CHEMISTRY, TOXICITY AND BENTHIC COMMUNITY CONDITIONS

IN SEDIMENTS OF THE SAN DIEGO BAY REGION

FINAL ADDENDUM REPORT

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California State Water Resources Control Board

San Diego Regional Water Quality Control Board

California Department of Fish and Game
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INTRODUCTION

This addendum augments the report "Chemistry, Toxicity, and Benthic Community Conditions in Sediments of the San Diego Bay Region" submitted in September 1996 (Fairey *et al*., 1996). This and the original study were conducted as part of the Bay Protection and Toxic Cleanup Program, a legislatively mandated program designed to assess the degree of chemical pollution and associated biological effects in California's bays, estuaries, and harbors.

The original study objectives were:

1. Determine presence or absence of adverse biological effects in representative areas of the San Diego Bay Region;

2. Determine relative degree or severity of adverse effects, and distinguish more severely impacted sediments from less severely impacted sediments;

3. Determine relative spatial extent of toxicant-associated effects in the San Diego Bay Region;

4. Determine relationships between toxicants and measures of effects in the San Diego Bay Region.

The research involved chemical analysis of sediments, benthic community analysis and toxicity testing of sediments and pore water. Chemical analyses and bioassays were performed using aliquots of homogenized sediment samples collected synoptically at each station. Analysis of the benthic community structure was made on a subset of the total number of stations sampled.

Summary of findings from original report

Three hundred fifty stations were sampled between October, 1992 and May, 1994. Areas sampled included San Diego Bay, Mission Bay, the San Diego River Estuary and the Tijuana River Estuary and collectively are termed "the San Diego Bay Region". Two types of sampling designs were utilized: directed point sampling and stratified random sampling.

Chemical pollution was compared to established sediment quality guidelines. Two sets of guidelines were used: the Effects Range-Low (ERL)/Effects Range-Median (ERM) guidelines developed by NOAA (Long and Morgan, 1990; Long *et al*., 1995) and the Threshold Effects Level (TEL)/Probable Effects Level (PEL) guidelines used by the state of Florida (MacDonald, 1994). Copper, mercury, zinc, total chlordane, total PCBs and the PAHs most often were found to exceed critical ERM or PEL values and were considered the major chemicals or chemical groups of concern in the San Diego Bay Region. Chemical summary quotients were used to develop chemical indices for addressing the pollution of sediments with multiple chemicals. An ERMQ>0.85 or a PEL Q >1.29 was indicative of stations where multiple chemicals were significantly elevated using a 90^{th} percentile threshold. Stations with any chemical concentration >4 times its respective ERM or >5.9 times its respective PEL were considered to exhibit elevated chemistry. Summary quotients and magnitude of sediment quality guideline exceedances were used as additional information to help prioritize stations of concern for Regional Water Quality Control Board staff.

Identification of degraded and undegraded habitat (as determined by macrobenthic community structure) was conducted using a cumulative, weight-of-evidence approach. Analyses were performed to identify relationships between community structure within and between each station or site (*e.g.*, diversity/evenness indices, analyses of habitat and species composition, construction of dissimilarity matrices for pattern testing, assessment of indicator species, and development of a benthic index, cluster analyses, and ordination analyses).

Analyses of the 75 stations sampled for benthic community structure identified 23 undegraded stations, 43 degraded and 9 transitional stations. All sampled stations with an ERMQ>0.85 were found to have degraded communities. All sampled stations with P450 Reporter Gene System responses above 60 μg/g BaPEq. also were found to have degraded benthic communities.

The statistical significance of toxicity test results was determined using two approaches: the reference envelope approach and laboratory control comparison approach used by the United States Environmental Protection Agency- Environmental Monitoring and Assessment Program and NOAA- National Status and Trends programs. The reference envelope approach indicated that toxicity for the *Rhepoxynius abronius* (amphipod) survival sediment test was significant when survival was less than 48% in samples tested. No reference envelope was calculated for the urchin fertilization or development tests due to high variability in porewater data from reference stations.

The laboratory control comparison was used for the larval development test. This approach was used to compare test sediment samples against laboratory controls for determination of statistically significant differences in test organism response. Criteria for toxicity in this approach were 1) survival less than 80% of the control value and 2) significant difference between test samples and controls, as determined using a separate variance t-test. Using this approach, there was no absolute value below which all samples could be considered toxic, although survival below a range of 72-80% generally was considered toxic.

Using the EMAP definition of toxicity, 56% of the total area sampled was toxic to *Rhepoxynius*. For the *Strongylocentrotus* larval development test, percent of total area toxic was 29%, 54%, and 72% respectively for 25%, 50%, and undiluted porewater concentrations. Samples representing 14%, 27%, or 36% of the study area were toxic to both *Strongylocentrotus* in pore water (25%, 50%, or undiluted, respectively) and *Rhepoxynius* in solid phase sediment.

Linear regression analyses failed to reveal strong correlations between amphipod survival and chemical concentration. It is suspected that instead of a linear response to chemical pollutants, most organisms are tolerant of pollutants until a threshold is exceeded. Comparisons to established sediment quality guideline thresholds demonstrate an increased incidence of toxicity for San Diego Bay Region samples with chemical concentrations exceeding the ERM or PEL values. It is further suspected that toxicity in urban bays is caused by exposure to complex mixtures of chemicals. Comparisons to chemical summary quotients (multiple chemical indicators) demonstrate that the highest incidence of toxicity (>78%) is found in samples with multiple elevated chemicals (ERMQ >0.85).

Statistical analyses of the P450 Reporter Gene System responses versus the PAHs in sediment extracts demonstrated that this biological response indicator was significantly correlated (r^2 = 0.86, n=30) with sediment PAH (total and high molecular weight) concentration.

Stations requiring further investigation were prioritized based on existing evidence. Each station receiving a high, moderate or low priority ranking meets one or more of the criteria under evaluation for determining hot spot status in the Bay Protection and Toxic Cleanup Program. Those meeting all criteria were given the highest priority for further action. A ranking scheme was developed to evaluate stations of lower priority.

Seven stations (representing four sites) were given a high priority ranking, 43 stations were given a moderate priority ranking, and 57 stations were given a low priority ranking. The seven stations receiving the high priority ranking were in the Seventh Street channel area, two naval shipyard areas near the Coronado Bridge, and the Downtown Anchorage area west of the airport. A majority of stations given moderate rankings were associated with commercial areas and naval shipyard areas in the vicinity of the Coronado Bridge. Low priority stations were interspersed throughout the San Diego Bay Region.

A review of historical data supports the conclusions of the current research. Recommendations were made for complementary investigations which could provide additional evidence for further characterizing stations of concern.

Unresolved issues from earlier studies

Although an attempt was made to gain complete information on the most important sites during the original study, some sites did not receive a full suite of analyses due to budgetary or programmatic constraints. After analysis of the original data set, eight sites were identified as probable areas of concern based on existing information, but appropriate prioritization could not be accomplished because of one or more types of missing data (Table 1). These sites were revisited and samples collected to obtain additional information regarding chemical, toxicological and benthic community conditions. This information was needed to better evaluate the station's priority for future investigation.

Los Penasquitos Lagoon (95006), which was visited during a study of southern California estuaries, exhibited strong toxic responses in bioassays and was determined to have a degraded benthic community (Anderson *et al*, 1997). However, no associated elevated chemical levels were indicated. The possibility existed at this site that pollutants were present that were not included in the normal suite of analyses or that toxicity was a result of non-anthropogenic effects. A toxicity identification evaluation (TIE) was proposed for the current study to

Table 1. Stations to be Revisited

Station #	Station	IDORG	Previous Results
90007.0	25 Swartz (Naval Base O10)	1673	Single toxicity, elevated chem, previous degraded benthics
90008.0	27 Swartz (Naval Base O13)	1674	Single toxicity, previously degraded benthics, low chem
90022.0	P Swartz (Naval Base O12)	1675	Single toxicity, previously degraded benthics, moderate chem
90039.0	Cl	1676	Single toxicity, elevated chem, benthics not analyzed
93179.0	Naval Shipyards O3	1677	Repeated toxicity, elevated chem, Adjacent site degraded benthics
90020.0	G De Lappe	1678	Elevated chem, marginal toxicity, benthics not analyzed
93178.0	Naval Shipyards O2	1679	Elevated chem, marginal toxicity, benthics not analyzed
95006.0	Los Penasquitos (319)	1681	Repeated toxicity, low chem, degraded benthics
90013.0	37 Swartz (Marina)	1680	Reference Site

evaluate the source of this toxic response. A TIE was designed to evaluate pore water toxicity using the *Strongylocentrotus purpuratus* larval development test and the *Eohaustorius estuarius* 10 day survival test.

Figure 1 shows sample locations for the eight revisited stations in San Diego Bay and the TIE station in Los Penasquitos Lagoon.

Data reported for the P-450 Reporter Gene System responses in the appendix of the original report were mismatched against station numbers. This error is corrected in the appendix of this report and stations are correctly matched .

METHODS

Methods for sample collection and processing, trace metal analysis, trace organic analysis, total organic carbon analysis, grain size analysis and benthic community taxonomy are identical to those described in the original San Diego report (Fairey *et al*., 1996). Methods for toxicity have been modified slightly and are described in the following section. Methods for TIE analysis also are described in the following section.

Toxicity Testing

Toxicity testing for this study utilized slightly different protocols than were used for the previous San Diego Bay study. Solid phase testing used the estuarine amphipod *Eohaustorius estuarius* due to concerns that *Rhepoxynius* might be sensitive to fine grained sediments at

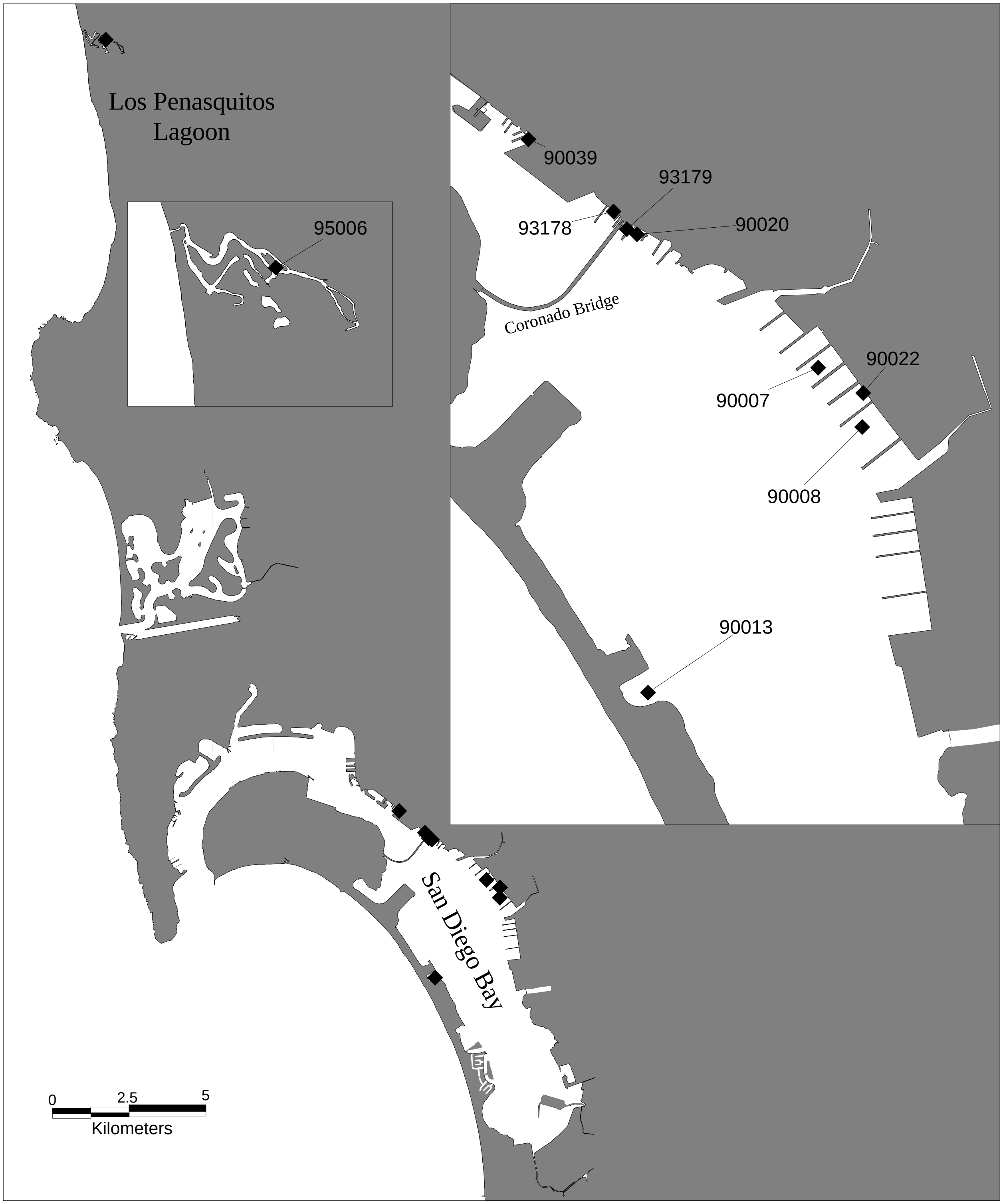

Figure 1. San Diego Bay Region Study Area and Sampling Sites.

some of the stations investigated. Test protocols for the two species are nearly identical with only salinity adjustments being of note, as described below.

The sea urchin larval development test was conducted on sediment pore water samples for the previous San Diego bay study. Recent research using this protocol has indicated that exposure of developing embryos at the interface between sediment and water provides a more ecologically relevant bioassay for this species (Anderson *et al*, 1997). The current study utilized the sediment water interface exposure, as described below.

Amphipod Solid Phase Survival Tests

Solid-phase sediment sample toxicity was assessed using the 10-day amphipod survival toxicity test protocols outlined in EPA 1994. All *Eohaustorius estuarius* were obtained from Northwestern Aquatic Sciences in Yaquina Bay, Oregon. Animals were separated into groups of approximately 100 and placed in polyethylene boxes containing Yaquina Bay collection site sediment, then shipped on ice via overnight courier. Upon arrival at Granite Canyon, the *Eohaustorius* were acclimated to 20‰ (T=15°C). Once acclimated, the animals were held for an additional 48-hours prior to addition to the test containers.

Test containers were one liter glass beakers or jars containing 2-cm of sediment and filled to the 700-ml line with control seawater adjusted to the appropriate salinity using spring water or distilled well water. Test sediments were not sieved for indigenous organisms prior to testing although at the conclusion of the test, the presence of any predators was noted and recorded on the data sheet. Test sediment and overlying water were allowed to equilibrate for 24 hours, after which 20 amphipods were placed in each beaker along with control seawater to fill test containers to the one-liter line. Test chambers were aerated gently and illuminated continuously at ambient laboratory light levels.

Five laboratory replicates of each sample were tested for ten days. A negative sediment control consisting of five lab replicates of Yaquina Bay home sediment for *Eohaustorius* was included with each sediment test. After ten days, the sediments were sieved through a 0.5-mm Nitex screen to recover the test animals, and the number of survivors was recorded for each replicate.

Positive control reference tests were conducted concurrently with each sediment test using cadmium chloride as a reference toxicant. For these tests, amphipod survival was recorded in three replicates of four cadmium concentrations after a 96-hour water-only exposure. A negative seawater control consisting of one micron-filtered Granite Canyon seawater, diluted to the appropriate salinity, was compared to all cadmium concentrations.

Amphipod survival for each replicate was calculated as:

$$\frac{\text{(Number of surviving amphipods)}}{\text{(Initial number of amphipods)}} \times 100$$

Sea Urchin Embryo-Larval Development Test using the Sediment-Water Interface Exposure System

The purple sea urchin (*Strongylocentrotus purpuratus*) embryo/larval development test at the sediment-water interface was conducted on intact core sediment samples taken with minimal disturbance from the Van Veen grab sampler. Details of the test protocol are given in the MPSL Standard Operating Procedure, which follows the EPA methods manual (1995). A brief description of the method follows.

Sea urchins were collected from the Monterey County coast near Granite Canyon, and held at MPSL at ambient seawater temperature and salinity until testing. Adult sea urchins were held in complete darkness to preserve gonadal condition. On the day of the test, urchins were induced to spawn in air by injection with 0.5 ml of 0.5M KCl. Eggs and sperm collected from the urchins were mixed in seawater at a 500 to 1 sperm to egg ratio, and embryos were distributed to the test containers within one hour of fertilization. Sediment-water interface test containers consisted of a polycarbonate tube with a 25-µm screened bottom placed so that the screen was within 1-cm of the surface of an intact sediment core (Anderson *et al*. 1996). Seawater at ambient salinity was poured into the core tube and allowed to equilibrate for 24 hours before the start of the test. After inserting the screen tube into the equilibrated cores, each tube was inoculated with approximately 250 embryos. The laboratory control consisted of Yaquina Bay amphipod home sediment from Northwestern Aquatic Sciences. Tests were conducted at ambient seawater salinity ± 2‰. Ambient salinity at Granite Canyon is usually 32 to 34‰. A positive control reference test was conducted concurrently with the test using a dilution series of copper chloride as a reference toxicant.

After an exposure period of 96 hours, larvae were fixed in 5% buffered formalin. One hundred larvae in each container were examined under an inverted light microscope at 100x to determine the proportion of normally developed larvae as described in EPA 1995. Percent normal development was calculated as:

$$\frac{\text{Number of normally developed larvae counted}}{\text{Total number of larvae counted}} \times 100$$

Determination of Toxicity

Determination of toxicity to amphipods relied on the reference envelope approach described previously (Fairey *et al*., 1996). In determination of toxicity for the reference envelope approach, values must be chosen for alpha and the percentile (p) to calculate the edge of the reference envelope (L) using the following equation:

$$L = X_r - [\, g_{a,p,n} * S_r \,]$$

The values of alpha and p are chosen to express the degree of certainty desired when classifying a sample as toxic. In this study values of alpha=.05 and p=1 were used to distinguish the most toxic samples which have a 95% certainty of being in the most toxic 1% . This calculation resulted in a determination of toxicity for the *Rhepoxynius* test when samples had a mean survival of less than 48%. This cutoff is as a statistical determination chosen as a conservative guideline for setting priorities for future work, by identifying only the most toxic stations. This same determination of toxicity was applied to the *Eohaustorius* test assuming exposure routes and sensitivities were similar for the two species.

Determination of toxicity to urchin larvae using the sediment water interface exposure was made by comparisons to laboratory controls. Samples were defined as significantly more toxic than laboratory controls if the following two criteria were met: 1) a separate-variance t-test determined there was a significant difference ($p<0.05$) in mean toxicity test organism response (e.g., percent survival) between the sample and the laboratory control and 2) mean organism response in the toxicity test was lower than a certain percentage of the control value, as determined using the 90th percentile Minimum Significant Difference (MSD).

Statistical significance in t-tests is determined by dividing an expression of the difference between sample and control by an expression of the variance among replicates. A “separate variance” t-test that adjusted the degrees of freedom was used to account for variance heterogeneity among samples. If the difference between sample and control is large relative to the variance among replicates, then the difference is determined to be significant. In many cases, however, low between-replicate variance will cause the comparison to be considered significant, even though the magnitude of the difference can be small. The magnitude of difference identified as significant is termed the Minimum Significant Difference (MSD) which is dependent on the selected alpha level, the level of between-replicate variation, and the number of replicates specific to the experiment. With the number of replicates and alpha level held constant, the MSD varies with the degree of between-replicate variation. The “detectable difference” inherent to the toxicity test protocol can be determined by identifying the magnitude of difference detected by the protocol 90% of the time (Schimmel *et al*., 1991; Thursby and Schlekat, 1993). This is equivalent to setting the level of statistical power at 0.90 for these comparisons. This is accomplished by determining the MSD for each t-test conducted, ranking them in ascending order, and identifying the 90th percentile MSD, the MSD that is larger than or equal to 90% of the MSD values generated.

Current BPTCP detectable difference (90th percentile MSD) for the urchin SWI test is 59% of controls, based on an evaluation of 109 samples. Samples with toxicity test results lower than the values given, as a percentage of control response, would be considered toxic if the result also was significantly different from the control in the individual t-test.

Toxicity Identification Evaluations (TIEs)

Phase I TIEs were designed to characterize samples by isolating broad classes of compounds to determine their relationship to observed toxicity. Phase I TIE procedures include adjustment of sample pH, chelation of cationic compounds (including many trace metals), neutralization of oxidants (such as chlorine), aeration to remove volatiles, inactivation of metabolically activated toxicants, solid-phase extraction (SPE) of non-polar organic compounds on C-18 columns, and subsequent elution of extracted compounds. Each sample fraction, in which classes of compounds have been removed, inactivated, or isolated, then is tested for toxicity. TIE procedures followed the methods described by US EPA (1996).

AVS/SEM Methods

Samples were prepared for Acid Volatile Sulfide (AVS) extraction by weighing a 2 gram sediment sample into a pre-weighed Teflon® bomb. Samples were diluted with 100 ml of oxygen-free MilliQ® water and bubbled with nitrogen gas for 10 minutes. AVS in the sample was converted to hydrogen sulfide gas (H_2S) by acidification with 20 ml of 6 M hydrochloric acid at room temperature. The H_2S was then purged from the sample with nitrogen gas and trapped in 80 ml of 0.5 M sodium hydroxide. The amount of sulfide that has been trapped is then determined by colorimetric methods. The Simultaneously Extracted Metals (SEM) are selected metals liberated from the sediment during the acidification procedure. SEM analysis is conducted with 20 ml of centrifuged sample supernatant taken after AVS extraction. The H_2S released by acidifying the sample is quantified using a colorimetric method:

Hydrogen sulfide is trapped in 80 ml of 0.5M NaOH. Ten ml of this solution is added to a 100 ml volumetric flask containing 70 ml of sulfide-free 0.5M NaOH, 10 ml of MDR reagent and 10 ml of DI water. The sulfide reacts with the N-N-dimethyl-p-phenylenediamine in the MDR reagent to form methylene blue. Absorbances are determined with a Milton Roy Spectronic 301 Spectrophotometer and compared to a standardized curve.

Table 2. AVS/SEM Analytes and Detection Limits

Analytes	*mmol/g*	*mg/g*
Cadmium	0.0001	0.01
Copper	0.02	1.0
Lead	0.001	0.1
Nickel	0.002	0.1
Zinc	0.001	0.05
Sulfide	0.5	n/a

RESULTS AND DISCUSSION

Tabulated data for all chemical, toxicological and benthic community analyses are detailed in the Appendices. The following section presents summarized data that highlights significant findings from analysis of the full data set.

Revised P450 Data

Appendix E in the original report incorrectly reported data for total PAHs when compared to P450 response at all stations sampled. It should be noted that the correct values were used for all data analyses so data interpretations were not affected by this error. Appendix G in the current report presents revised data to correct the earlier appendix error.

Chemistry

Individual chemical concentrations were compared to ERM and PEL sediment quality guidelines. These guidelines are used to indicate samples with a high probability of demonstrating biological effects (Lon and Morgan, 1990; MacDonald, 1994; Long *et al*., 1995; Long and MacDonald, in press). Chemical analysis was not performed on the sample from Los Penasquitos Lagoon in this study, so no comparisons to guidelines were made. Sediment quality guidelines were exceeded at all San Diego Bay stations and the number of guideline exceedances was high at most stations (Table 3). Chlordane, PAHs and PCBs were the pollutants most often found at elevated concentrations at these stations. Copper, lead, mercury and zinc were often found at elevated levels in the Naval Shipyard areas, although SEM/AVS ratios indicate the probability of metal toxicity is low. This is consistent with previous results demonstrating elevated chemical concentrations at several of these stations. Findings in this study also support the selection of the reference station (90013) as representative of current background chemical conditions in San Diego Bay.

Chemical summary quotients were utilized by the San Diego Bay study to evaluate multiple chemical pollutants in samples within the San Diego Bay region. Eight sediment samples received extensive chemical analyses during the current study, allowing for calculation of summary quotients (Table 3). This approach has been used previously in the BPTCP to identify elevated chemical levels in the San Diego Bay region (Fairey *et al*., 1996), based on evaluation of 220 sediment samples. Upper 90th percentile summary quotients for that data set were ERMQ>0.85 and PELQ>1.29, respectively. Although these values cannot be considered threshold levels with proven ecological significance, they can be used for comparative purposes to indicate the worst 10 % of the samples in the region, with respect to pollutant concentrations. These 90th percentile values were used in the current study to help identify areas of concern for the region based on comparisons to the earlier larger data set. Five of eight samples in the current study exceeded these ERMQ and PELQ percentiles demonstrating elevated multiple pollutants at these stations.

Table 3. Chemical Summary Quotient Values and Sediment Quality Guideline Exceedances

Station #	Station	IDORG	ERMQ	PELQ	> ERMs	>PELs
90007.0	25 Swartz (Naval Base O10)	1673	0.646	0.944	3	15
90008.0	27 Swartz (Naval Base O13)	1674	0.532	0.835	1	13
90022.0	P Swartz (Naval Base O12)	1675	0.958	1.398	13	19
90039.0	Cl	1676	2.180	3.785	7	20
93179.0	Naval Shipyards O3	1677	2.483	2.227	16	20
90020.0	G De Lappe	1678	2.028	2.463	12	17
93178.0	Naval Shipyards O2	1679	1.526	1.875	8	16
90013.0	37 Swartz (Marina)	1680	0.280	0.407	0	2
95006.0	Los Penasquitos (319)	1681	n/a	n/a	n/a	n/a

Use of chemical summary quotients also allows comparisons to be made between regions within the state and demonstrate that the San Diego Bay region has relatively greater pollutant levels compared to more pristine settings in northern and central California. The greatest quotient values for the north coast of California (ERMQ=0.243; PELQ=0.528) (Jacobi *et al.*, in prep) and for the central coast of California (ERMQ=0.447; PELQ=0.735)(Downing *et al.*, in prep) are considerably lower than those in the upper 10% from San Diego Bay. This is to be expected because the north coast and central coast are not as heavily populated or industrialized as the urban areas of southern California. This comparison is useful though by giving insight to the range of pollution that is represented in the state and that samples from San Diego Bay often fall within the upper end (most polluted) of the range.

Long and MacDonald (in press) further examined the use of sediment quality guidelines and the probability of toxicity being associated with summary quotient ranges. This extensive national study developed four sediment categories to help prioritize areas of concern, based on the probability of toxicity associated with summary quotients and number of individual ERM/PEL guideline exceedances. Sediments with ERM quotients > 0.51or PEL quotients >1.5, or more than 5 guideline exceedances, were generally assigned to categories of elevated concern (medium high to high priority) because the probability of associated toxicity was greater than 50%. Five sediment samples from the current San Diego Bay study exceed these thresholds. Three of these five sediment samples demonstrated ERM quotients > 1.5 or PEL quotients >2.3 and fall within the survey's highest category. Nationwide, samples in this range were assigned the highest priority as sites of concern, based on a probability of toxicity to amphipods of >74%, and should further highlight the concern for these stations within the region. It should be noted that current BPTCP calculation methods of summary quotients vary slightly from the national study based on incorporation of a modified suite of chemicals. These modifications were incorporated because the predictability of toxicity is enhanced thus providing stronger evidence of the value of this multiple chemical indicator of biological effects.

Toxicity

Station CL (90039) exhibited toxicity to the amphipod *Eohaustorius*, based on comparison to the reference envelope (<48% survival) (Figure 2; Table 4). Samples from the remaining stations were not toxic to amphipods. Unionized ammonia concentrations in these bioassays were all below the application limit (0.8 mg/L; EPA, 1995) and likely did not contribute to observed toxicity. Hydrogen sulfide (H_2S) concentrations were well above the observed "low effects" level (0.114 mg/L; Knezovich, 1996) for three samples, including station CL (90039). H_2S might have contributed to toxicity at this station, but this seems unlikely because the H_2S concentration in the sample from station Naval Shipyard O2 (93178) was over twice as high without demonstrating toxicity.

Determination of toxicity to urchin development is based on t-test and comparison to the MSD as described earlier. Three stations exhibited toxicity to urchins in the SWI exposure (Figure 2; Table 4). Ammonia levels in these bioassays were all below the "no effects" level (0.07 mg/L; Bay, 1993) and likely did not contribute to observed toxicity. H_2S concentrations were above the observed "low effects" level (0.0076 mg/L; Knezovich, 1996) for four samples, three of which exhibited a toxic response. H_2S might have contributed to toxicity at both of these stations, but this seems unlikely at the Naval Shipyard (93178) or P Swartz (90022) stations because greater sulfide levels were measured in the 25 Swartz (90007) sample with no

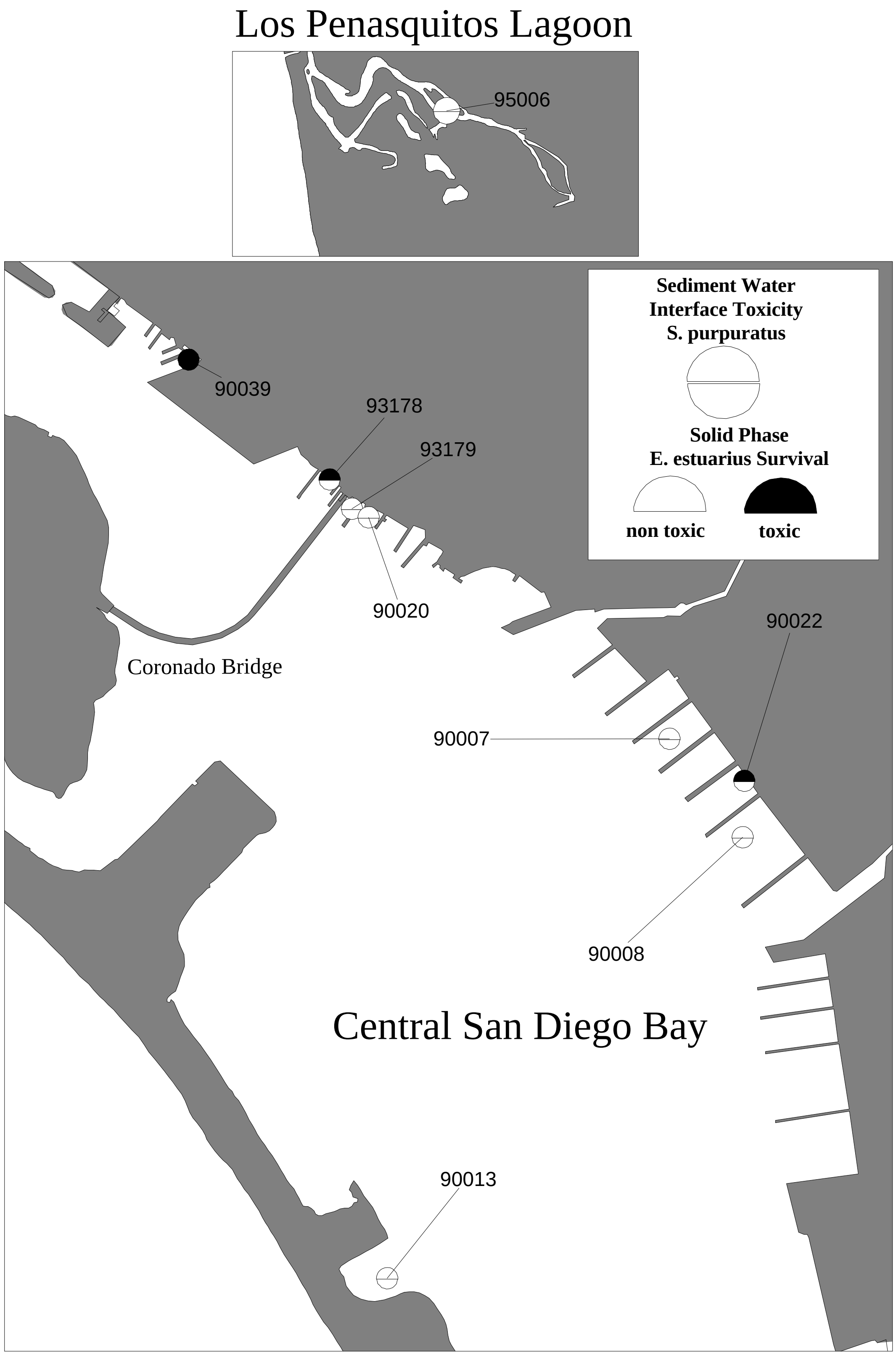

Figure 2. San Diego Bay Region Toxicity. Samples were toxic if significantly different from controls using a t-test and less than control based MSD values (see text for complete toxicity definition).

concurrent toxic effect. The concentration of H_2S in the other toxic sample (CL, 90039) should be considered as a potential confounding factor.

Only one station (CL, 90039) demonstrated concurrent toxicity to both amphipods and urchins .

Toxicity was not exhibited in the pore water sample from Los Penasquitos Lagoon. This was contrary to expectations based on two previous visits to this site. Because the initial test was not toxic, TIE analysis was not carried out using *Strongylocentrotus purpuratus*, but was initiated using *Eohaustorius estuarius* as a precautionary measure. No toxic effect was measured at any level for this test so the TIE investigation was abandoned.

Table 4. Toxicity Test Results for Amphipods (EE) and Urchins (SPDI)

Station #	Station	IDORG	EE	NH_3	H_2S	SPDI	NH_3	H_2S
90007.0	25 Swartz (Naval Base O10)	1673	87	<MDL	0.008	76	0.008	**0.050**
90008.0	27 Swartz (Naval Base O13)	1674	91	0.008	<MDL	94	0.003	0.006
90022.0	P Swartz (Naval Base O12)	1675	83	0.003	0.007	**43**	0.004	**0.008**
90039.0	Cl	1676	**22**	0.056	**0.269**	**38**	0.001	**0.277**
93179.0	Naval Shipyards O3	1677	87	0.007	0.007	74	<MDL	0.002
90020.0	G De Lappe	1678	66	0.064	0.050	57	0.003	0.001
93178.0	Naval Shipyards O2	1679	88	0.042	**0.646**	**2**	0.010	**0.016**
90013.0	37 Swartz (Marina)	1680	83	0.020	**0.173**	78	0.010	0.007
95006.0	Los Penasquitos (319)	1681	84	0.069	0.071	67	0.004	0.005

Bolded values indicate samples that were toxic or exceeded water quality effects thresholds

Benthic Community Degradation

Results of all benthic community analyses conducted as part of this study are presented in tables in Appendix F. These tables show the species, taxa, number of individuals per core, and summary statistics for the 8 stations sampled.

The current study utilizes a Relative Benthic Index (RBI) based on modification of indices used in San Diego (Fairey *et al.,* 1996) and in southern California (Anderson *et al.,* 1997). The San Diego study had 75 samples for which the indices were derived and used a number of techniques to generate categorical community classifications as degraded, transitional or undegraded. The southern California study contained 43 samples and was a modified version of the earlier San Diego evaluation. The modification was primarily based on quantifying community classifications on a graduated scale from 0 to 1. The Relative Benthic Index used in this study incorporates refinements from both previous studies and quantifies community health on a graduated scale of 0 to 1. It combines use of benthic community data with the presence or absence of positive and negative indicator species in order to provide a measure of the relative degree of degradation within the benthic fauna. The index does not require the presence of an uncontaminated reference station and relies on the larger data set from the 1996 San Diego study to establish high and low ranges for the region. Because of small sample size (n=8) the current index is not based on samples collected exclusively during the current study. The RBI however does provide the relative "health" of each of the stations in the current data set compared to stations from the previous data set.

The Relative Benthic Index for the current 8 samples region ranged between 0.02 and 1.0 (Table 5). Stations with greater numbers of negative indicator species, such as polychaetes and oligochaetes, in association with low species diversity generally denote an area of disturbance and score lower with the index. In contrast, stations with a greater number of positive indicator species, such a gammarid amphipods or ostracods, and higher species diversity indicate a relatively undisturbed area with a mature benthic community and score higher with the index. Selection of indicator species is based on the best professional judgement of benthic ecologist familiar with species in the region. Four stations with a RBI ≤ 0.3 were classified as having degraded benthic communities (Figure 3). Three stations were classified as having transitional benthic communities (characteristics of both healthy and impacted communities; 0.3≤ RBI ≤ 0.6) and one station was classified as undegraded (RBI>0.6). The undegraded station was selected for this study as a reference site due to previously determined low chemical concentrations and undegraded benthic community. Findings in the current study support the selection of this station as representative of reference conditions.

Table 5. Relative Benthic Index (RBI) Values

Station #	Station	IDORG	RBI
90007.0	25 SWARTZ (NAVAL BASE O10)	1673	0.16
90008.0	27 SWARTZ (NAVAL BASE O13)	1674	0.24
90022.0	P SWARTZ (NAVAL BASE O12)	1675	0.38
90039.0	CL	1676	0.02
93179.0	NAVAL SHIPYARDS O3	1677	0.42
90020.0	G DE LAPPE	1678	0.29
93178.0	NAVAL SHIPYARDS O2	1679	0.41
90013.0	37 SWARTZ (MARINA)	1680	1.00
95006.0	LOS PENASQUITOS (319)	1681	n/a

Station Specific Sediment Quality Assessments

Sediment samples from each of the stations in San Diego Harbor were analyzed for chemical concentration, toxicity and benthic community structure. This synoptic study design allows for the assessment of sediment quality using a complementary weight of evidence from observed biological effects and potential pollutants. Prioritizations were made to help focus RWQCB and SWRCB staff on sediments that pose a threat to the water body. Assessments followed those of the previous San Diego Region report by relying on the combination and severity of environmental measures to categorize stations as a high, moderate, or low priority. Sediments that exhibited strong toxic responses, and/or degraded resident communities, and were associated with identifiable pollutants, were given the highest priority for further investigation. Sediments with reduced or negligible responses were given lower priorities for investigation or recommended for no further action. Limited personnel and resources can therefore be focused on sediments that most likely pose a threat to the environment in San Diego Bay.

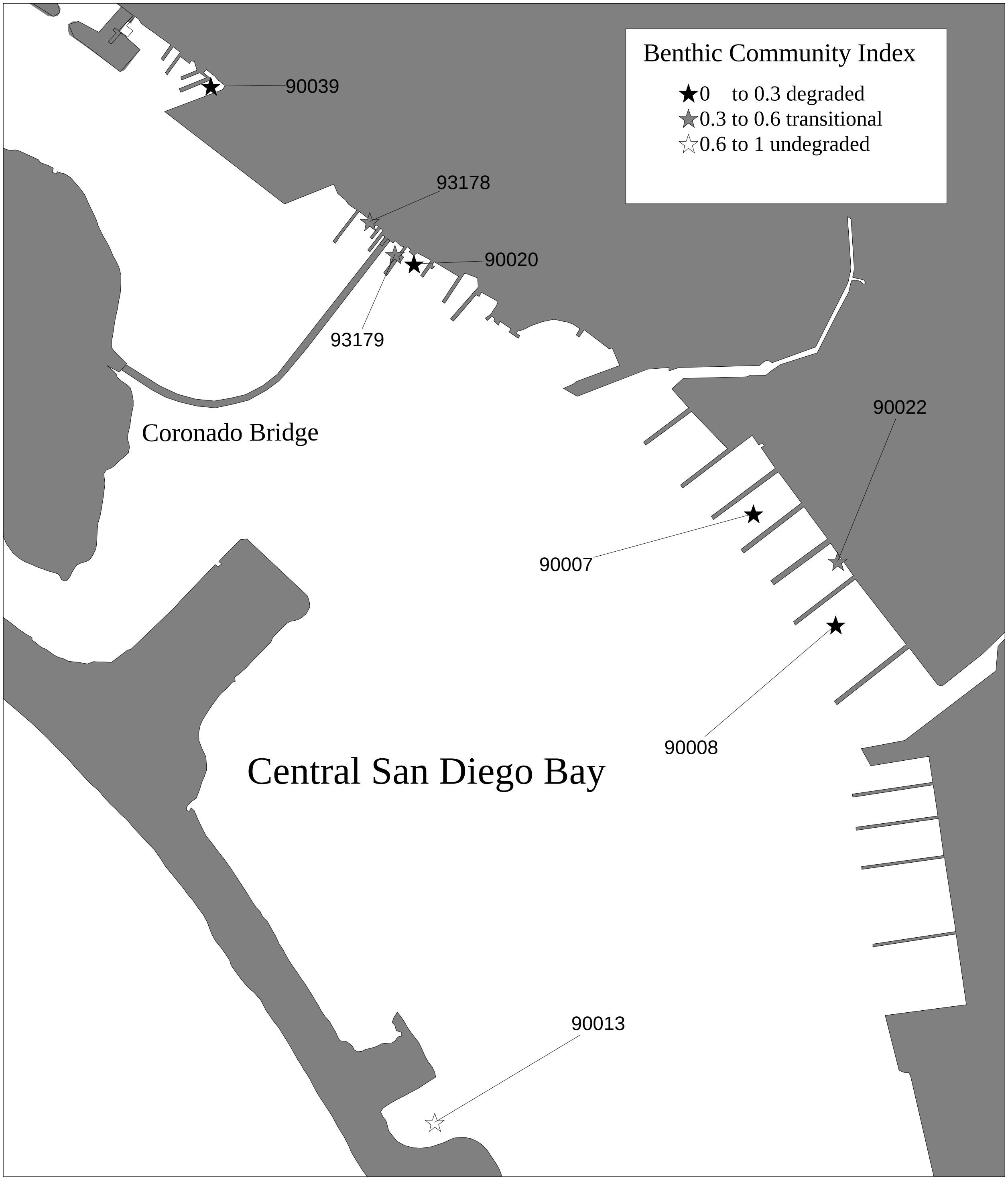

Figure 3. San Diego Bay Region Benthic Community Indices.

Table 6 summarizes chemical concentrations, toxicity and benthic community structure for the eight stations sampled in San Diego Bay. Comments summarize the weight of evidence at each station and a priority is assigned for future investigation. The locations and priority categories for each station are shown in Figure 4.

Table 6. Station Prioritization

Station #	Station	IDORG	ERMQ	PELQ	EE	SPDI	RBI	Comments	Priority
90039.0	CL	1676	**2.14**	**3.79**	**22**	**38**	**0.02**	Elevated Chem. Toxicity Degraded Comm.	High
93178.0	Naval Shipyards O2	1679	**1.37**	**1.88**	88	**2**	0.41	Elevated Chem. Toxicity Transitional Comm.	Moderate
90022.0	P Swartz (Naval O12)	1675	**0.86**	**1.40**	83	**43**	0.38	Elevated Chem. Toxicity Transitional Comm.	Moderate
90020.0	G De Lappe	1678	**1.84**	**2.46**	66	57	**0.29**	Elevated Chem. No Toxicity Degraded Comm.	Moderate
93179.0	Naval Shipyards O3	1677	**1.55**	**2.23**	87	74	0.42	Elevated Chem. No Toxicity Transitional Comm.	Moderate
90007.0	25 Swartz (Naval O10)	1673	0.59	0.94	87	76	**0.16**	Chem. Not Elevated No Toxicity Degraded Comm.	Low
90008.0	27 Swartz (Naval O13)	1674	0.49	0.84	91	94	**0.24**	Chem. Not Elevated No Toxicity Degraded Comm.	Low
90013.0	37 Swartz (Marina)	1680	0.23	0.40	83	78	1.00	Chem. Not Elevated No Toxicity Undegraded Comm.	No action

Bolded values indicate samples that were toxic or exceeded BPTCP thresholds

Station CL (90039) was assigned the highest priority. This station was given a moderate priority in the previous report because benthic community analysis had not been performed and only one toxic response had been observed. The sample collected at this station during the current study again exhibited toxicity to amphipods and urchin larvae, elevated chemicals, particularly pesticides and PAHs, and a degraded resident benthic community. The station is located at the mouth of Switzer Creek where a concrete culvert empties into the bay.

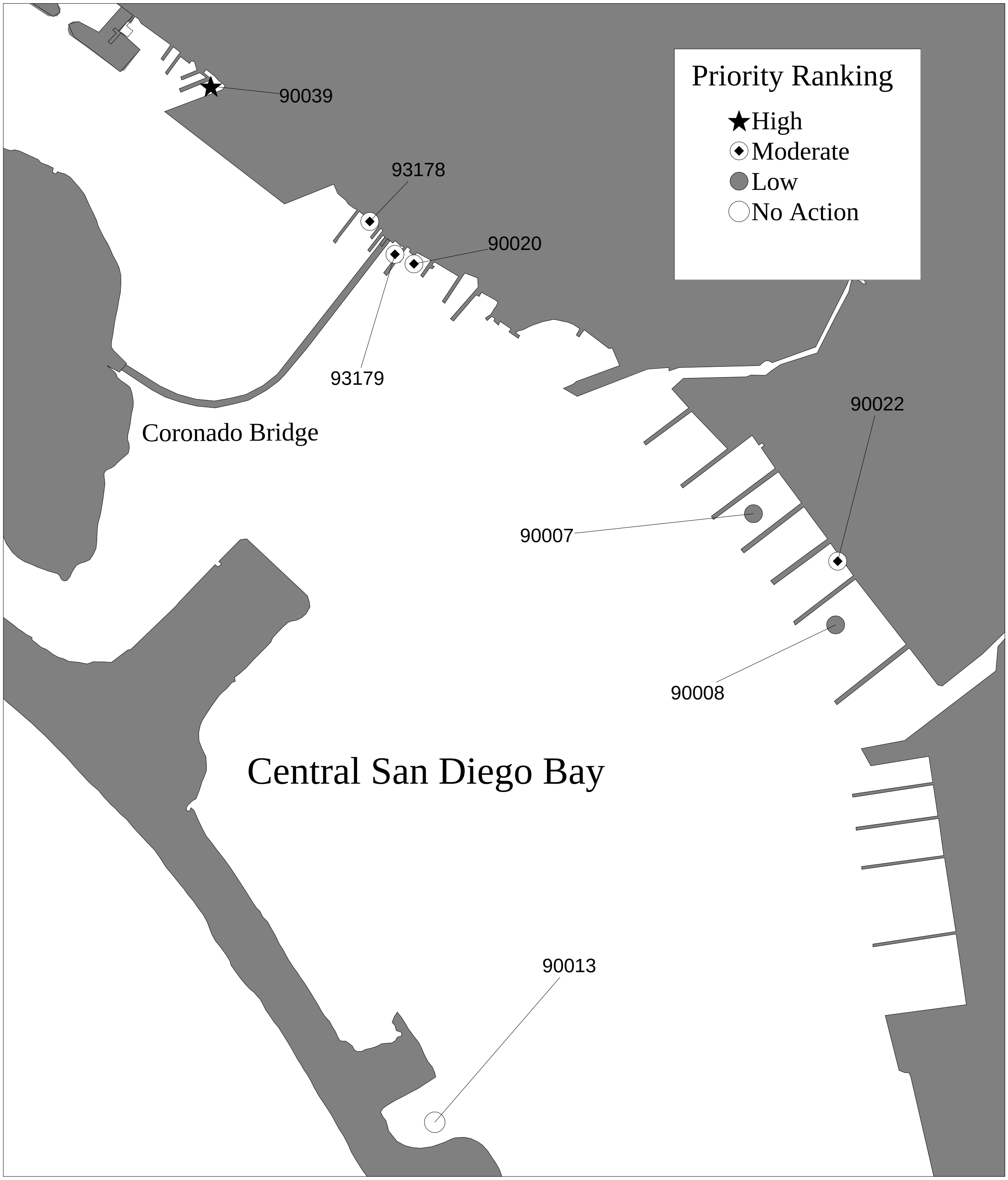

Figure 4. San Diego Bay Region Priority Ranking.

Historically this area served as a PAH waste dump site for a San Diego Gas and Electric coal gasification plant. Prior to that the site served as one of the original garbage dumps in the San Diego region (Port of San Diego, 1996). Pesticide residues and organic matter were prevalent in the sediment samples and indicate a probable link to urban and storm runoff. Moving this station to higher priority is strongly supported by evidence gathered in the current and previous study.

Three stations were assigned to a moderate priority category based on elevated chemical levels and one measure of biological effect. Each of these stations is in an area of current or past ship repair operations. The Naval Shipyard O2 station (93178), just north of the Coronado Bridge and near Continental Maritime, represents an area which has served as a ship repair facility for the past ten years and prior to that was the location of a tuna cannery. PCBs are the principal pollutant at this site. The P Swartz (90022) station is in the Naval Shipyard between Piers 5 and Pier 6, near the mouth of the Graving Dock. Ship repair activities are a likely source of PAHs, PCBs and copper which were the prominent pollutants at the site. Station G De Lappe (90020) is located just south of the Coronado Bridge, near Southwest Marine, where industrial and shipping activities have been in operation for many years. Sources of elevated PCBs and PAHs in samples may be from commercial activities or from fill material that was added along the shoreline in the past. Each of these stations received a moderate priority in the previous study and the current study supports this prioritization.

One station was assigned to a moderate priority category based on an inconclusive measure of biological effects. The Naval Shipyards O3 station (93179) was assigned a high priority in the previous study based on elevated chemistry, presence of toxicity, and degradation of the benthic community at an adjacent station. In the current study lack of toxicity, continued elevated chemistry and a transitional benthic community prompted re-assignment of this station to the moderate category.

Stations 25 Swartz (90007) and 27 Swartz (90008) were assigned moderate priorities in the previous study based on moderate chemical levels, a single toxic response and a degraded benthic community at an adjacent station. Data from the current study indicated low to moderate chemical levels, however toxicity was absent. The benthic communities were classified as degraded, but unclear association of elevated chemicals prompted re-classification of these two stations to a lower priority.

CONCLUSIONS

The current study was designed to better evaluate sediment quality at eight stations within San Diego Harbor where missing or inconclusive data from a previous study confounded interpretations. Collection of synoptic chemical, toxicological and benthic community data provided the needed information to prioritize these stations, utilizing a strong weight of evidence approach. This approach helped identify stations with sediments that have a high probability of causing adverse environmental impacts. A significant limitation of this study is the inability to directly link cause and effect or to delineate the boundaries of the impacted area. Subsequent studies will be required to address these critical issues. The current study does, however, help focus future management efforts on the stations of greatest concern.

The investigation of toxicity at Los Penasquitos Lagoon was terminated when initial tests revealed that samples were not toxic. Low levels of measured chemicals in the previous study and the transitory nature of toxicity at this location make it difficult to attribute a cause to the observed effects. No further action is recommended for this location.

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