Executive Summary

The 1995 Regional Monitoring Program (RMP) Annual Report includes monitoring results from the Base Program, Pilot and Special Studies, and summary and perspective articles contributed by RMP investigators and other scientists.

The purpose of the RMP is to provide information on the status and trends of contamination in San Francisco Estuary water, sediment, and bivalve tissue, and to assess the potential for biological effects from exposure to those contaminants. The objectives, background, and rationale for the RMP are described in the Introduction (Chapter 1).

The 1995 RMP Base Program was essentially the same as in 1994. Water monitoring was conducted in February, April, and August at 24 stations throughout the Estuary. Aquatic bioassays were conducted in February and August at 13 of those stations. Sediment monitoring was conducted in February and August at all 24 stations, and sediment bioassays were conducted at 12 of those stations. Bioaccumulation of contaminants by transplanted bivalves was monitored at 15 stations during two 90 day sampling periods: January to April and July to September.

Pilot Studies on benthic fauna and tidal wetlands were conducted and Special Studies on trends in trace elements and development of sediment indicators were also included.

Water Monitoring

Water Quality

Monthly water quality monitoring was conducted by the US Geological Survey (USGS). This component of the RMP describes water quality (e.g., salinity, suspended sediments, dissolved oxygen, etc.) throughout the Estuary (Chapter 2). Their monthly samples provide supplementary information about water quality at the times between RMP Base Program sampling periods.

In general, the patterns of salinity in 1995 reflected the effects of river flow on the distribution of dissolved constituents. Salinity decreased from the Golden Gate into northern San Francisco Estuary during most of the year, whereas salinity in the South Bay was usually homogeneous. This reflects the role of Delta outflow as a continual source of freshwater into the North Bay. The North Bay salinity gradient changed rapidly in response to changing flows during the year. Salinity in the South Bay may be diluted by freshwater arriving from the northern connection to Delta-derived flows, as well as by runoff from the local watershed.

> Salinity patterns reflected the effects of river flow on dissolved constituent distributions.

The patterns of total suspended sediments (TSS) showed that strong freshwater flows deliver new sediments to the Estuary. This is important because concentrations of TSS are directly related to concentrations of many contaminants. TSS was generally lowest in the Central Bay, far from the riverine supplies of sediments and far from the shallow habitats where wind-wave resuspension creates high turbidity.

The potential for biological transformations of dissolved chemicals in water into organic forms was monitored by measuring chlorophyll. Phytoplankton comprise one of the largest components of living biomass in San Francisco Bay. Phytoplankton biomass, as measured by chlorophyll, was usually low in the Bay-Delta. However, during spring blooms in the South Bay, biomass increased rapidly. During these blooms, dissolved inorganic carbon, nitrogen, phosphorus, and silicon, as well as some trace elements (cadmium, nickel, zinc) were removed from water and transformed into organic forms. As the 1995 RMP sampling in April occurred at the end of a two-month bloom, reduced concentrations of those dissolved trace elements were observed in the South Bay samples (pages 15, 20, and 23).

Contaminants in Water

Different contaminants exhibited different patterns of distribution in the Estuary. In 1995, overall, the South Bay had the highest concentrations of both trace elements and trace organic contaminants (Chapter 2). However, concentrations of dissolved copper and nickel were much higher at the Petaluma River suggesting the presence of a source of these elements near that station. The distribution of total (or near-total) concentrations of chromium, copper, lead, mercury, nickel, silver, and zinc reflected the distribution of TSS, with the highest concentrations in the Southern Sloughs and at the Petaluma River, intermediate concentrations at the Northern Estuary and River stations, and lowest concentrations in the Central Bay. Analysis by USGS showed that seven trace elements were well-correlated with TSS in the Estuary (page 53). Concentrations of trace organic contaminants that tend to be associated with particles, such as PAHs, PCBs, DDTs, and chlordanes, also displayed the same basic pattern as TSS; the highest concentrations occurred in the South Bay, lower concentrations in the Central Bay, higher concentrations in the Northern Estuary, and intermediate concentrations in the Rivers. Most dissolved trace organic contaminants, including PCBs, chlordanes, DDTs, HCHs (hexachlorocyclohexanes) and diazinon, were elevated in the South Bay relative to other reaches of the Estuary, with concentrations progressively decreasing from Coyote Creek to the Golden Gate. Diazinon concentrations were highest at nearly all stations in February, reflecting its seasonal usage.

In water, the South Bay had the highest concentrations of most trace elements and trace organic contaminants.

Seasonal variation was also observed in many other contaminants. Total arsenic, near-total cadmium, and dissolved silver, arsenic, cadmium and PAHs were highest in August. Total concentrations of chromium, copper, lead, mercury, nickel, silver, PAHs, PCBs, chlordanes, and DDTs tend to be associated with particles and were often highest in April, coinciding with high concentrations of TSS.

Long-term trends in total trace element concentrations were examined in detail using data collected from April 1989 to April 1995 under the RMP and Pilot Studies that preceded the RMP (pages 78–84). There were no obvious increasing or decreasing trends in trace element concentrations. For certain persistent trace organics, the long-term rate of decline in concentrations appears to be very slow. Data for water organics from the mid-1970s and early 1980s compared to RMP data showed that concentrations of PCBs have generally not declined appreciably, although they have been been banned for decades. Neither have PAHs declined, as continuous sources still exist. DDTs and chlordanes appear to have declined since being banned in the 1970s.

Comparisons to Water Quality Objectives and Criteria

Concentrations of many contaminants were above applicable water quality objectives or criteria. Of the 10 trace elements measured, concentrations of chromium, copper, lead, mercury, and nickel were above applicable water quality objectives or criteria on one or more occasions. Copper, mercury, and nickel were most frequently above objectives or criteria. PCBs were always above EPA criteria, PAHs were frequently above criteria, and DDTs, chlordanes, dieldrin, and diazinon were occasionally above water quality objectives or criteria. The stations with the largest number of concentrations above guidelines were Coyote Creek, the Dumbarton Bridge, and the Petaluma River. The overall pattern of exceedances was very similar in 1994 and 1995.

Copper, mercury, and nickel were most frequently above water quality objectives or criteria. PCBs were always above criteria, PAHs were frequently above criteria, and DDTs, chlordanes, dieldrin, and diazinon were occasionally above objectives or criteria.

Aquatic Bioassays

Aquatic toxicity was observed in only one water sample in 1995, in the *Mysidopsis* (mysid shrimp) test of San Joaquin River water collected in February. However, the presence of some contaminants, particularly organophosphate insecticides, is known to be episodic, with high concentrations entering the Estuary during periods of heavy use and/or high runoff. The lack of significant results in 1995, therefore, does not necessarily mean that the Estuary was free of ambient toxicity for the entire year. RMP sampling at fixed times may have missed elevated pesticides entering the Estuary at other times.

> Aquatic toxicity was observed only in the February *Mysidopsis* test of San Joaquin River water.

Sediment Monitoring

Contaminants in Sediments

Despite the very wet year of 1995, the distributions and concentrations of sediment contaminants in the Estuary remained similar to those in previous years. There were two patterns of trace element concentrations in sediments: 1) average concentrations of arsenic, chromium, copper, nickel, and zinc were highest in the Northern Estuary. Chromium, copper, and nickel were highest at Pinole Point in February, and 2) average concentrations of silver, cadmium, lead, mercury, and selenium were highest in the South Bay and Southern Sloughs. Cadmium, lead, silver, and zinc were highest at San Jose in August. Concentrations of most elements (except arsenic and chromium) were lowest at the stations with the sandiest sediments, particularly at Red Rock, reflecting the influence of sediment-type on sediment contaminant concentrations. For trace organics, sediment concentrations were always higher south of the Golden Gate than in other parts of the Estuary. Concentrations of PCBs and DDTs were lowest at stations with the most sand in the sediments, but PAH concentrations were lowest at the Rivers confluence stations (Chapter 3).

The only consistent seasonal pattern for trace elements was that nearly all concentrations were highest in August at both Southern Slough stations. Seasonally, PAHs were generally highest in February in the South and Central Bays. PCBs were generally highest in August in the South Bay. DDTs were always higher in August than February throughout the Estuary.

Examination of sediment contaminants over the first three years of the RMP showed that trace element concentrations have generally remained constant in all locations since 1993 with no apparent increasing or decreasing trends (page 127–136). There were no observable increasing or decreasing trends in PAHs. However, PAH concentrations were elevated in the Northern Estuary, Central, and South Bays in February 1994. Average PCB concentrations appear to have decreased slightly in the Rivers, Northern Estuary, and Central Bay, and average DDTs appear to have decreased slightly in the Rivers. Average chlordanes have also decreased in most Estuary reaches.

Comparisons to Sediment Quality Guidelines

There are currently no Basin Plan objectives or other regulatory criteria for sediment contaminant concentrations in the Estuary. Effects Range concentrations developed by the National Oceanic and Atmospheric Administration were used by the RMP in the interpretation and assessment of sediment contaminant concentrations in the Estuary (pages 132–138), but hold no regulatory status. As in past years, nickel concentrations in nearly all samples were above the Effects Range-Median (ERM). Nickel is present naturally in serpentine soils abundant in the region. Concentrations in USGS sediment cores were generally constant for centuries. Also similar to past years, concentrations of arsenic, chromium, copper, mercury, nickel, and

> In sediment, arsenic, chromium, copper, mercury, nickel, and total DDT concentrations were usually above the ERLs, and nickel was usually above the ERM.

Sediment bioassays indicated that sediments were toxic at many Estuary stations, but there was no indication of sediment toxicity at San Bruno Shoal, Horseshoe Bay, Davis Point, or Napa River.

total DDTs were usually above the Effects Range-Low (ERL). In 1995, concentrations of several PAH compounds were above ERLs at Alameda. Stations with the greatest number of contaminants above ERLs included Alameda where eight contaminants exceeded ERL concentrations in February, and Honker Bay had six exceedances in each sampling period. The stations with more sand in the sediments had only one or two ERL exceedances (Davis Point, Pacheco Creek, Red Rock, and Sunnyvale).

Sediment Bioassays

Results of the amphipod and larval mussel bioassays indicated that sediments were toxic at many Estuary stations (page 103), but there was no indication of sediment toxicity at San Bruno Shoal, Horseshoe Bay, Davis Point, or Napa River in 1995. Redwood Creek was toxic to amphipods in both sampling periods. Grizzly Bay and the Sacramento and San Joaquin Rivers were toxic to mussel larvae during both sampling periods, but none of the South Bay stations were toxic to larval mussels. Yerba Buena Island was toxic to both amphipods and bivalve larvae in August.

Bioassays conducted over the past six years in the San Francisco Estuary have indicated that toxicity in Estuary sediments was widespread in space and time. Overall, the highest incidence of toxicity occurred at Grizzly Bay where sediments were toxic in 60% of the tests conducted between 1991 and 1996. Toxicity occurred much less frequently in the Central Bay and sediments were never toxic at Davis Point probably due to the low contamination in sandy sediments. The incidence of amphipod toxicity has decreased at most stations since 1991, but bivalve larval toxicity has remained rather constant. The cause of the observed toxicity is not well understood. However, analyses presented show that when more than seven contaminants in sediments exceeded ERL values, toxicity to amphipods was usually observed, suggesting that several contaminants present in low concentrations may cause toxicity. However, the number of contaminants above ERLs was not a good predictor of larval bivalve toxicity (page 106).

The RMP Special Studies on the development of sediment bioassays using the resident amphipod *Ampelisca abdita* showed that they were equally or more sensitive to contamination as other amphipods commonly used in bioassays, but depended on which toxicants were used in the exposures (page 108–115). Since *A. abdita* is a resident of the Estuary, is numerically dominant at many RMP benthic stations, and can be used in controlled sediment bioassays, it could become a powerful indicator for the RMP in attempting to understand sediment contaminant effects.

Benthic Pilot Study

For 1995, this study focused on the identification of “normal” or reference benthic (animals that inhabit sediments) assemblages (communities). Based on monitoring in 1994 and 1995, four benthic assemblages were identified that appear to reflect differences in salinity or sediment types. This information may eventually be useful for comparisons to sites where the benthos is degraded due to contamination or other factors. However, those results are based on only two years of data and require verification through several years of varying environmental conditions. In general, benthic assemblages appeared mostly unimpacted, but indicators of contamination occurred at some sites in the Central Bay, Delta and Rivers suggesting slight impacts.

Bioaccumulation Monitoring

Contaminants in Bivalve Tissues

Bivalves are very useful for assessing the capacity of contaminants in water to accumulate in animal tissues. Lead and nickel were the only trace elements that accumulated substantially above background concentrations (between two and 33 times) in all three bivalve species used in the RMP (Chapter 4). Lead bioaccumulated at all Estuary stations, and nickel at all but one. Cadmium, chromium, copper, selenium, silver, and zinc accumulated between two and nine times above reference levels at one or more stations, but primarily in the South Bay and the Northern Estuary. Arsenic and mercury showed no appreciable bioaccumulation. Arsenic is the only trace element that did not bioaccumulate in any of the three species at any station since the inception of the RMP.

Bivalves accumulate most trace organic contaminants to a much larger degree than trace elements, particularly certain highly fat-soluble compounds. For some compounds, accumulation can be on the order of hundreds of times above initial tissue concentrations measured at control sites. The ratios of the various PAH compounds in tissue was fairly uniform throughout the Estuary, suggesting consistent sources.

In bivalves, lead and nickel were the only trace elements that accumulated above background concentrations. However, nearly all trace organic compounds accumulated substantially.

Many of the chlorinated pesticides showed distinct seasonal differences in bioaccumulation. DDTs, chlordanes, and dieldrin concentrations were elevated at Coyote Creek during the wet sampling period, suggesting that runoff was a source, despite the fact that most chlorinated pesticides have long been banned. PAH concentrations in tissues were also variable between seasons, but without any consistent patterns.

Bivalve tissue concentrations monitored between 1993 and 1995 showed no obvious increasing or decreasing trends for any contaminants. The three-year RMP database suggests that the bioaccumulation potential for oysters is considerably higher than for the other two species in the case of copper, silver, selenium, and zinc, while mussels accumulate lead to a greater extent than the other two species.

Arsenic and most of the trace organic contaminants measured in bivalves were above the MTRL guidelines, but cadmium, nickel, and mercury were below the guidelines.

Comparisons to Tissue Guidelines

For the 1995 Annual Report, Maximum Tissue Residue Levels (MTRLs) were used as a relative yardstick to evaluate how much tissue levels deviate from guidelines (page 140). Arsenic, cadmium, nickel (freshwater only), and mercury are the only trace elements for which MTRLs apply, and as in 1993 and 1994, bivalve tissue concentrations were far below the threshold level for each of these elements, except arsenic. It should be noted, however, that the MTRL for arsenic was exceeded even at the uncontaminated control site. As in previous years, most of the trace organic contaminants measured were above the MTRL guidelines. At Coyote Creek during the wet season, and the Rivers during both wet and dry seasons, tissues were consistently above the MTRLs for most pesticides. PCB and PAH tissue levels were consistently well above MTRLs throughout the Estuary. These same patterns were observed in previous years.

Bivalve Condition and Survival

Survival and biological condition measurements were made to determine if animals were capable of bioaccumulation. However, changes in condition and survival may also reflect exposure to adverse conditions such as elevated salinities or lack of food. Bivalve condition in the dry season was almost always lower than in the wet season for all species (page 159). Mussels condition improved at all stations during the wet season (except Red Rock) but showed approximately 20–45% reductions in condition during the dry season. For the second year in a row, the two stations with the most elevated tissue contaminant concentrations (Napa River, Coyote Creek) also showed pronounced decreases in condition in oysters. Clam condition decreased at all Estuary stations in both the wet and dry seasons. Bivalve condition indices of the last three years are remarkably similar among stations and between the seasons.

Bivalve survival was below 50% during the wet season at Dumbarton Bridge, Redwood Creek, Red Rock, and Pinole Point, and at the Petaluma and Napa Rivers in the dry season. The decreased salinities at many Estuary stations due to the unusually wet year may be partly responsible for those results.

Wetlands Monitoring Pilot Study

Tidal wetlands provide a broad range of ecological services including support of endangered species, filtration of contamination, stabilization of coasts, and regulation of air quality. The RMP Wetlands Pilot Study was initiated in 1995 to provide information about how and where to sample wetlands habitats in order to develop a monitoring program for wetlands that would complement the RMP (page 197).

Two locations believed to represent natural tidal marshes were sampled: China Camp State Park and Petaluma Marsh. These locations were sampled concurrently with the RMP Estuary samples. Contaminant concentrations were consistently higher in Petaluma Marsh than at China Camp. Concentrations of most contaminants were higher in the marshlands than at the adjacent RMP San Pablo Bay station. Contaminant concentrations may be higher in marshes because they are retentive filters washed twice daily by the tides. Concentrations of most trace elements tended to be higher in the channel stations than on the drainage divides, but concentrations of trace organics tended to be much higher on the drainage divides than in the marsh channels. Silver, copper, PAHs, and chlordane concentrations tended to be higher in winter.

The natural physiography of the tidal marsh was shown to be a useful template for a stratified sediment sampling plan. Potential effects of these elevated concentrations on the ecological functions of the tidal marshes remains to be assessed.

Conclusions

RMP results for 1995 indicated that concentrations of several contaminants were high enough to raise concern over possible effects on aquatic biota or human health. The contaminants of concern were generally different in water, sediment, and bivalve tissue. In water, PCBs and nickel were most often above water quality objectives or criteria. In sediments arsenic, chromium, copper, mercury, nickel, lead, and DDTs were above guidelines at most Estuary stations. In bivalve tissues, dieldrin, chlordanes, PAHs and PCBs were usually above the MTRLs at all stations.

The total number of contaminants above the various guidelines at each RMP station provides an indication of where contaminants may be the greatest problem and where they may be the least problem. For water, Coyote Creek and Petaluma River had the largest numbers of water quality exceedances and the Central Bay stations generally had the fewest. For sediments, Alameda and Honker Bay had the most ERL exceedances, and the stations with the coarsest sediments at Red Rock and Davis Point had the fewest ERL exceedances. For bivalve bioaccumulation, most stations had similar numbers of exceedances of MTRLs, but stations in San Pablo Bay had the fewest exceedances.

The potential for biological effects from contamination at each station was evaluated by summing the number of samples that were toxic in bioassays and that had reduced bivalve condition or survival. The Central Bay generally had the fewest indications of biological effects and the Sacramento and San Joaquin Rivers had the most indications of possible biological effects. The San Joaquin River station indicated possible biological effects in about 50% of the measurements made between 1993 and 1995. Grizzly Bay and Napa River indicated biological effects about 47% of the time. It is not yet known what may be causing these measured biological effects.

The Central Bay generally had the fewest indications of biological effects and the Sacramento and San Joaquin Rivers had the most.