CENTRAL SAN FRANCISCO BAY SUSPENDED-SEDIMENT TRANSPORT PROCESSES STUDY AND COMPARISON OF CONTINUOUS AND DISCRETE MEASUREMENTS OF SUSPENDED-SOLIDS CONCENTRATIONS

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Sediments are an important component of the San Francisco Bay estuarine system. Potentially toxic substances, such as metals and pesticides, adsorb to sediment particles. The sediments on the bottom of the Bay provide the habitat for benthic communities which can ingest these substances and introduce them into the food web. The bottom sediments are also a reservoir of nutrients. The transport and fate of suspended sediment is an important factor in determining the transport and fate of the constituents adsorbed on the sediment. Suspended sediments also limit light availability in the bay, which limits photosynthesis and primary production, and deposit in ports and shipping channels, which require dredging. Dredged materials are disposed in Central San Francisco Bay.

The objectives of the Central San Francisco Bay suspended-sediment transport processes study are to estimate which factors determine suspended-solids concentrations in Central Bay and to collect time series of suspended-solids concentrations that are appropriate for 1) continuous monitoring of suspended-solids concentrations and 2) calibration and validation of numerical models. Potentially important factors include semi-diurnal and diurnal tides, the springheap cycle, delta discharge, dredging and dredged material disposal, and wind waves.

Suspended-solids concentration monitoring sites were established at Point San Pablo in December 1992 and at the Bay Bridge in May 1993. At each site, optical backscatterance (OBS) sensors are positioned at mid-depth and near the bottom. The OBS sensors optically measure the amount of material in the water every 15 minutes, and the output of the sensors is converted to suspended-solids concentrations with calibration curves developed from analysis of water samples. The sites are serviced every 1 to **4** weeks to clean the sensors, which are susceptible to biological fouling, and to collect water samples for sensor calibration.

Initial results indicate that the springheap cycle was the factor with the greatest effect on the suspended-solids concentration at Point San Pablo during the winter of 1993, not runoff from the Sacramento-San Joaquin Delta or semidiurnal and diurnal tides. A singular spectrum analysis indicates that the springheap cycle, which accounted for 40 to 50 percent of the signal variation, was the factor with the greatest effect on the data. During the same period, however, the springheap cycle accounted for approximately **2** percent of the water level variation. Suspended-solids concentrations respond to lower tidal frequencies probably because of an accumulation of response caused by slow settling of the fine material compared to higher (diurnal and semidiurnal) tidal frequencies. The springheap component of the suspended-solids concentration lags the springheap tidal component by one or two days. This lag indicates that net resuspension continues after the spring tide and net deposition continues after the neap tide. Runoff from the Sacramento-San Joaquin Delta with relatively high suspended-solids concentration had a smaller effect than the springheap cycle because Point San Pablo was seaward of the freshwater/saltwater mixing zone where flocculation and deposition occurs.

The continuous suspended-solids concentration data can also be used to help place the discrete data collected by the RMP into a proper context. Discrete samples were collected at **16** sites in the Bay 3 times in 1993 — early March, late May, and mid September. Discrete samples were collected one meter below the water surface.

The March discrete data were collected during a high, but diminishing, delta discharge (figure 1). Sites closest to the Central Valley had the greatest suspended-solids concentrations and the least salinity. As the salinity increased in the seaward direction, suspended-solids concentrations decreased. Data collected by Cloem and Cole from USGS R\V Polaris during winter 1993 had a

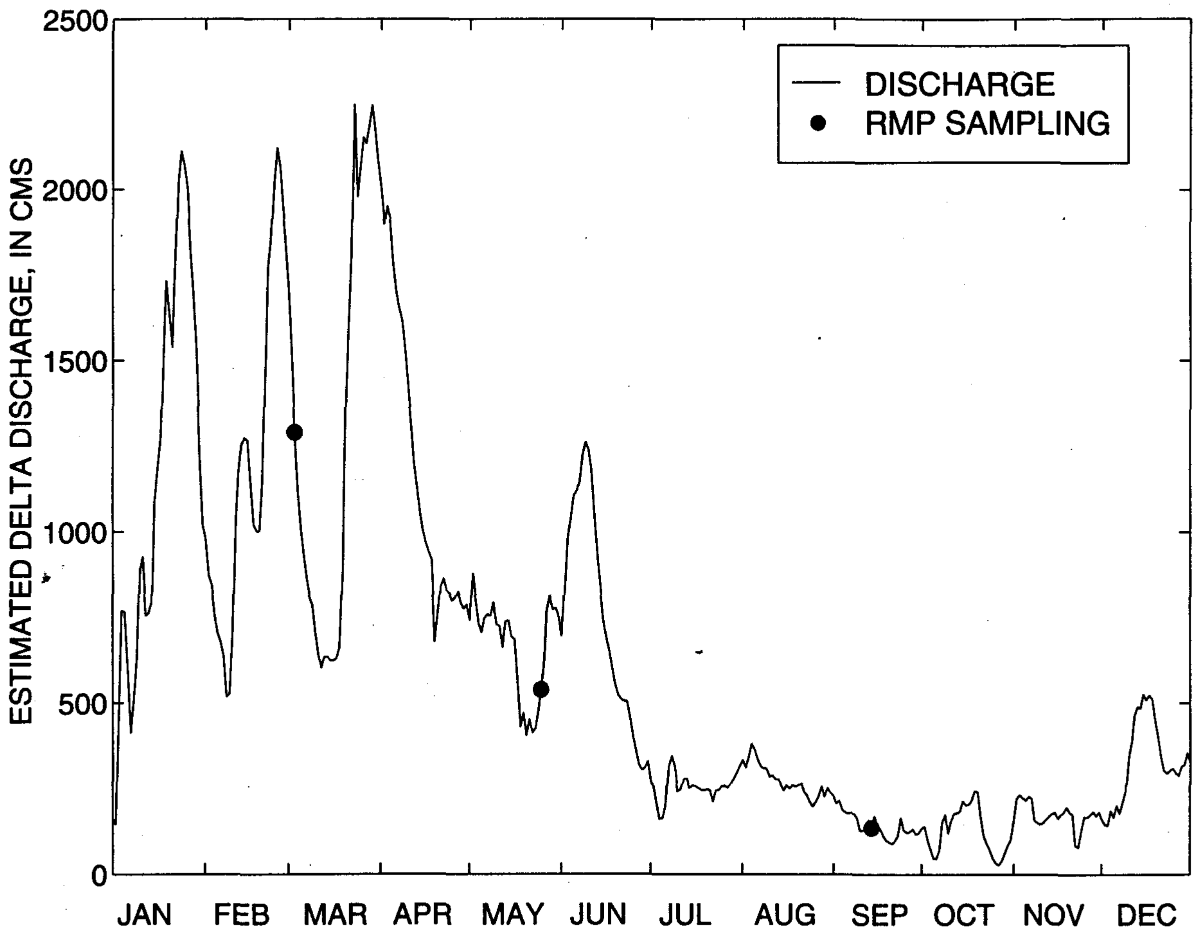

Figure 1. Estimated Delta discharge and times of discrete sample collection in 1993.

similar trend. When the fresh water, which contains relatively high concentrations of clay minerals, mixes with salt water, the clays flocculate and settle. The March discrete data indicate that a similar but less obvious trend may also be present in South Bay. The March discrete data were collected between a neap and spring tide (figure 2). As mentioned earlier, spring/neap variations in suspended-solids concentrations are significant and suspended-solids concentrations lag the spring/neap cycle by 1 to 2 days.

The May discrete data were collected during a moderate but increasing delta discharge (figure 1). An inverse salinity and suspended-solids concentration relation in north bay was also present. The May discrete data was collected during a weak spring tide (figure 2).

The September discrete data were collected during a low delta discharge (figure 1) and near a spring tide (figure 2). The inverse salinity/suspended-solids concentrations relation was not present. For the September and the other discrete data, the Central Bay sites have the lowest suspended-solids concentrations and the more landward sites have the highest concentrations. This is consistent with the usual gradient of suspended-solids concentration that decreases from shallow to deep water and in the seaward direction.

Only one of the discrete sampling sites is located at a continuous USGS suspended-solids concentration monitoring site — the Dumbarton Bridge in South Bay. Only the March 2 discrete sample was collected at a time when the optical OBS sensors at the Dumbarton Bridge were not fouled. Figure 3 shows the continuous data from

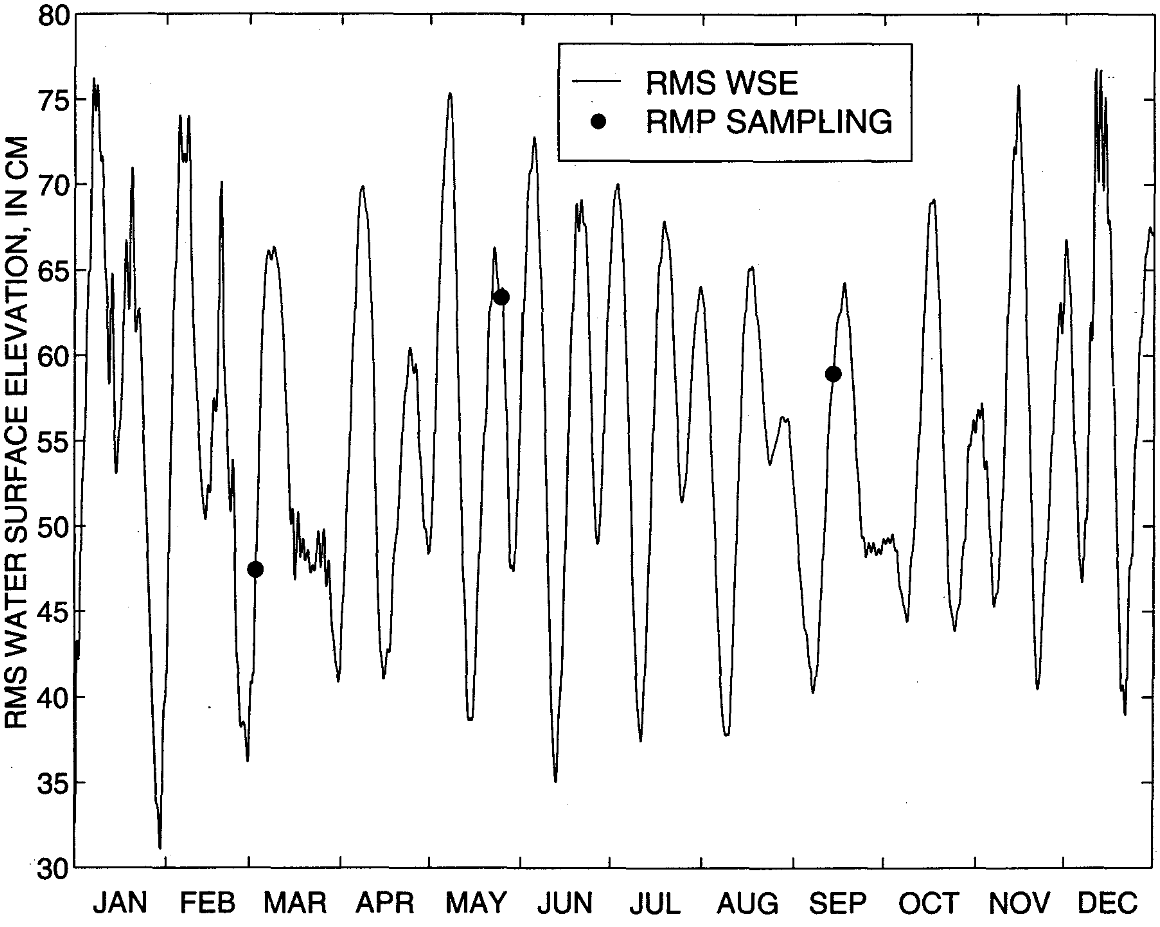

Figure 2. Root-mean-squared water surface elevation (RMS WSE) and times of discrete sample collection in 1993. Larger values of RMS WSE indicate spring tides and smaller values indicate neap tides.

mid-depth and near-bottom OBS sensors and the discrete sample collected one meter below the water surface between 1115 and 1225 hours. A vertical gradient of suspended-solids was present in the water column with greater concentrations near the bed. Predicted ebb velocities and tidal stage for the Dumbarton Bridge are also shown on figure 3. The near-bottom suspended-solids concentration increases with the large near-bottom velocities at 1000 hours and decreases several hours later. Settling from above may have maintained high near-bottom suspended-solids concentrations at the 1400 hour low tide. The additional suspended solids at the mid-depth sensor arrived shortly before low tide — this is a common feature of South Bay data and indicates a landward gradient of suspended-solids concentration with larger values to the south and in shallower water. The discrete sample was collected about the time the increased suspended-solids concentration was detected by the mid-depth OBS sensor.

One of the interesting features of the discrete data was the large suspended-solids concentration at the San Pablo Bay site on May 26, 1993. The closest continuous site is at Point San Pablo, and the mid-depth suspended-solids concentration is shown on figure 4. The Point San Pablo suspended-solids concentration was greatest in the late morning soon after low tide as the concentration increased from 50 to 150 mg/L. The San Pablo Bay discrete sample had a high suspended-solids concentration of 190 mg/L and a fairly high salinity (16.3 ppt). Thus, the high suspended-solids concentration was probably not associated with a large discharge from the nearby Petaluma River but the normal tidal fluctuation

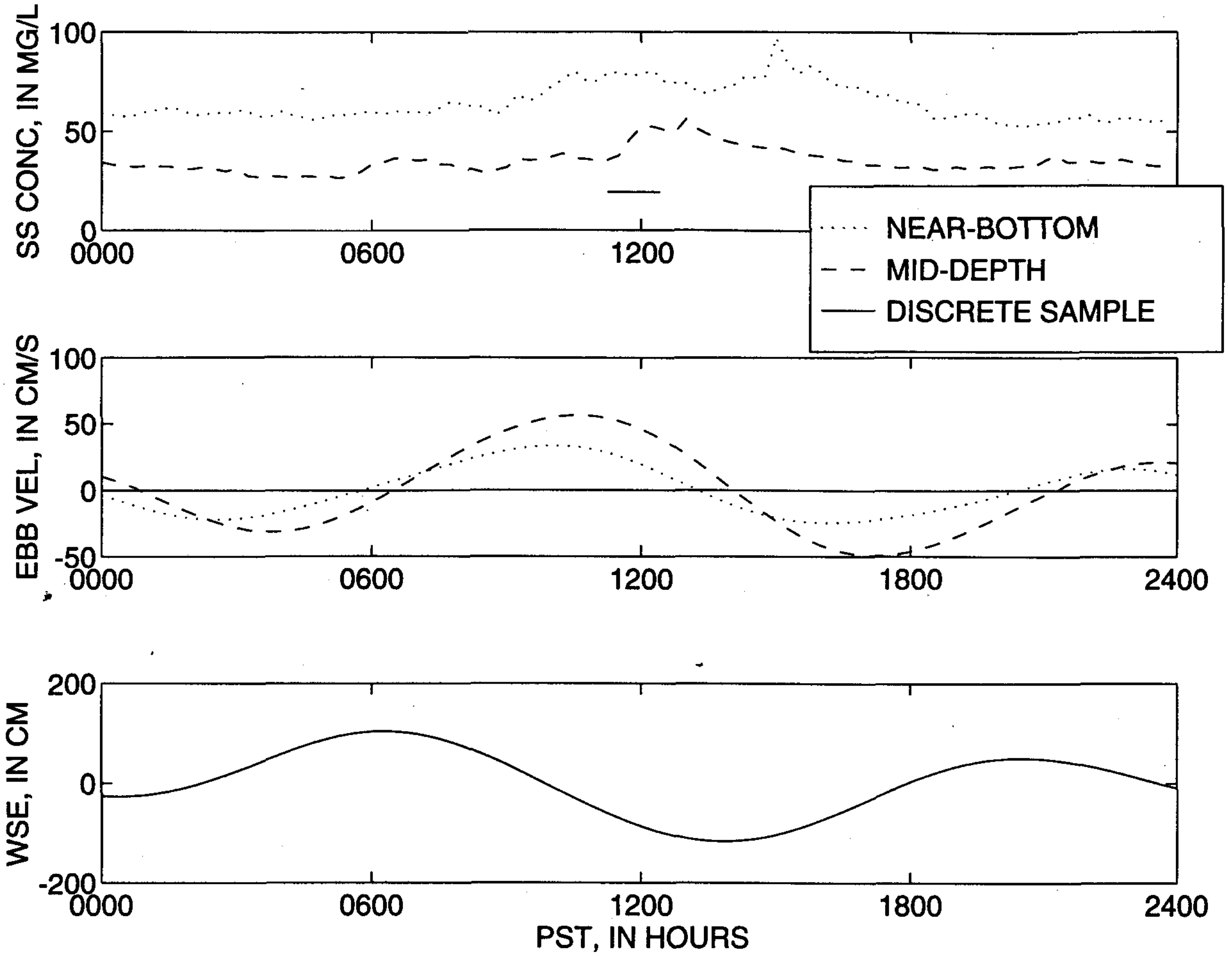

Figure 3. Suspended-solids concentrations, predicted ebb tidal velocities, and predicted water surface elevation at the Dumbarton Bridge on March 2, 1993.

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of suspended-solids concentration. At Pinole Point at mid-day the discrete suspended-solids concentration was 87.5 mg/L, which is high compared to other discrete samples collected that day but is consistent with the magnitude of the tidal variation of suspended-solids concentration at Point San Pablo.

These two examples show that, while the discrete data are useful, they are limited in their spatial and temporal coverage and these limitations must be recognized in any analysis of the synoptic data. Both examples show how suspended-solids concentration can vary during the tidal cycle. Spring/neap variations in suspended-solids concentration are also significant. Differences in suspended-solids concentrations during discrete sampling trips and at discrete sampling sites may largely be caused by collection of samples at different phases of the tidal and spring/neap cycles. Diurnal wind-wave resuspension will also make suspended-solids concentrations dependent on the time of day the sample was collected, especially in or near shallow water (perhaps less than 4 m). Horizontal and vertical gradients of suspended solids also exist in the Bay, so where a sample is collected will also affect its concentration. For example, at the time of sampling at the Dumbarton Bridge on March 2, the suspended-solids concentration varied from 19 to 75 mg/L in the water column. Thus, tidal variations introduce significant uncertainty to the analysis of the discrete data,

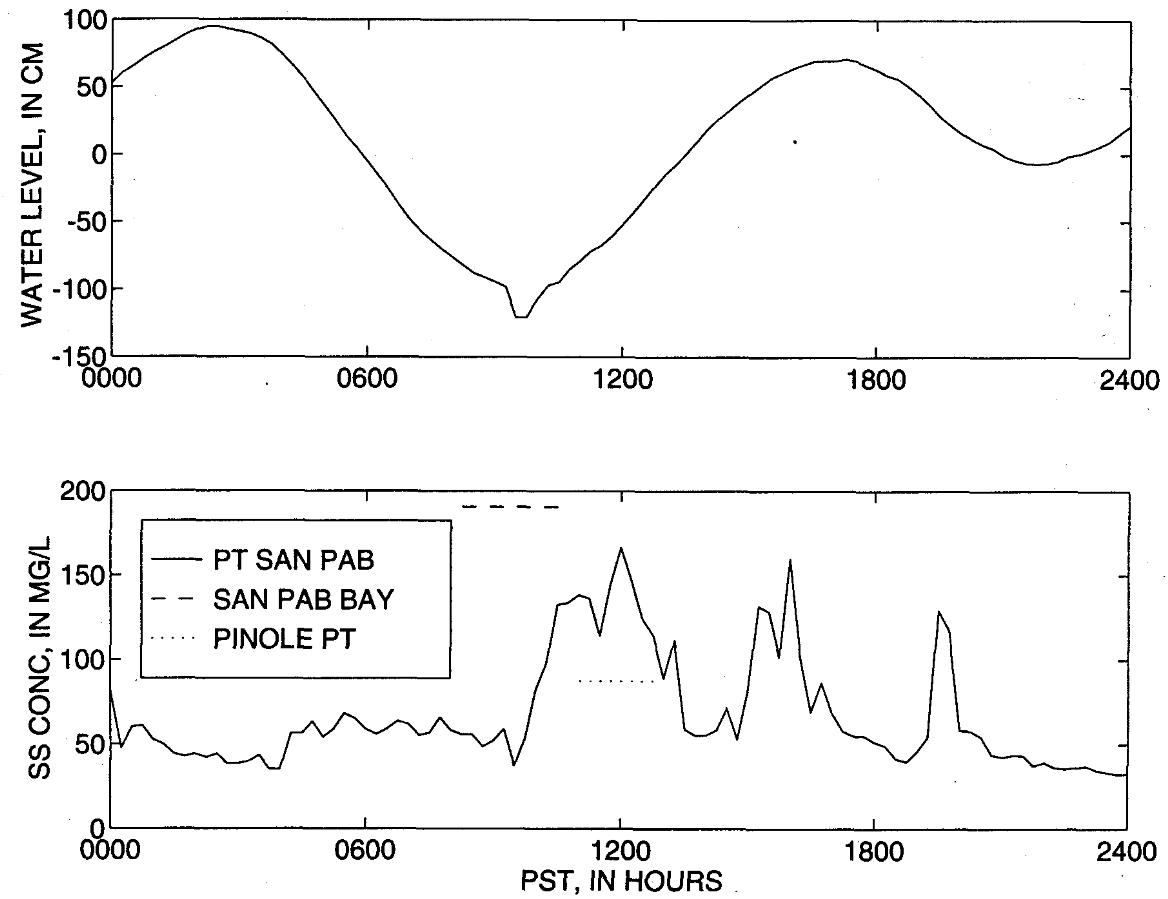

Figure 4. Water surface elevation and suspended-solids concentrations in San Pablo Bay on May 26, 1993.

which is really best viewed as a set of point samples in space and time, nothing more.

Water quality monitoring provides a data base to help better manage the bay and to improve the quality of specific scientific studies, especially as a data base covering several years is developed. Based upon this analysis, possible improvements to the RMP discrete sampling program are:

1. A statement regarding the temporal and spatial limits of the data and information on the time of day, wind, tidal phase, spring/neap cycle, precipitation, and delta discharge should be included with the data.
2. If resources are available, sampling frequency should be increased. It is difficult to analyze variability at a site with a sampling frequency of three samples in one year. Perhaps automatic pumping samplers could be deployed at some sites and collect a single composite sample over a tidal day and these samplers could be serviced monthly. This, however, may not be feasible due to the need to preserve samples.
3. If resources are available, the sampling should be synoptic. Because of the tidal variations, even if samples could be collected in half a day, the sampling would not be synoptic. Perhaps water samples could be collected from several shore sites and vessels simultaneously, preserved, and transported to a laboratory for analysis. Volunteer groups are often willing to loan vessels and captains to such efforts. Although fewer and less

desirable sites probably would be sampled, this scheme would give a true snapshot of water quality in the bay. Samples could be collected at a consistent tidal phase, like a low spring tide at the sampling sites, or at the same time, like when a low spring tide occurs at the Golden Gate. This would significantly reduce the uncertainty caused by tidal variations.

4. If resources are available, collection of data at more than one point in the vertical would reduce uncertainty regarding vertical variability. Additional samples one meter above the bed and at mid-depth help identify vertical gradients.

5. Sampling at sites where continuous water level, salinity, and suspended-solids are being operated would permit data comparisons that would benefit analysis of both discrete and continuous data.

In 1994, the Central Bay suspended-sediment transport processes study will continue operation of the existing sites, install an additional site at the Golden Gate Bridge, monitor suspended-sediment transport processes in shallow water, prepare a report summarizing data collected during water year 1993, further analyze the data, and prepare an interpretive report.