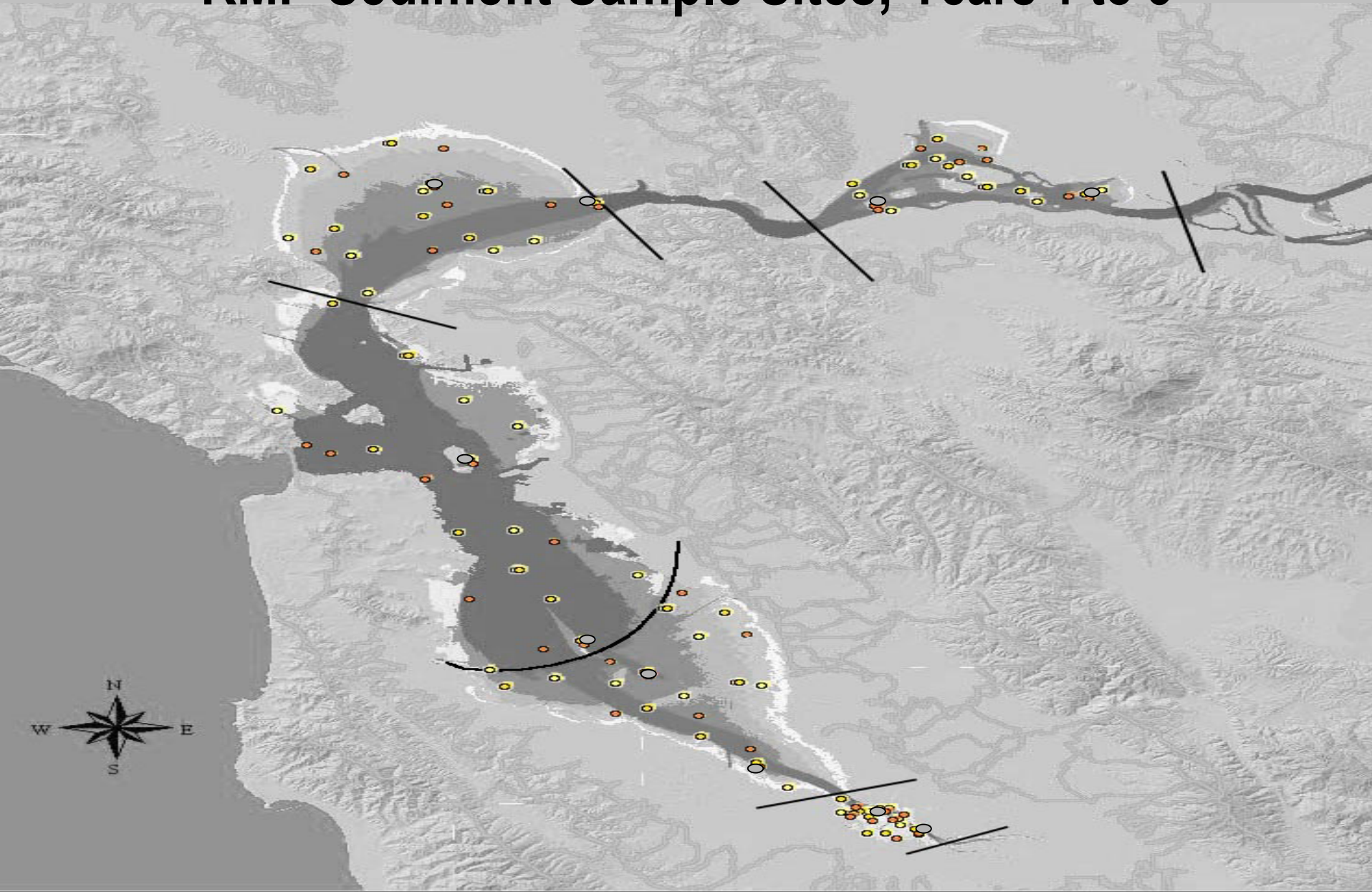Revisit 2 sites per segment on a bi-annual, five-year, 10 and 20-year cycle.

RMP Sediment Sample Sites, Years 1 & 2

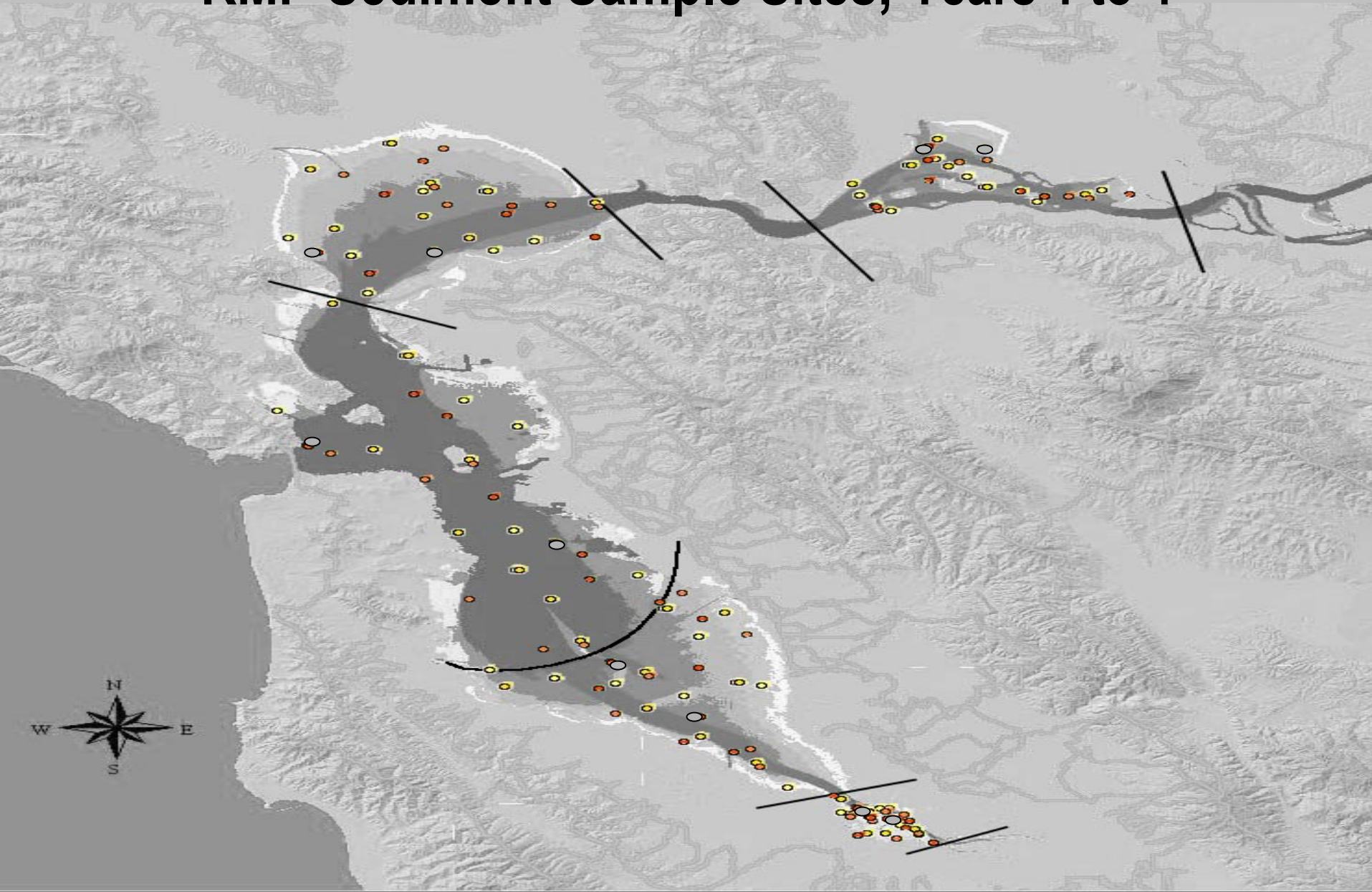○ = bi-annual: revisit previous year's site (2 per segment)
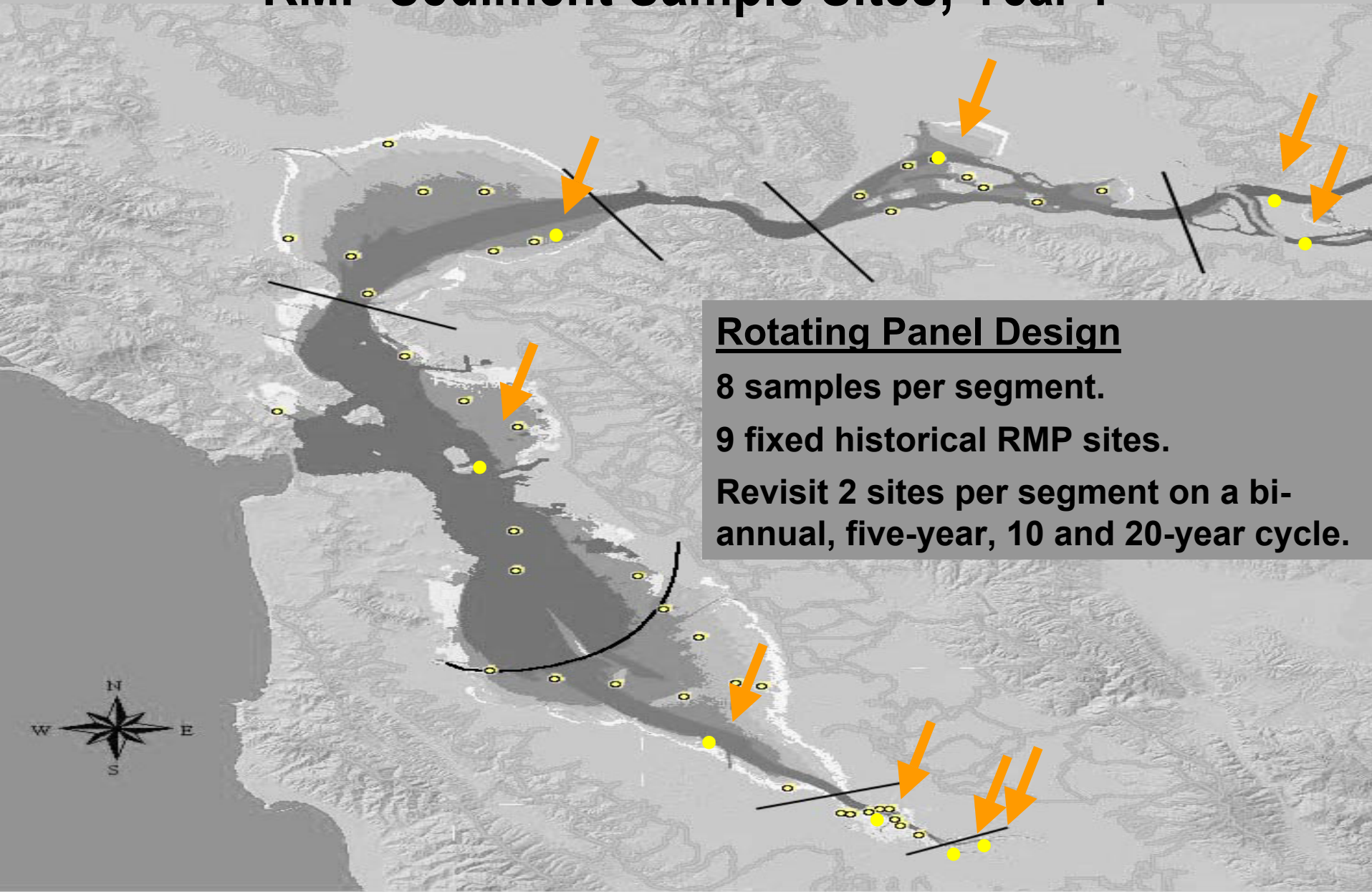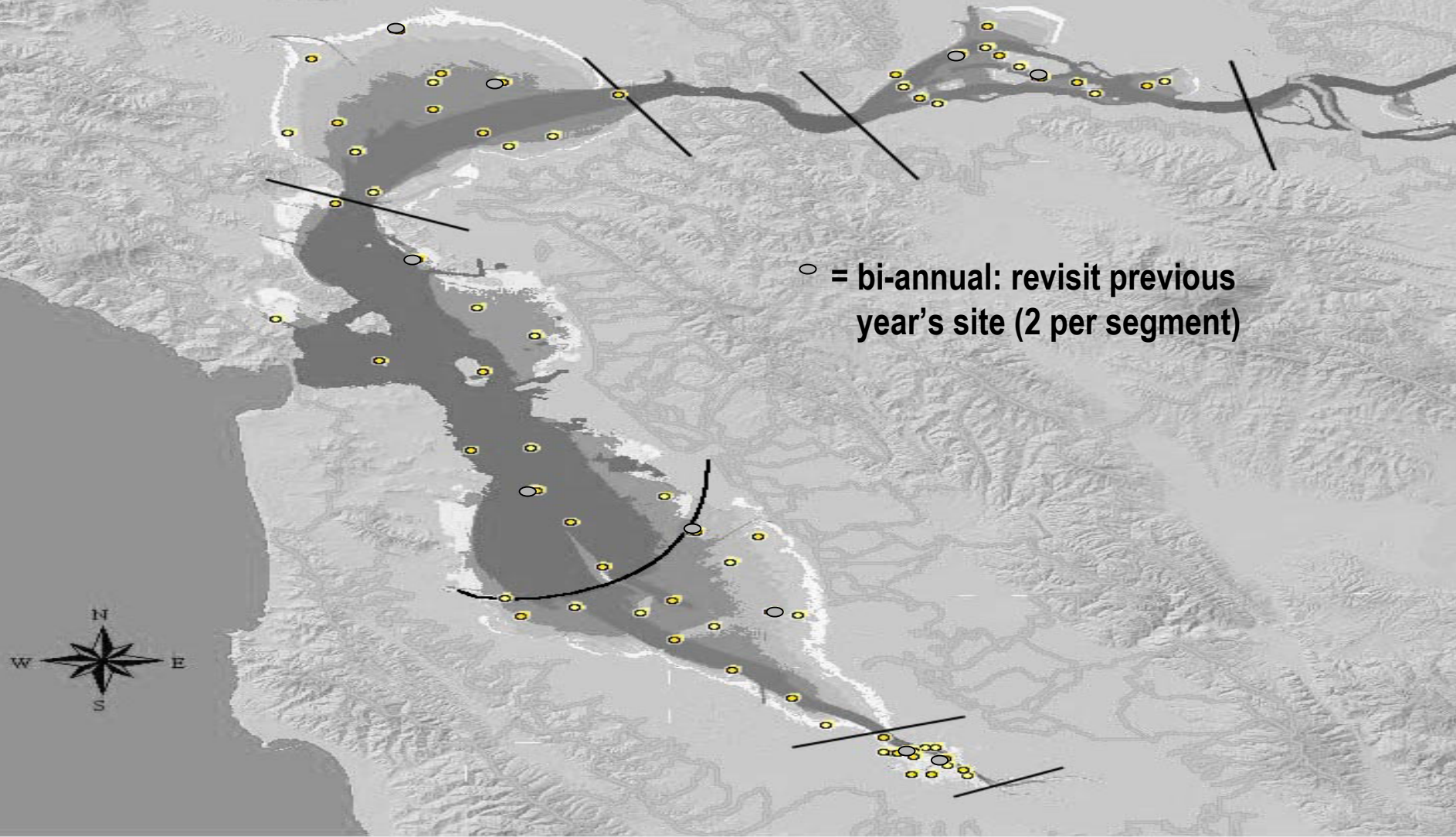
RMP Sediment Sample Sites, Years 1 to 3
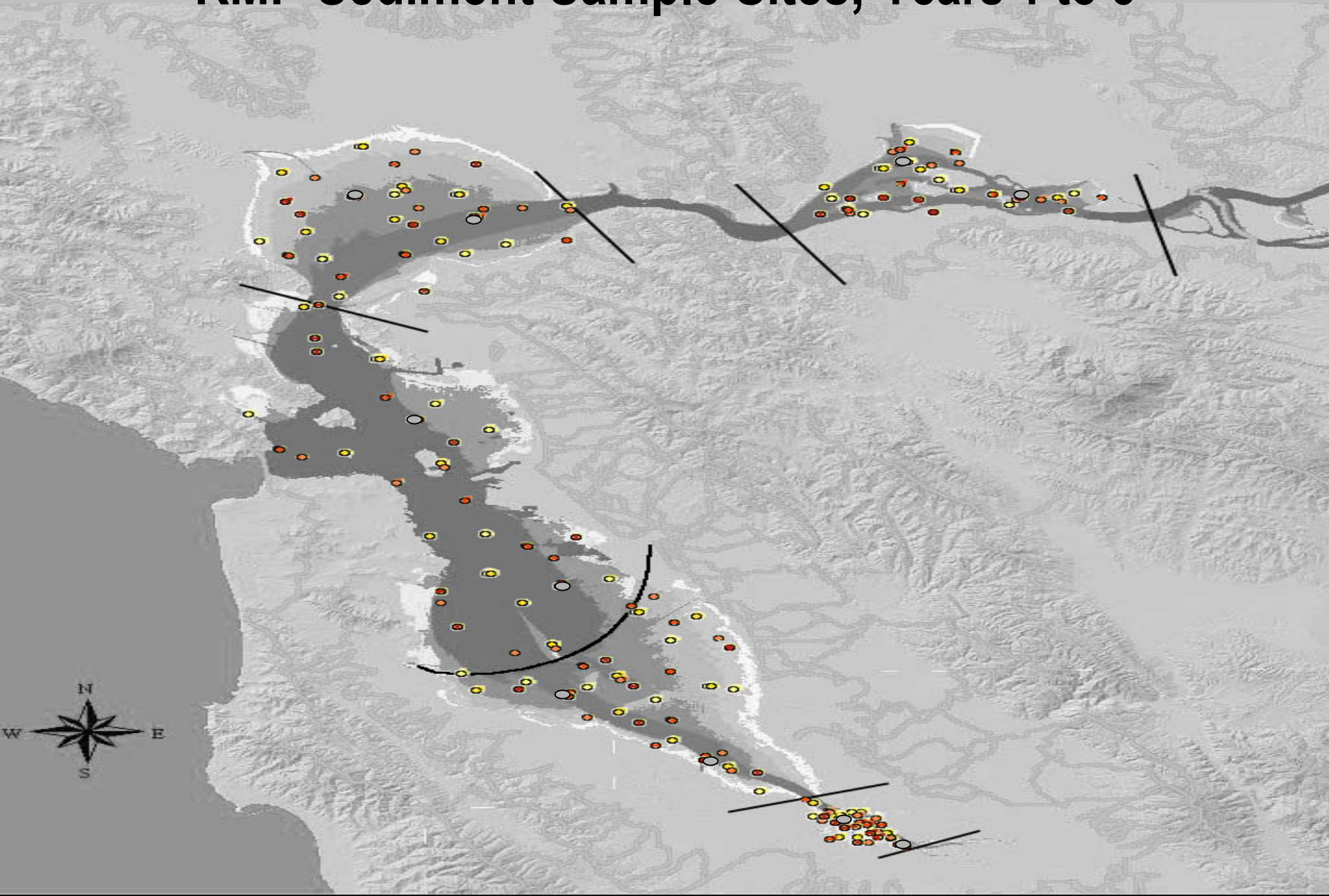
RMP Sediment Sample Sites, Years 1 to 4

RMP Sediment Sample Sites, Years 1 to 5
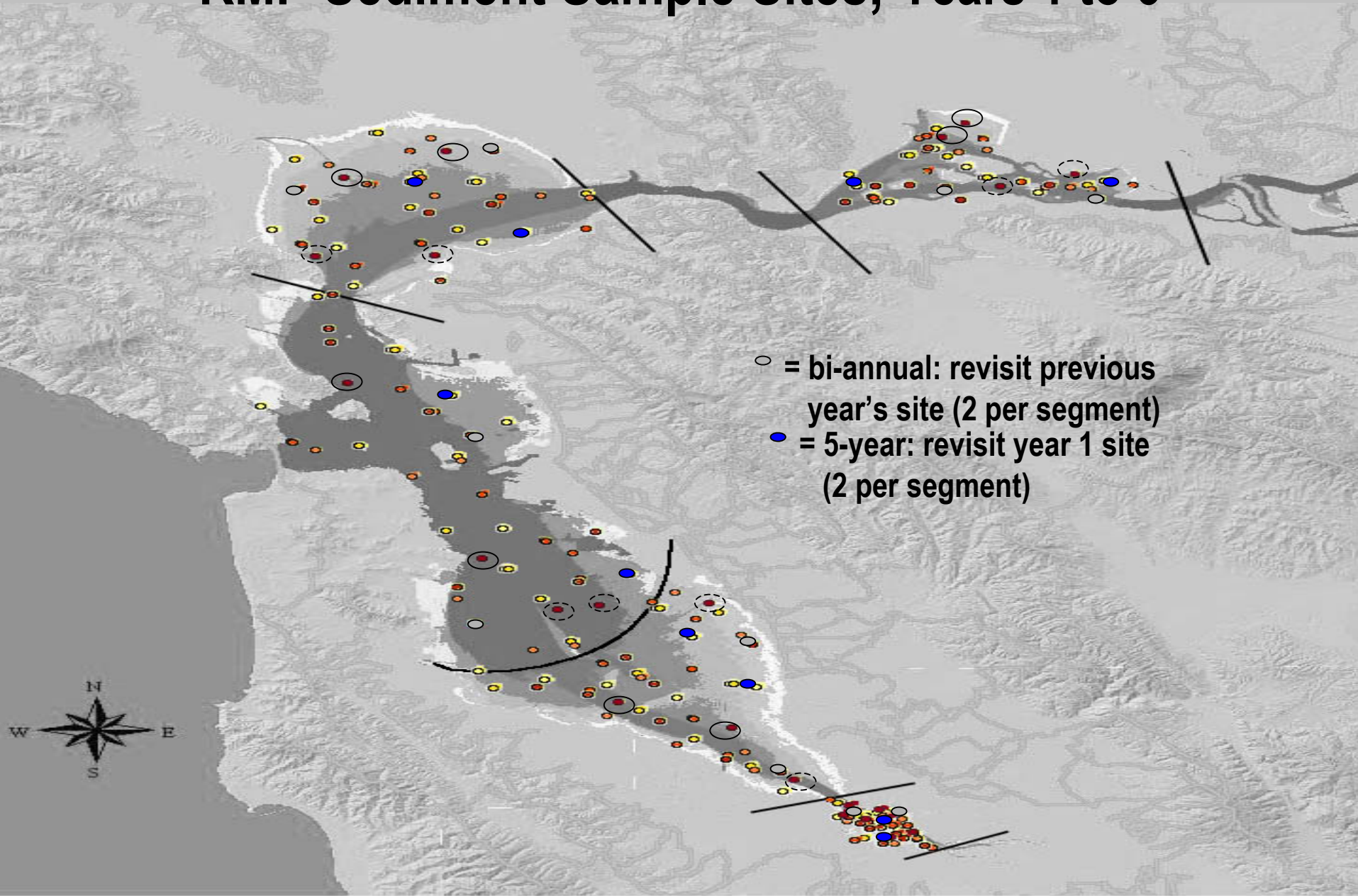
RMP Sediment Sample Sites, Years 1 to 6

○ = bi-annual: revisit previous year's site (2 per segment)

● = 5-year: revisit year 1 site (2 per segment)

Benefits of New Base Program Design

- Data will be truly representative of the Estuary and segments of the Estuary which will result in better evaluation of:
  - temporal and spatial patterns of contamination and toxicity,
  - whether the Estuary or segments of the Estuary exceed WQOs,
  - the proportion of the estuary that is contaminated and/or toxic
- Better geographic spread of stations can be back stratified to evaluate depths and shallows
- Maintains fixed stations at historical stations including water boundaries:
  - provides link with historic RMP data
  - inputs and outputs for conceptual models
  - compare different water years
- Resampling of sediment sites (2, 5, 10, 20 years)
  - decreases variance
  - increases ability for temporal comparison

Conclusions

- The RMP has been extremely valuable to Regional Board priority setting and decision making.

- Continual review and adjustment of the program has allowed the RMP to adapt to regulatory changes and new scientific information.

- The RMP redesign has resulted in a more sophisticated approach to contaminant studies that better meets the needs of the Regional Board.

INFORMATION

- SFEI provides information on the RMP to government agencies, scientists, dischargers and the public:
  - Web Page (www.sfei.org)
  - Annual Report
  - Annual Meeting
  - Peer Reviewed Journals
  - Presentations

FINITO