# Sediment Quality

NASSCO Shipyards, located south of downtown San Diego

# *Chapter 2*
# Sediment Quality

## INTRODUCTION

The quality of sediments in San Diego Bay has historically been altered by human activity (USDoN, SWDIV and SDUPD 2000). Major anthropogenic disturbances have included the removal and displacement of sediments by channel dredging, and the direct input of sewage, industrial wastes and pesticides. For example, the use and disposal of petroleum products (e.g., oils, paint sludge, diesel fuel, and creosote) throughout the Bay introduced high levels of polycyclic aromatic hydrocarbons (PAHs) into the sediments. Moreover, various metals have been released to the water and sediments through the leaching of hull paints, and from the disposal of industrial wastes.

Many of the above contaminants have accumulated within shipyards and marinas where fine sediments often accumulate. Fine particles tend to sorb and transport biological wastes, organic chemicals, gases, and other pollutants because of their chemical make-up and physical structure (i.e., high surface area per unit weight volume) (Manahan 2000). Consequently, elevated levels of pollutants are often correlated with the distribution of fine sediments. Sediment distribution within bays is, in turn, affected by a complexity of factors, such as tidal influence, current velocity, sedimentary input, the presence or absence of large structures (e.g., piers or docks), channel dredging, and breakwaters (USDoN, SWDIV and SDUPD 2000). The analysis of contaminant loads as well as percentages of silt and clay provides useful information on sediment conditions, which also influences the distribution of organisms living within the Bay.

This chapter presents summaries and analyses of sediment grain size and chemistry data collected in San Diego Bay in conjunction with the Bight'98 regional survey. The major objectives of this chapter are to describe the physical sediment characteristics within the Bay, and to assess overall sediment quality with respect to the presence and distribution of various chemical contaminants. In addition, sediment conditions in San Diego Bay are compared to those of the other bays and harbors sampled during the Bight'98 survey.

## MATERIALS & METHODS

### Field Sampling

Sediment samples were collected at 46 randomly selected stations within San Diego Bay during July and August of 1998 (Figure 2.1). The stations ranged in depth from 3.0 to 15.6 m and encompassed an area extending from the Ballast Point Naval Facility at the bay entrance to the Coronado Cays Marina located in the back region of the Bay. Samples for sediment chemistry and particle size analyses were obtained using a modified 0.1 $m^2$ chain-rigged van Veen grab. These samples were taken from the top 2 cm of the sediment surface and processed according to procedures described in the Bight'98 field manual (FSLC 1998).

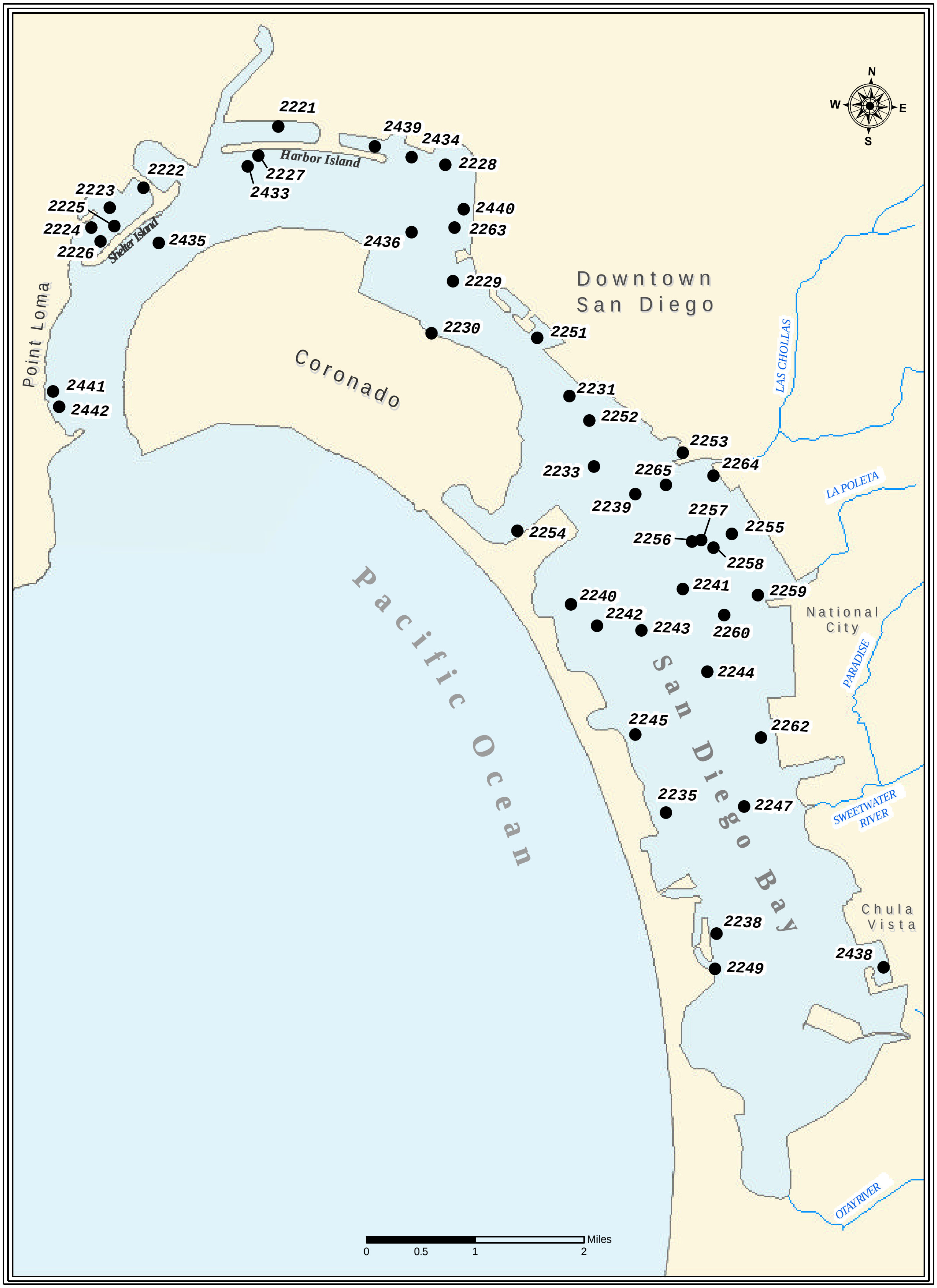



**Figure 2.1**

Sediment quality stations sampled in San Diego Bay during 1998.

## Laboratory Analyses

Analyses of sediment particle size and the presence of chemical constituents were performed by the City of San Diego Wastewater Chemistry Laboratory, the City of Los Angeles Hyperion Wastewater Laboratory, and the Southern California Coastal Water Research Project. Each sediment sample was analyzed for the presence of two indicators of organic loading, 18 metals, 24 polycyclic aromatic hydrocarbons (PAHs), 41 polychlorinated biphenyl compounds (PCBs), a biocide, and 28 chlorinated pesticides (see Appendix B.1). Details of the analytical techniques employed are available in Noblet et al. (2002). Samples for grain size analysis were first sieved through a 1.0 mm mesh screen in order to separate the coarse and fine sediment fractions. The fraction of coarse sediments (e.g., coarse sand, gravel, and shell hash) in each sample was determined by measuring the weight of particles retained on the sieve (i.e., > 0 phi), and was expressed as the percent weight of the total sample. Analysis of the fine fraction was performed using either: (1) a Horiba LA-900 laser analyzer, which measures particles from zero to10 phi in size (i.e., 1.0 - 0.00098 mm in diameter); or (2) a Coulter LS230 particle size analyzer that measures particles from -1 to12 phi (i.e., 2.0 - 0.00024 mm in diameter). Sand was defined as all particles ranging in size from zero to 4 phi, while fine sediments included all particles > 4 phi.

## Data Analyses

***San Diego Bay***

The sediment grain size composition at each station was characterized by calculating median and mean phi size, the sorting coefficient (i.e., standard deviation), and the percent fines (i.e., percent of silt and clay combined). Most of these parameters were calculated using the normal probability scale described by Folk (1968) based on whole phi sizes; however, percent fines were calculated using half phi sizes. Patterns in the sediment chemical composition were analyzed using area means and quartile plots generated for the following parameters: total nitrogen (TN), total organic carbon (TOC), metals, PAHs, PCBs, and pesticides. The concentration of many of these compounds, however, fell below laboratory method detection limits (MDLs). Any concentration reported at less than the MDL was set to zero for the calculation of mean values. In contrast, such concentrations were omitted from the quartile ranks. Covariance among the above parameters was tested using Pearson correlation coefficients. Levels of sediment contamination in San Diego Bay were further evaluated by comparing the results of this study to several previously established sediment quality guidelines. These guidelines include the Effects Range-Low (ERL) and Effects Range-Medium (ERM) of Long et al. (1995), and the Threshold Effects Level (TEL) and Probable Effects Level (PEL) of MacDonald (1994).

***Comparison of San Diego Bay to Other Embayments***

Sediment samples were collected from 114 stations distributed among San Diego Bay and eight other bays and harbors during Bight'98. From north to south these embayments were Ventura Harbor, Channel Islands Harbor, Marina Del Rey, Los Angeles/Long Beach Harbor, Anaheim Bay, Newport Bay, Dana Point Harbor, Mission Bay, and San Diego Bay. Differences in the sediment conditions among these embayments were evaluated by comparing particle size composition (i.e., percent fines) and concentrations of TOC, TN, various metals, total PCBs (tPCBs), total PAHs (tPAHs), and pesticides (i.e., total DDT, chlordane). Means, standard deviations, and confidence intervals were determined for detected values of these parameters. In order to address the inherent differences in analytical techniques and instrumentation among the different participating agencies, the highest MDL for each chemical constituent was used in all inter-bay comparisons

## RESULTS

### San Diego Bay

***Sediment Grain Size***

The percentage of fine sediments at a station in San Diego Bay ranged from 10 to 91%, with the median phi size ranging between 2.3 and 6.0 (Appendix B.2). Sites with the highest percent fines were usually located near or within small boat marinas or shipyards for large vessels (Figure 2.2). These include two sites near Naval Station San Diego (stations 2257, 2264), one site near the 10$^{th}$ Avenue Marine Terminal (station 2251), three sites within Shelter Island Yacht Basin (stations 2222, 2223, 2226), and two sites near Naval Submarine Base San Diego, located at Ballast Point near the mouth of the Bay (stations 2441, 2442). The finest sediments occurred at station 2226 within the Shelter Island Yacht Basin. In contrast, the coarsest sediments were typically found at sites in the middle of the Bay. An exception to this pattern occurred at station 2230, which is an exposed area located along the east side of Coronado Island and where the coarsest sediments were found.

***Indicators of Organic Loading***

Concentrations of total nitrogen (TN) and total organic carbon (TOC) in San Diego Bay sediments ranged from about 0.03 to 0.24% and 0.20 to 2.01%, respectively (Appendix B.2). These indicators were strongly correlated with each other ($r = 0.92$, $p < 0.05$) and had similar patterns of distribution within the Bay. Concentrations of TN and TOC were also strongly correlated with percent fines ($r > 0.84$, $p < 0.05$), and their distribution patterns were consistent with that described above for percent fines (see Figure 2.2). The highest concentrations of both TN and TOC were found at one site near the southeast entrance to Las Chollas Creek (i.e., station 2264), one site near the 10$^{th}$ Avenue Marine Terminal (i.e., station 2251), one site in the Shelter Island Yacht Basin (i.e., station 2226), and at two sites near Naval Submarine Base San Diego where storm drains and a bait barge are located (i.e., stations 2441, 2442). The lowest concentrations of both organic indicators were located primarily in the central portions of the Bay where channel dredging has occurred.

***Metals***

Metal contamination was widespread in San Diego Bay sediments, with every station containing measurable quantities of at least 15 different metals. Antimony and thallium were detected at less than half the stations, and tin was not detected at all (Appendix B.3).

The highest concentrations of metals were found where the percent of fine sediments was high. These included sites near Naval Station San Diego (i.e., stations 2264, 2257, 2258) and within or near small boat marinas and commercial piers (i.e., stations 2222, 2226, 2263, 2251). The concentrations of several metals (i.e., aluminum, arsenic, barium, chromium, copper, iron, manganese, nickel, zinc) were strongly correlated with the percentage of fine sediments ($r > 0.69$, $p < 0.01$). Aluminum and iron are naturally occurring elements in silt and clay bearing minerals and are considered to be normalizers. Normalizers can be used to account for natural mineralogical variations and provide baseline relationships with which to assess metal enrichment (Schiff and Weisberg 1998). In this survey,

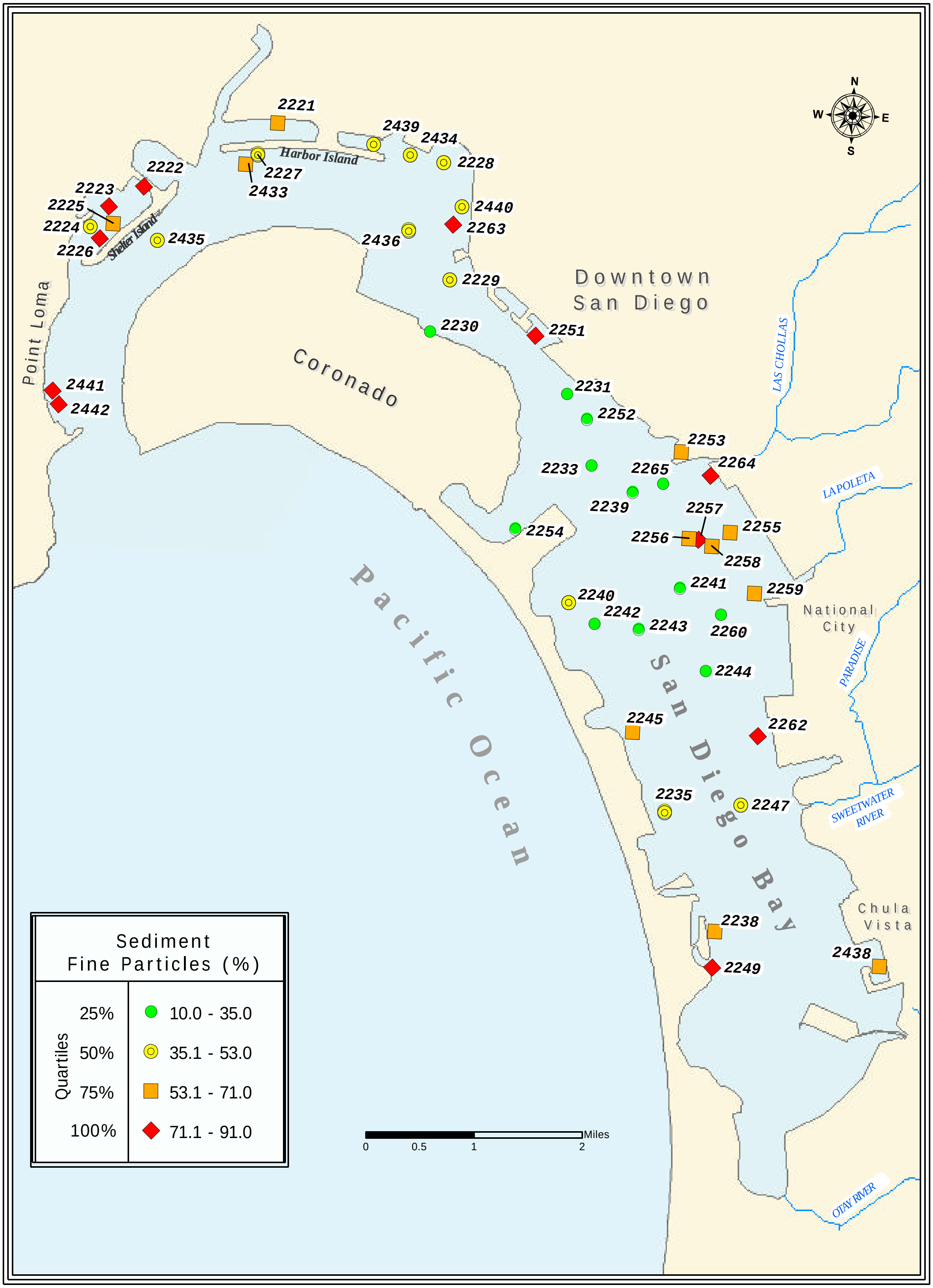



**Figure 2.2**
Quartile distributions of percent fine sediments for San Diego Bay during 1998.

**Table 2.1**

Summary of sediment contaminant loads for San Diego Bay during 1998 compared to available sediment screening criteria developed by the State of Florida (TEL/PEL: MacDonald 1994) and NOAA (ERL/ERM: Long et al. 1995). N = 46, except for cadmium and silver where n = 40; % Exceed = percent of detected values that exceeded threshold values (TV).

| | Metals (ppm) | | | | | | | | | | tPAH | tDDT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **As** | **Sb** | **Cd** | **Cr** | **Cu** | **Pb** | **Hg** | **Ni** | **Ag** | **Zn** | **(ppb)** | **(ppt)** |
| # Detected | 46 | 19 | 38 | 45 | 46 | 46 | 45 | 44 | 36 | 46 | 34 | 7 |
| **TEL** | | | | | | | | | | | | |
| %Exceed | **35** | **–** | **0** | **24** | **96** | **43** | **91** | **32** | **22** | **59** | **21** | **14** |
| (TV) | 7.24 | na | 0.676 | 52.3 | 18.7 | 30.24 | 0.13 | 15.9 | 0.733 | 124 | 1684 | 3890 |
| **ERL** | | | | | | | | | | | | |
| %Exceed | **22** | **100** | **0** | **0** | **91** | **17** | **91** | **2** | **11** | **39** | **9** | **57** |
| (TV) | 8.2 | 2 | 1.2 | 81 | 34 | 46.7 | 0.15 | 20.9 | 1 | 150 | 4022 | 1580 |
| **PEL** | | | | | | | | | | | | |
| %Exceed | **0** | **–** | **0** | **0** | **35** | **2** | **9** | **0** | **0** | **4** | **0** | **0** |
| (TV) | 41.6 | na | 4.21 | 160.4 | 108.2 | 112.18 | 0.7 | 42.8 | 1.77 | 271 | 16771 | 51700 |
| **ERM** | | | | | | | | | | | | |
| %Exceed | **0** | **100** | **0** | **0** | **0** | **0** | **9** | **0** | **0** | **2** | **0** | **0** |
| (TV) | 70 | 2.5 | 9.6 | 370 | 270 | 218 | 0.7 | 51.6 | 3.7 | 410 | 44792 | 46100 |

the range of concentrations of iron and aluminum within the Bay had similar distributions to most of the other metals.

Fairly et al. (1996) concluded that five metals (i.e., chromium, copper, lead, mercury, zinc) should be considered contaminants of concern in San Diego Bay based on their concentrations in sediments or their potential for causing detrimental effects. Stations with the highest concentrations of these five metals occurred near naval shipyards and marinas (Figures 2.3-2.7). Copper, mercury, and zinc were the most prevalent of these metals in the Bay and also occurred in the highest concentrations.

Four sediment quality criteria (TEL < ERL < PEL < ERM) were available for 10 of the 18 metals listed in Appendix B.1 (see Table 2.1). Of these metals, all except cadmium were detected at concentrations that exceeded at least one of the four sediment quality criteria thresholds. Exceedences of the lower-level criteria (i.e., TEL and ERL) ranged from 22 to 96% and from 2 to 100%, respectively. Moreover, many stations contained concentrations of metals that exceeded the TEL/ERL for three or more metals (Table 2.2). Two metals of concern, copper and mercury, exceeded these criteria at over 90% of the sites. Fewer metals exceeded the higher level PEL and ERM screening thresholds at which toxic effects are likely (Table 2.1). For example, the PEL was exceeded by copper, lead, mercury, and zinc in 2-35% of the sediment samples, while the ERM was exceeded by antimony, mercury, and zinc in 2-100% of the samples. Although antimony was detected at less than half the stations sampled, it was found in relatively high concentrations (i.e., >5.0 ppm) that exceeded the ERM 100% of the time.

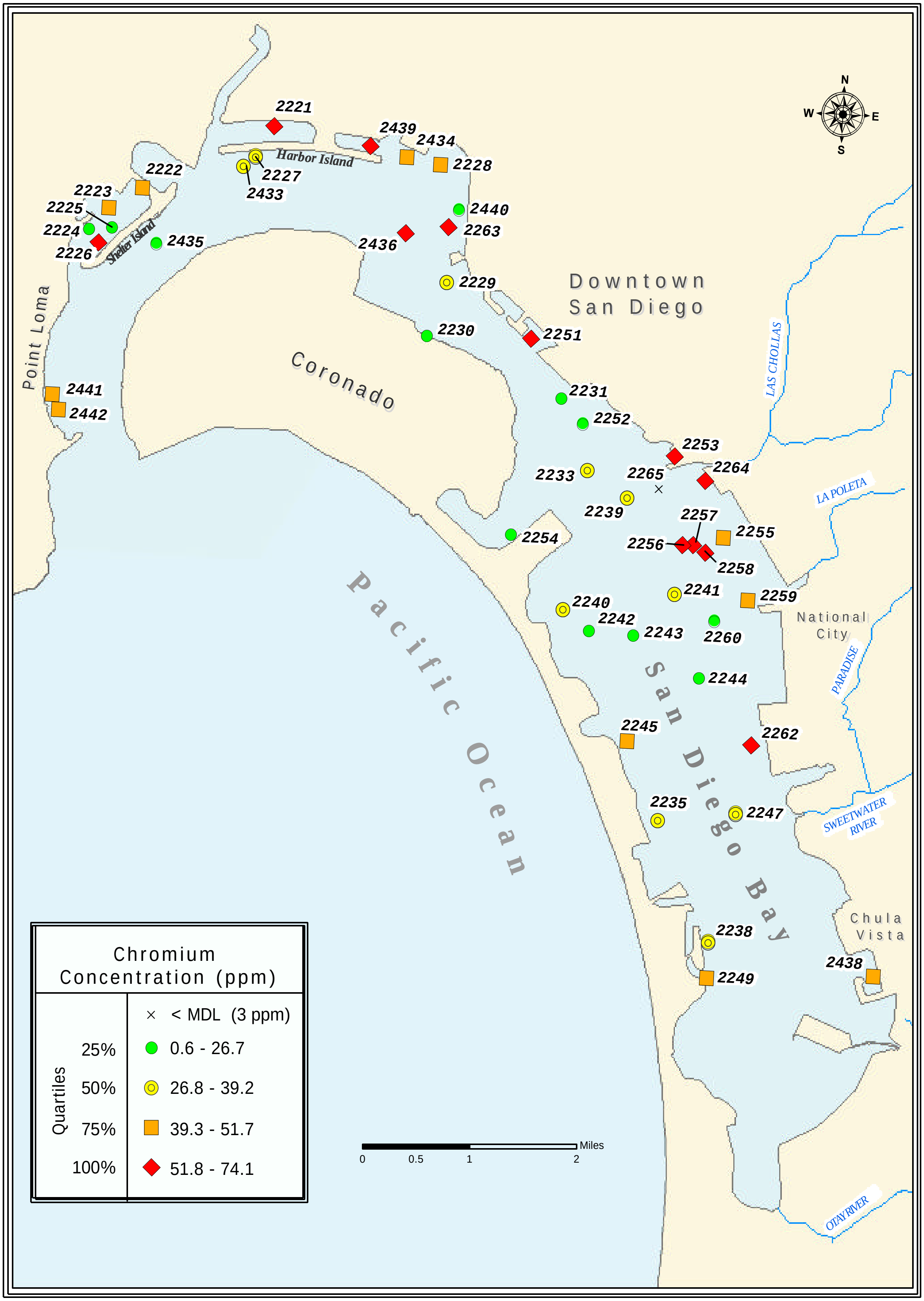



**Figure 2.3**

Quartile distributions of chromium concentrations (ppm) in San Diego Bay sediments during 1998.

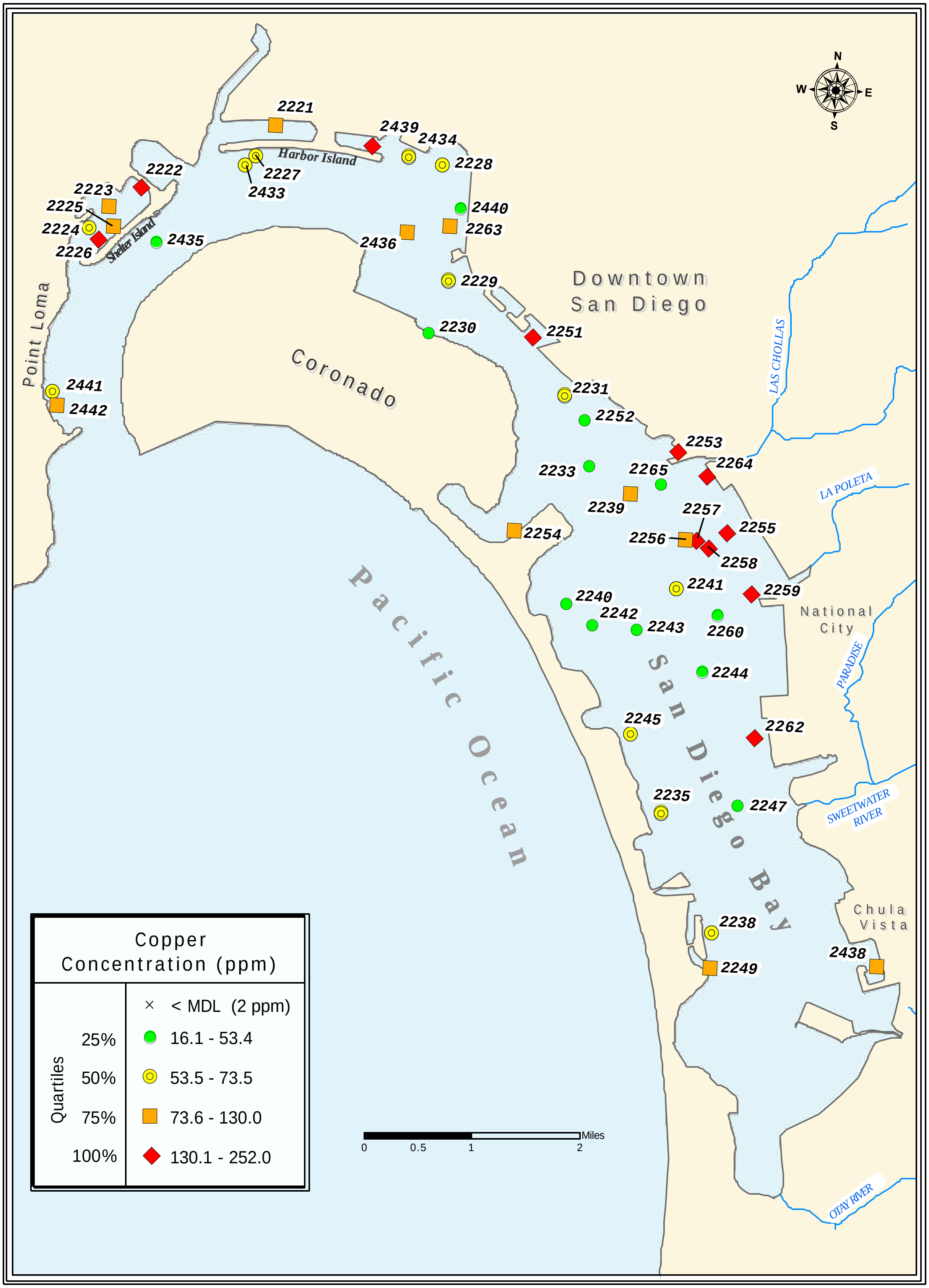



**Figure 2.4**

Quartile distributions of copper concentrations (ppm) in San Diego Bay sediments during 1998.

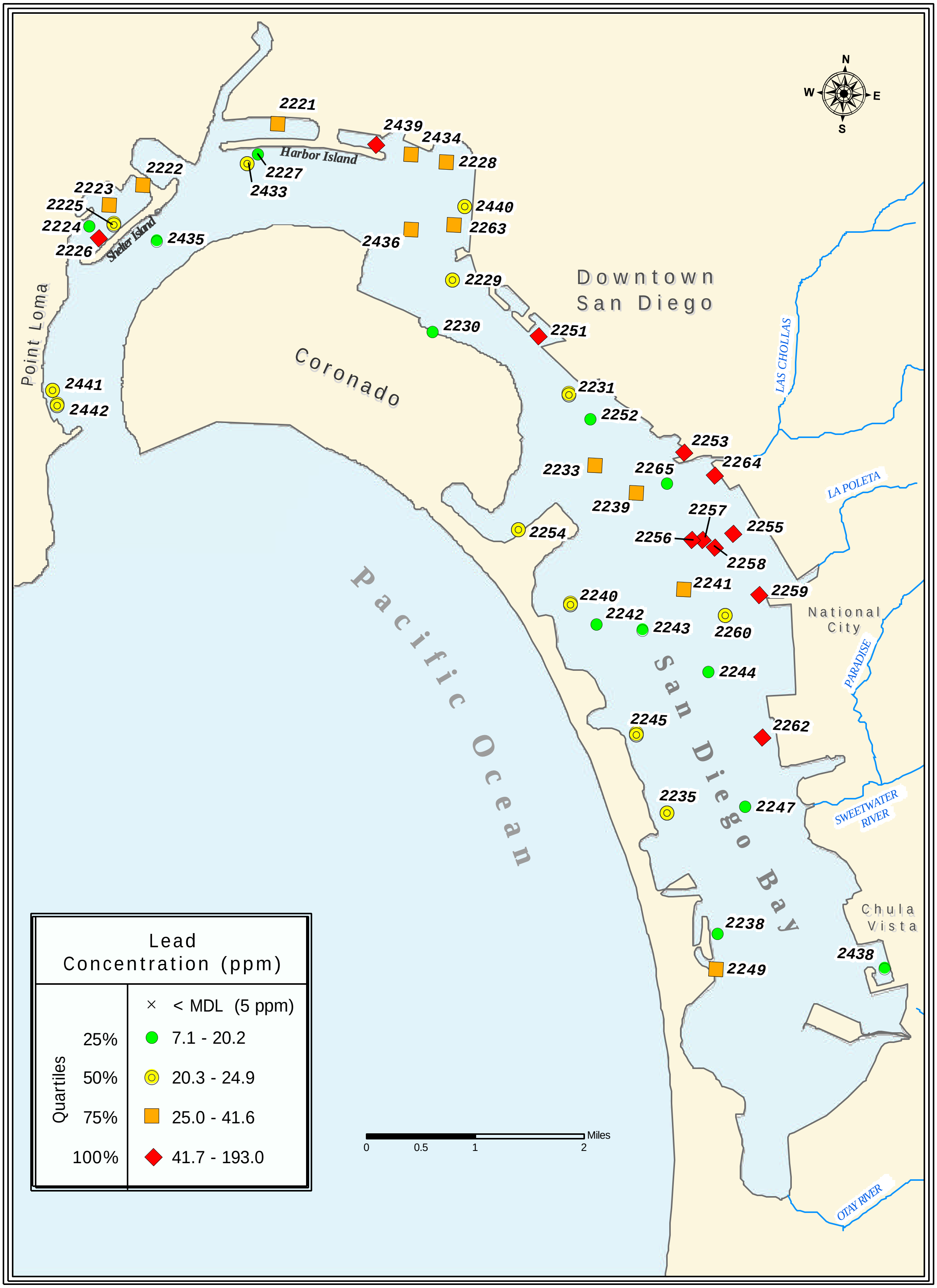
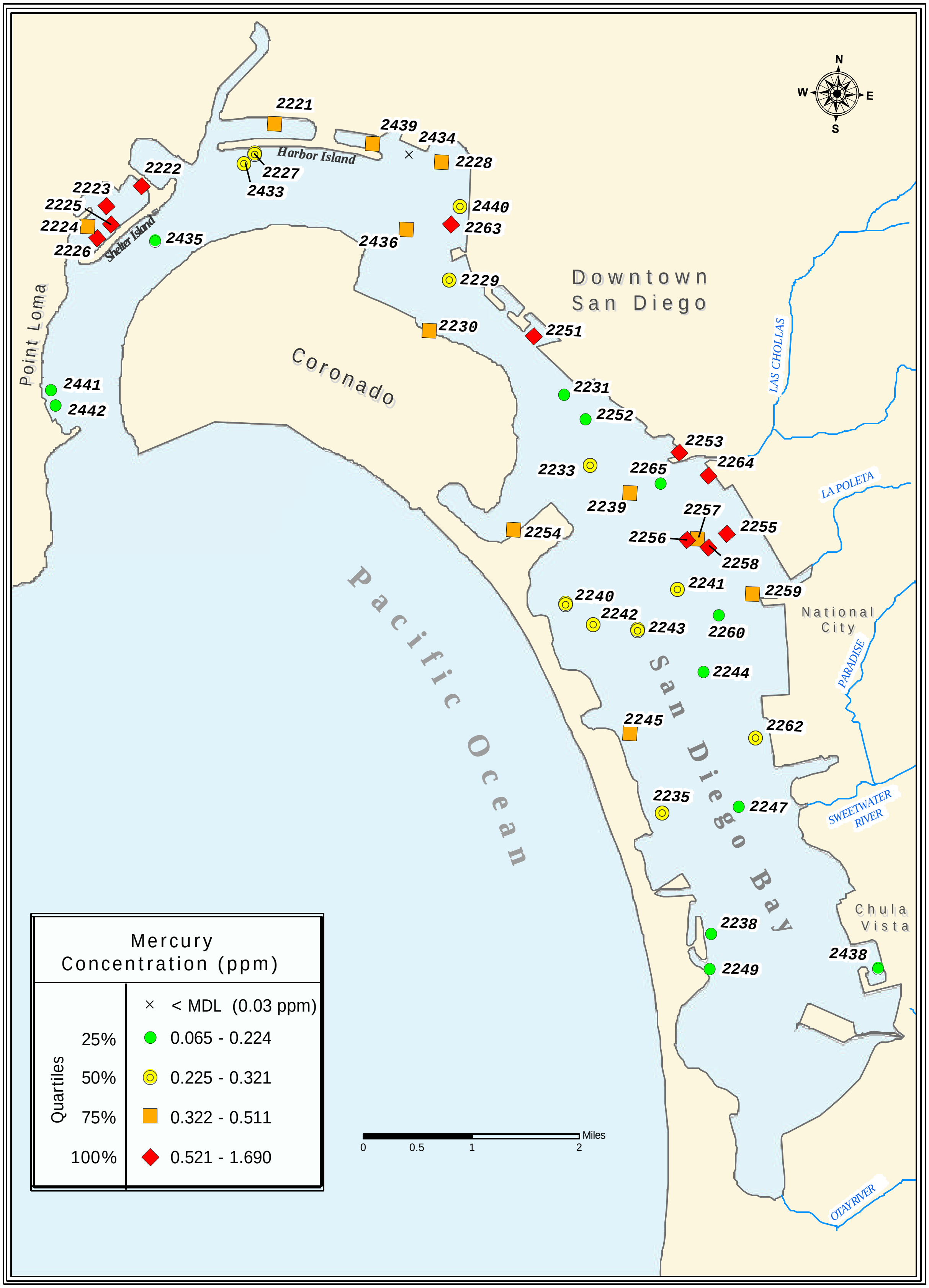



**Figure 2.5**

Quartile distributions of lead concentrations (ppm) in San Diego Bay sediments during 1998.




# Figure 2.6

Quartile distributions of mercury concentrations (ppm) in San Diego Bay sediments during 1998.

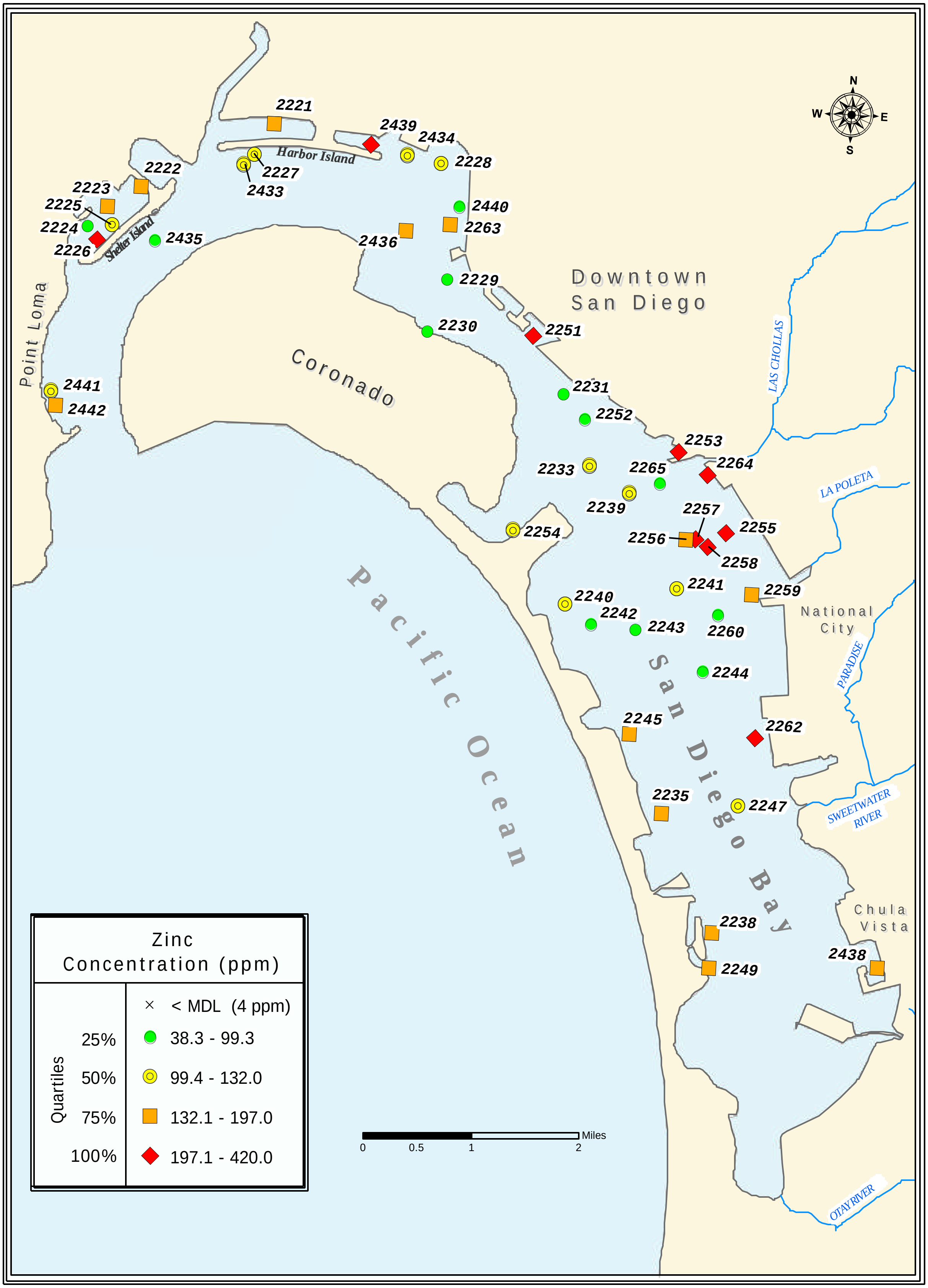



**Figure 2.7**

Quartile distributions of zinc concentrations (ppm) in San Diego Bay sediments during 1998.

### *Polycyclic Aromatic Hydrocarbons (PAHs)*

PAHs were detected in the sediments at 34 of the 46 stations sampled in San Diego Bay. Total PAH concentrations ranged from 16 to 10,768 ppb, with the highest concentrations occurring primarily within naval installations and large shipyards (Figure 2.8, Appendix B.4). For example, the highest concentrations were found in sediments located near the naval submarine station at Ballast Point (i.e., station 2442) and within the naval shipyard for small vessels in Glorietta Bay (i.e., station 2254). In contrast, the lowest PAH concentrations generally occurred in sediments in open areas of the Bay where tidal flushing is relatively strong. This distribution pattern is similar to that shown for both fine sediments and metals. In addition, most stations that exceeded the lower-level ERL and TEL sediment screening thresholds for tPAH occurred among naval facilities or small boat marinas (Table 2.2).

### *Polychlorinated Biphenyl Compounds (PCBs)*

PCBs were detected in sediments at 12 of the 46 stations sampled. These stations were located primarily in large shipyards, naval facilities, and along downtown waterfronts (Figure 2.9). Total PCB levels ranged from 1,500 to 123,800 ppt (Appendix B.5). The highest concentrations were found near the NASSCO shipyard (i.e., station 2253), the mouth of Las Chollas Creek (i.e., station 2264), and in Harbor Island East Basin near the mouth of Convair Basin, a PCB toxic cleanup site (i.e., station 2439).

The levels of PCB contamination reported during this survey were less than those detected previously for San Diego Bay (e.g., Fairey et al. 1996, USDoN, SWDIV and SDUPD 2000). The apparent decline in reportable values may reflect differences in the methods used to quantify PCB levels rather than an actual reduction of PCB contamination in the Bay. Factors that may affect MDLs and reported PCB concentrations include: (1) Sample size - larger samples produce higher concentrations of target analytes, increasing the potential for detectable quantities; (2) Detection limits used to qualify data – a Practical Quantification Limit produces fewer detected values and false positives than a statistical Quantification Limit; and (3) Tertiary Mass Spectrometry (TMS) confirmation - a third level of qualitative confirmation that differentiates between various congeners but with less sensitivity than the primary and secondary Electron Capture Detectors (ECD). Because PCB congeners are particularly vulnerable to false positive readings due to the regularity of their molecular weight and structure, City of San Diego staff used TMS to confirm each result that indicated the detection of a specific PCB on the two ECDs. The target analyte in question must have been above the detection limit of the TMS to be considered a reportable value. The use of TMS to confirm the presence of each detected PCB likely created the discrepancy in reported values between this and previous San Diego Bay surveys. Never-the-less, data reported herein are consistent with patterns of contamination found in previous studies (e.g., SAIC 1998).

### *Pesticides and Biocides*

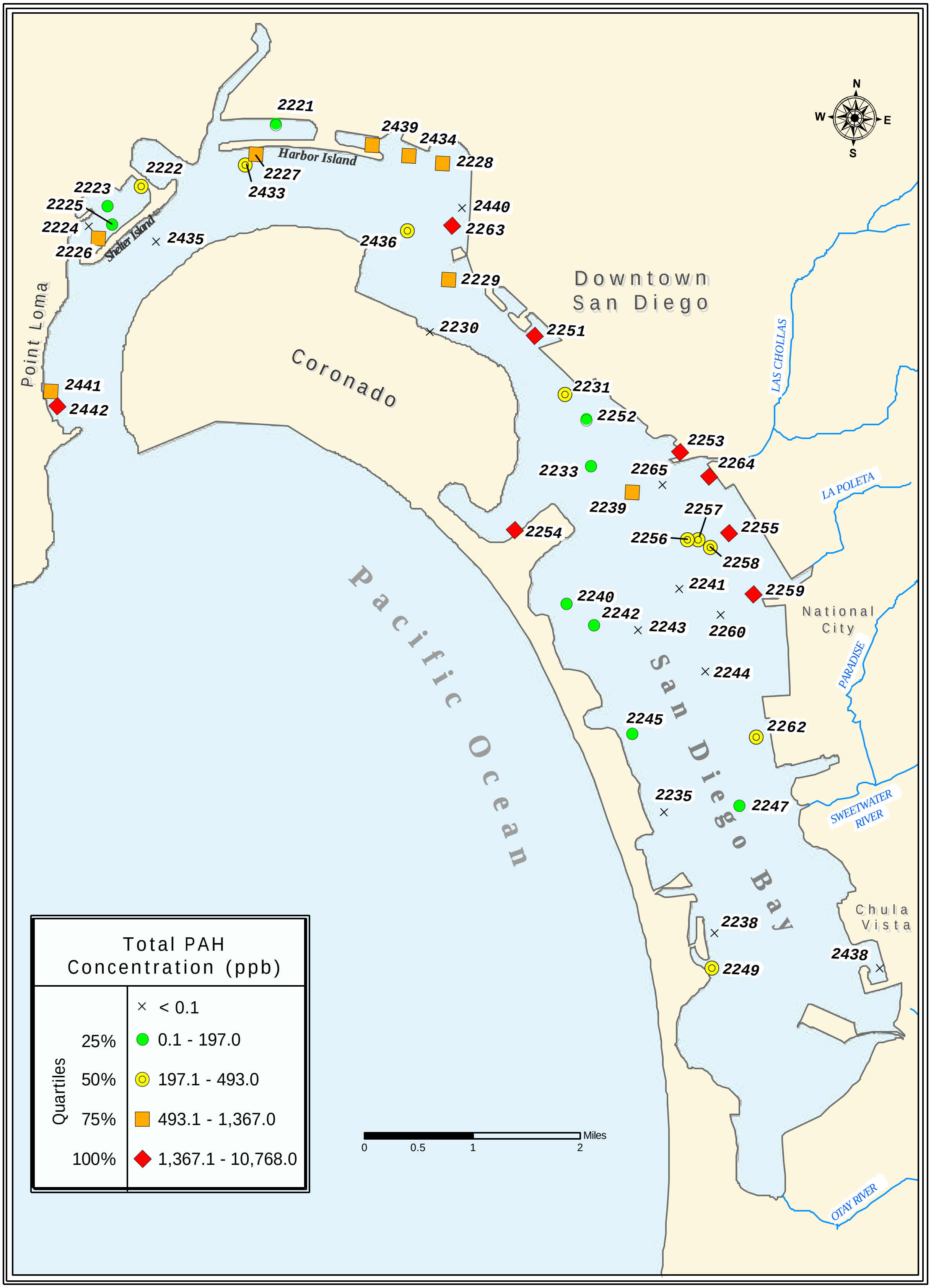
DDT was the only pesticide detected in San Diego Bay sediments in 1998. It occurred at only seven of the 46 San Diego Bay stations. Total DDT (tDDT) concentrations ranged from 780 to 7,300 ppt (Appendix B.6), and four stations exceeded the lower level ERL/TEL sediment screening criteria (Tables 2.1 and 2.2). These four sites were in the central portion of the Bay located near the NASSCO shipyard (i.e., station 2253), Las Chollas Creek (i.e., station 2264), Naval Station San Diego (i.e., station 2255), and near the Naval Amphibious Base at Glorietta Bay (i.e., station 2242). The station near the mouth of Las Chollas Creek had the highest tDDT concentration. Chlordane was not detected in any sediment sample during the 1998 survey, although this pesticide had been considered a contaminant of concern (e.g., Mearns et al. 1991, Fairey et al. 1996).

## Table 2.2

Summary of the San Diego Bay stations with three or more contaminants that exceeded sediment screening criteria: TEL (B) < ERL (△) < PEL (C) < ERM (▲). SIYB = Shelter Island Yacht Basin; HIWB = Harbor Island West Basin; HIEB = Harbor Island East Basin.

| Station | As | Sb | Cd | Cr | Cu | Pb | Hg | Ni | Ag | Zn | tPAH | tDDT | Field observations/site description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2221 | B | ▲ | | B | C | B | △ | B | | △ | | | small boat marina (HIWB) |
| 2222 | B | ▲ | | | C | B | ▲ | B | | △ | | | small boat marina (SIYB)* |
| 2223 | △ | ▲ | | | C | B | ▲ | | | △ | | | small boat marina (SIYB)* |
| 2224 | | ▲ | | | △ | | △ | | | | | | small boat marina (SIYB)* |
| 2225 | | ▲ | | | C | △ | B | | | | | | small boat marina (SIYB)* |
| 2226 | | ▲ | | | C | △ | ▲ | B | | △ | | | small boat marina (SIYB)* |
| 2227 | | ▲ | | | △ | | △ | | | | | | anchorage off Harbor Island |
| 2228 | | | | | △ | B | △ | | B | B | | | anchorage near Embarcadero tuna fleet* |
| 2235 | | | | | △ | | △ | | | B | | | north of Crown Cove - sandy shore |
| 2238 | | | | | △ | | △ | | | B | | | near Coronado Cays Yacht Club |
| 2239 | | | | | △ | B | △ | | | | | | dredged channel |
| 2241 | | ▲ | | | △ | B | △ | | | B | | | dredged channel |
| 2242 | | | | | △ | | △ | | | △ | | | near Naval Amphibious Base |
| 2244 | | ▲ | | | △ | | △ | | | | | | dredged channel |
| 2245 | | ▲ | | | △ | | △ | | | B | | | near small boat marina (Navy Yacht club) |
| 2249 | B | ▲ | | | △ | | △ | B | | △ | | | small boat marina (Coronado Cays) |
| 2251 | △ | | | B | C | △ | △ | B | △ | △ | △ | | shipyard near 10th Ave. Marine Terminal* |
| 2253 | △ | | | B | C | △ | ▲ | B | | C | | △ | NASSCO Shipyard* |
| 2254 | | ▲ | | | △ | | △ | | | | △ | | small boat marina (Naval vessels) |
| 2255 | | ▲ | | | C | △ | △ | | △ | △ | B | △ | Naval Station SD* |
| 2256 | B | | | B | C | △ | △ | | △ | △ | | | dredged channel, near Naval Station SD |
| 2257 | △ | | | B | C | △ | △ | B | △ | △ | | | dredged channel, near Naval Station SD |
| 2258 | B | | | B | C | △ | △ | B | B | △ | | | dredged channel, near Naval Station SD |
| 2259 | | | | | C | B | △ | | B | △ | B | | Naval Station SD / 7th St. Channel* |
| 2260 | | ▲ | | | △ | | △ | | | | | | dredged channel |
| 2262 | △ | | | B | C | B | △ | B | | △ | | | near 24th St. Marine Terminal* |
| 2263 | B | | | B | C | B | △ | B | B | △ | B | | downtown (Broadway & Navy Piers)* |
| 2264 | △ | | | B | C | C | △ | △ | | ▲ | B | B | Naval Station SD, near Las Chollas Crk* |
| 2433 | △ | ▲ | | | △ | | △ | | | B | | | anchorage off Harbor Island |
| 2434 | | ▲ | | | △ | B | | | | B | | | near Coast Guard facility |
| 2436 | △ | ▲ | | B | △ | B | △ | B | | △ | | | dredged channel |
| 2439 | | | | B | C | B | △ | | | △ | | | small boat marina (HIEB) |
| 2440 | | ▲ | | | △ | | △ | | | | | | downtown (B St. Pier)* |
| 2441 | △ | ▲ | | | △ | | △ | B | | | | | Ballast Point Naval Submarine Base* |
| 2442 | △ | | | | △ | | △ | B | | B | △ | | Ballast Point Naval Submarine Base* |

* = Areas previously identified as having elevated contaminant loads or toxicity levels by the State Water Resources Control Board (CRWQCB-SDR 1997).




## Figure 2.8

Quartile distributions of detected tPAH concentrations (ppb) in San Diego Bay sediments during 1998.

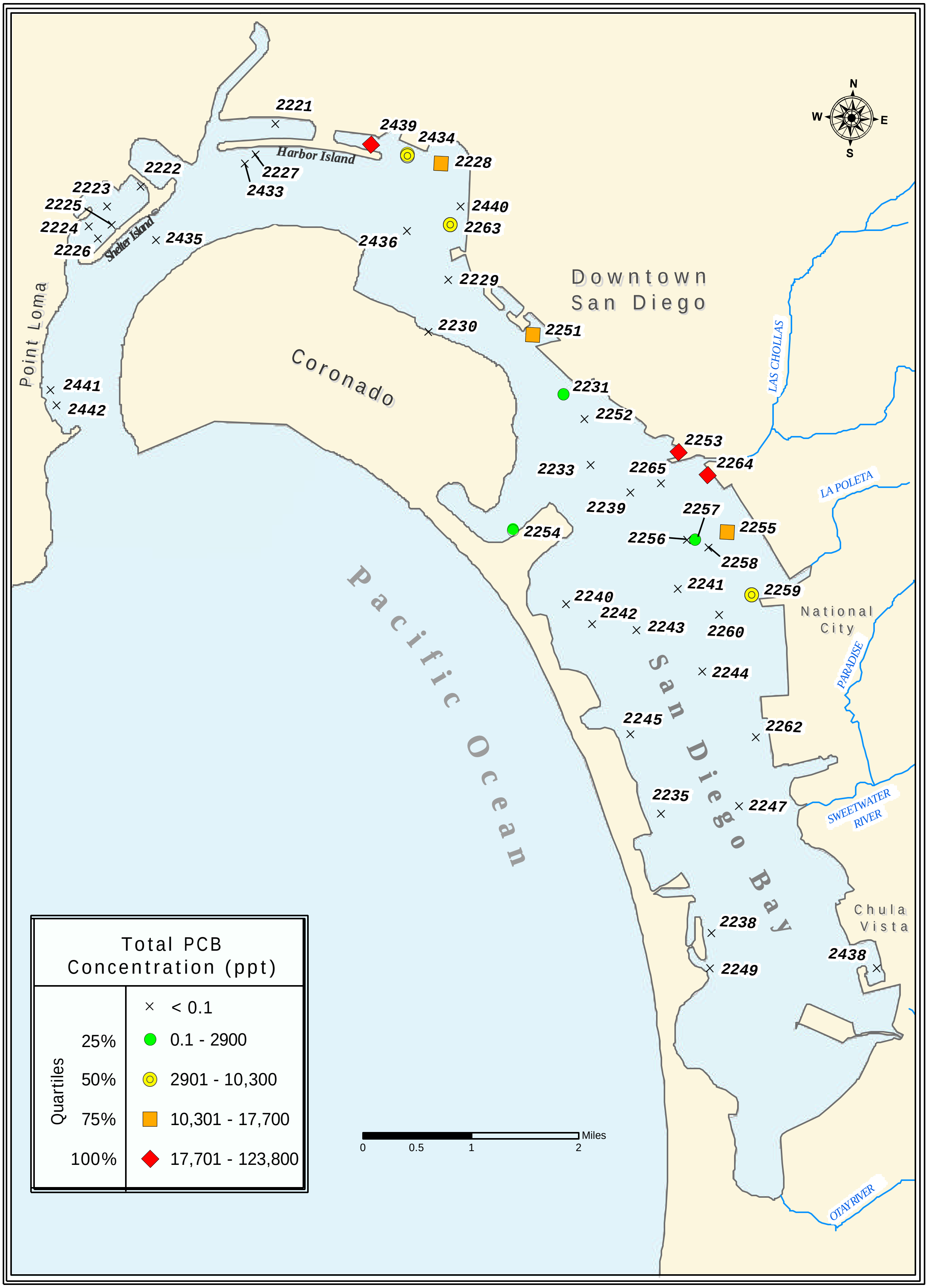



**Figure 2.9**

Quartile distributions of detected tPCB concentrations (ppt) in San Diego Bay sediments during 1998.

The biocide tributyltin (TBT) was detected in sediments at only two sites in San Diego Bay. These included a concentration of 89 ppt at station 2222 in the Shelter Island Yacht Basin and a value of 160 ppt at station 2253 located near the NASSCO shipyard. TBT is the active agent of antifouling paints that degrades naturally into tin, a metal that was not detected in any of the bay sediment samples.

***Comparisons of San Diego Bay to Other Embayments***

Generally, the sediment sites in San Diego Bay grouped consistently with sites located in other bays and harbors from the southern portion of the Southern California Bight (SCB) (i.e., Orange and San Diego counties). These southern embayments, with the exception of Newport Harbor, generally had lower levels of organic indicators and lower concentrations of contaminants than the more northern embayments of Los Angeles and Ventura counties (Table 2.3 and Appendix B.7). The lower contaminant loads may reflect the fact that these southern sites contained fewer fine particles. For example, San Diego Bay, Mission Bay, Anaheim Bay, and Dana Point Harbor averaged less than 60% fines and had the lowest overall concentrations of metal and pesticides. In contrast, all of the more northern bays and harbors averaged over 60% fine particles and were first or second in average concentration for all 19 reported contaminants. Nonetheless, San Diego Bay had the highest mean value for antimony, the second highest value for mercury, and the third highest value for copper. The highest values for tPAH were found in Mission Bay, followed by Los Angeles/Long Beach Harbor, San Diego Bay, and Anaheim Bay. All contained mean values greater than 1,000 ppt with individual values that exceeded the TEL sediment screening criteria. San Diego Bay ranked fourth in PCB contamination, below LA/LB Harbor, Marine del Rey, and Newport Harbor. Finally, San Diego Bay had the lowest overall pesticide contamination. DDT was the only pesticide detected in San Diego Bay and the average tDDT concentrations were well below those of the other bays and harbors. The highest concentrations of tDDT in sediments were found in Ventura and Channel Island Harbors, while total chlordane was highest in Channel Island Harbor and Marina Del Rey. However, the absence of chlordane from San Diego Bay sediments may have resulted from differences in analytical techniques and instrumentation employed by the various laboratories. For example, the MDLs for chlordane-*a* among agencies participating in the Bight'98 survey were 14 and 7.6 times higher in Los Angeles County and San Diego Laboratories, respectively, than those established by the Orange County Laboratory.

## SUMMARY & DISCUSSION

The results of the 1998 survey for sediment particle size and sediment chemistry suggest that the highest levels of pollutants in San Diego Bay were widely distributed among commercial shipyards, naval installations, and small vessel marinas where fine sediments were often most concentrated. The potential for fine particles to sorb contaminants and settle in areas of reduced water flow, such as shipyards and marinas, may explain this pattern. For example, stations with the greatest number of contaminants that exceeded recognized sediment screening criteria (i.e., TEL/PEL, ERL/ERM) tended to have the highest percentage of fine sediments (i.e., $\geq$ 60% fines) (Figure 2.10).

The distribution of fine sediment particles appears to reflect, in part, the circulation patterns within the Bay (see Sutton 2002). Fine particles were more prevalent in shipyards and marinas where currents were less strong and the presence of various structures reduce tidal flow or create eddies

**Table 2.3**

Comparison of various sediment grain size and sediment chemistry parameters among the nine bays and harbors sampled during Bight'98.

| | Ventura Harbor | Channel Is. Harbor | Marina Del Rey | LA/LB Harbor | Anaheim Bay | Newport Harbor | Dana Pnt Harbor | Mission Bay | San Diego Bay |
|---|---|---|---|---|---|---|---|---|---|
| **N** | 1 | 3 | 7 | 36 | 3 | 11 | 3 | 3 | 46 |
| ***%Fines*** | | | | | | | | | |
| **Mean** | 87 | 81 | 69 | 71 | 59 | 75 | 48 | 39 | 52 |
| **95% CI** | — | 8 | 10 | 6 | 38 | 12 | 25 | 34 | 6 |
| ***%TN*** | | | | | | | | | |
| **Mean** | 0.176 | 0.202 | 0.125 | 0.110 | 0.129 | 0.130 | 0.097 | 0.168 | 0.102 |
| **95% CI** | — | 0.075 | 0.024 | 0.014 | 0.091 | 0.032 | 0.051 | 0.161 | 0.013 |
| ***%TOC*** | | | | | | | | | |
| **Mean** | 1.736 | 2.085 | 1.529 | 1.429 | 1.751 | 1.323 | 0.927 | 1.626 | 0.987 |
| **95% CI** | — | 0.795 | 0.291 | 0.216 | 1.456 | 0.274 | 0.489 | 1.897 | 0.141 |
| ***Metals (ppm)*** | | | | | | | | | |
| **Chromium** | | | | | | | | | |
| **%Detect** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 98 |
| **Mean** | 38.0 | 43.5 | 46.0 | 53.9 | 27.4 | 51.6 | 33.1 | 19.4 | 39.8 |
| **95%CI** | — | 5.0 | 13.3 | 6.3 | 14.1 | 9.4 | 16.4 | 17.7 | 4.6 |
| **Copper** | | | | | | | | | |
| **%Detect** | 100 | 67 | 100 | 92 | 100 | 100 | 100 | 100 | 100 |
| **Mean** | 131.0 | 63.3 | 171.9 | 71.3 | 48.1 | 52.4 | 85.3 | 34.1 | 95.1 |
| **95%CI** | — | 65.0 | 76.0 | 12.2 | 36.2 | 28.2 | 104.3 | 50.1 | 17.3 |
| **Mercury** | | | | | | | | | |
| **%Detect** | 0 | 100 | 86 | 89 | 33 | 100 | 100 | 67 | 98 |
| **Mean** | — | 0.063 | 0.567 | 0.283 | — | 0.271 | 0.028 | 0.056 | 0.415 |
| **95%CI** | — | 0.018 | 0.276 | 0.076 | — | 0.288 | 0.020 | 0.028 | 0.088 |
| **Zinc** | | | | | | | | | |
| **%Detect** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **Mean** | 205 | 154 | 245 | 153 | 179 | 145 | 104 | 65 | 148 |
| **95%CI** | — | 57 | 76 | 23 | 130 | 39 | 77 | 69 | 21 |
| ***Total PAHs (ppb)*** | | | | | | | | | |
| **%Detect** | 100 | 100 | 100 | 97 | 100 | 91 | 100 | 33 | 74 |
| **Mean** | 177.6 | 389.7 | 675.5 | 1541.8 | 1101.8 | 832.2 | 121.2 | 2291.3 | 1283.8 |
| **95%CI** | — | 156.9 | 374.4 | 817.1 | 1022.5 | 390.0 | 66.8 | — | 722.7 |
| ***Total PCBs (ppt)*** | | | | | | | | | |
| **%Detect** | 100 | 67 | 100 | 94 | 100 | 100 | 100 | 0 | 26 |
| **Mean** | 2.1 | 4.3 | 80.6 | 55.2 | 18.0 | 27.2 | 14.3 | — | 23.4 |
| **95%CI** | — | 2.9 | 40.4 | 27.0 | 16.8 | 20.9 | 21.5 | — | 19.4 |

that allow suspended particles to settle (Valkirs et al. 1991, USGS 1994, USDoN, SWDIV and SDUPD 2000, Knox 2001). In contrast, coarse sediments were most prevalent in the central portion of the Bay where the current flow is high and dredging is practiced regularly. A review of the cumulative history of dredge and fill activity in the Bay showed that those stations with less than 36 percent fines were located within areas of the Bay where dredging has exposed sandier sediment layers (USDoN, SWDIV and SDUPD 2000).

Metal contamination in San Diego Bay continues to be widespread. Every station had measurable quantities of at least 15 metals in 1998, and many stations exceeded the lower level sediment quality thresholds for multiple metals. Copper, mercury, and zinc were the most prevalent metals of concern and frequently exceeded available sediment quality guidelines. Antimony, although not considered a contaminant of concern, is associated with shipyard activity (e.g., solder, metal bearings and castings, adhesives) and exceeded the more stringent ERM sediment threshold 100% of the time. The contamination levels of some metals appears to be in decline, however. For example, although tin has been found in high concentrations in San Diego Bay (Mearns et al. 1991), it was not detected in any sediment samples collected in 1998. Additionally, San Diego Bay had the third highest average copper concentration in the present study in spite of being listed by Dailey et al. (1993) as having the highest copper contamination of all SCB embayments.

PAH contamination was also prevalent in Bay sediments, but in relatively low concentrations. Although 74% of the stations had measurable quantities of PAHs, only seven exceeded the lower level sediment screening criteria, and these were concentrated among naval facilities and small boat marinas. Overall, it appears that PAH concentrations in San Diego Bay have fallen over time because PAH inputs to the environment have declined. In San Diego Bay, creosote leaching from pier pilings was thought to be one of the main sources of PAH contamination, followed by in-place sediments introduced to the water column (Katz 1998; USDoN, SWDIV and SDUPD 2000). At the Naval facility, half of the pier pilings treated with creosote and copper have been removed, and the discharge of bilge water into gravity separators located in the Bay has ceased (Katz 1998). As a result, PAH inputs to the environment have declined.

PCB congeners were mostly undetected in San Diego Bay sediments during 1998 even though Fairey et al. (1996) previously found PCBs to be widespread. The low detection rates presented herein may reflect, in part, differences in instrumentation and confirmation techniques as discussed previously (see Results section). In spite of these differences, however, PCB-contaminated sediments were distributed among areas previously identified as having elevated PCB contamination, such as large shipyards, naval facilities, and the downtown waterfronts (e.g.,

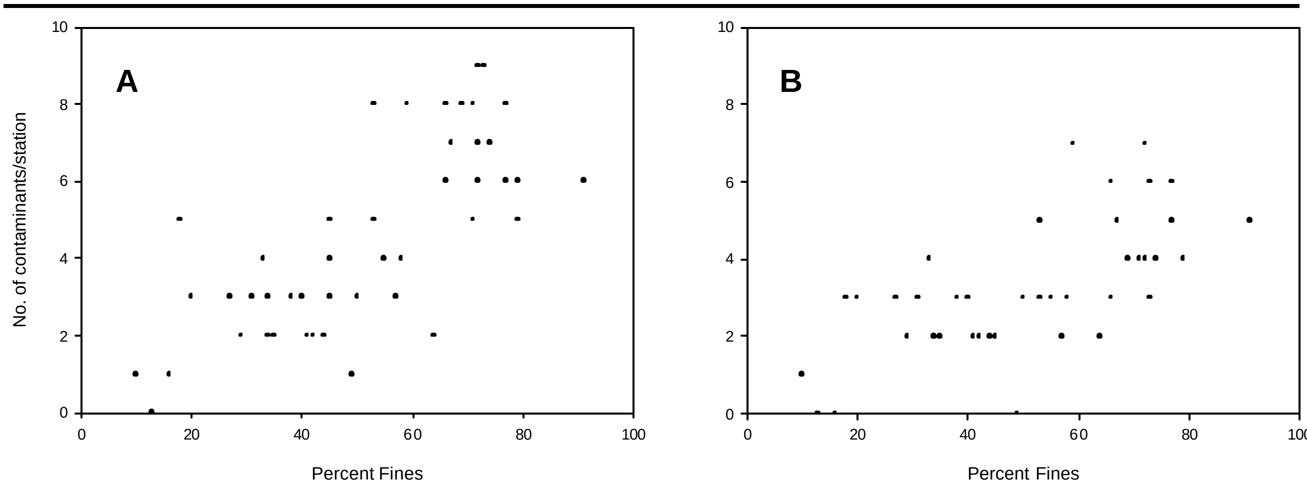



**Figure 2.10**

The number of instances per station that (A) TEL and (B) ERL sediment screening criteria were exceeded plotted against the percentage of fine sediments per station.

Fairey et al. 1996, SAIC 1998, CRWQCB-SDR 2001). The high stability of PCBs and the extent of their use in paints, electronics, and plastics has contributed to their widespread dispersion and accumulation in the environment (Manahan 2000). Moreover, most PCBs in the sediments exist in anaerobic conditions where degradation via anaerobic bacteria requires a very long residence time. Additional surveys using similar detection techniques should help determine whether or not PCB contamination is in decline.

Pesticide and biocide contamination was found in such high concentrations throughout San Diego Bay that chlordane and tributyltin (TBT) were considered chemicals of concern by Mearns et al. (1991) and Fairey et al. (1996). However, DDT was detected at only seven stations in 1998, TBT was detected at only two stations, and chlordane was not detected at all. The apparent reduction in chlordane contamination may result from differences in analytical techniques and instrumentation as discussed above (see Results section). On the other hand, the decline in TBT likely reflects a reduction in usage of TBT within the United States. TBT has been linked to endocrine disruption in shellfish, oysters, and snails (Manahan 2000) and was banned from antifouling paint for ship hulls by the Organotin Antifouling Paint Control Act of 1988. The affect of this legislation was to limit the use of TBT to Navy ships and larger commercial vessels. Finally, mean concentrations of tDDT in sediments from San Diego Bay were the lowest among the nine bays sampled during Bight'98.

Overall, the results of this study are in keeping with previous investigations for toxic hot spots (see Fairey et al. 1996, CRWQCB-SDR 1997, MESO 1998, CRWQCB-SDR 2001). The areas of concern continue to be the naval shipyards and various marinas, including the Naval Submarine Base San Diego, Shelter Island Yacht Basin, the downtown waterfront (i.e., anchorage off Grape Street and B Street Pier), Switzer Creek outlet and the Tenth Avenue Marine Terminal, NASSCO shipyard, Naval Station San Diego, Las Chollas and La Paleta Creeks (including the Seventh Street Channel), and the $24^{th}$ Street Marine Terminal. These areas reflect zones of heavy industrial/naval use and point source discharges, such as storm drains and creek mouths. In comparison to other bays and harbors in the SCB, however, San Diego Bay has relatively low levels of widespread contamination and has considerably less contamination than in decades past.

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