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Stormwater Toxicity in Chollas Creek and San Diego Bay

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ABSTRACT

Stormwater discharges from Chollas Creek, a tributary of San Diego Bay, have been shown to be toxic to aquatic life. In-channel wet-weather monitoring from previous storm seasons showed that samples of Chollas Creek stormwater were toxic to the water flea (*Ceriodaphnia dubia*), the fathead minnow (*Pimephales promelas*), and the purple sea urchin (*Strongylocentrotus purpuratus*). However, no receiving water sampling has ever been conducted to determine whether Chollas Creek discharges are toxic once they have been diluted and dispersed in San Diego Bay.

The primary objective of this study was to provide the linkage between in-channel measurements and potential impairments in the receiving waters of San Diego Bay. This study addressed this objective within the context of five questions: (1) How much area in San Diego Bay is affected by the discharge plume from Chollas Creek during wet–weather conditions? (2) How much of the wet-weather discharge plume is toxic to marine aquatic life? (3) How toxic is this area within the wet-weather discharge plume? (4) How long does the wet-weather toxicity persist? and (5) What are the constituent(s) responsible for the observed toxicity in the wet-weather plume?

The stormwater plume emanating from Chollas Creek was dynamic, covering areas up to 2.25 km^2. Approximately half of the plume appeared to be toxic to marine life, based upon the results of the purple sea urchin fertilization test. The area nearest the creek mouth was the most toxic (NOEC = 3 to 12% plume sample), and the toxicity decreased with distance from the creek mouth. The toxicity of plume samples was directly proportional to the magnitude of plume mixing and dilution until, once outside the plume margin, no toxicity was observed. The toxicity persisted at least 3 d following the storm event. Trace metals, most likely zinc, were responsible for the observed plume toxicity based upon toxicity identification evaluations (TIEs). Zinc was also the constituent identified from in-channel stormwater samples from Chollas Creek using TIEs on the storms sampled in this study, and in storms sampled during the previous storm season.

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INTRODUCTION

Stormwater inputs are a large source of pollutants discharged to receiving waters around the country (U.S. EPA 1995a). In southern California, stormwater inputs are among the largest of all sources that discharge pollutants to our coastal water bodies (Schiff *et al*. 2000). Runoff in the southern California region is exacerbated by the area's expansive urbanization, which increases the number of potential non-point sources and promotes runoff due to a larger proportion of impervious surfaces (e.g., cement). The problem is compounded further as a result of the area's infrequent, but intense rainfall events.

Previous monitoring of urbanized watersheds in San Diego demonstrated that stormwater runoff discharges significant loads of pollutants and is toxic to aquatic life (WCC 1998). One such watershed is Chollas Creek, a heavily urbanized tributary that discharges to San Diego Bay. The previous monitoring effort, which included chronic toxicity to *Ceriodaphnia dubia* and *Pimephales promelas*, was conducted as part of the National Pollutant Discharge Elimination System (NPDES) permit requirements for wet-weather discharges by the City and County of San Diego and associated co-permittees. The monitoring consisted of samples taken near the end of the Chollas Creek channel, approximately 5 km upstream of San Diego Bay.

The Chollas Creek watershed has been added to the 303(d) list as a result of the toxicity measured during wet-weather monitoring and other related measurements. As a requirement of the 303(d) listing, Chollas Creek is subject to a total maximum daily load (TMDL) for toxicity. Rather than conduct the TMDL for general toxicity (e.g., toxic units or TUs), the Regional Water Quality Control Board (RWQCB) has used a constituent-specific approach.

To determine which constituent(s) was responsible for the observed toxicity, toxicity identification evaluations (TIEs) were conducted on samples of wet-weather discharges from Chollas Creek during the 1998/1999 wet season (SCCWRP 1999). The TIEs were conducted on both freshwater (*Ceriodaphnia*) and marine (*Strongylocentrotus*, purple sea urchin) species. Although Chollas Creek runoff was toxic to both freshwater and marine organisms, the marine organisms were more sensitive (i.e., their response indicated more toxicity). Trace metals, most likely zinc, were the constituents responsible for the toxicity to the purple sea urchin.

The TIE study from 1998/1999 identified three recommendations to the TMDL process for Chollas Creek: (1) additional TIE testing to confirm toxicants and thus provide sufficient information to improve confidence in management actions; (2) establishing a link between in-channel measurements and impairments in the receiving water environment; (3) joint toxicological and chemical testing for source tracking. The present study goal was to accomplish recommendations (1) and (2).

The primary objective of this study was to provide the linkage between in-channel measurements and potential impairments in the receiving waters of San Diego Bay. A secondary goal was to provide additional TIE testing to enhance the justification and rationale for management actions pursuant to the TMDL. This report will address these objectives by answering five questions:

- How much area in San Diego Bay is affected by the discharge plume from Chollas Creek during wet–weather conditions?

- How much of the wet-weather discharge plume is toxic to marine aquatic life?

- How toxic is the area within the wet-weather discharge plume?

- How long does the wet-weather toxicity persist?

- What are the constituent(s) responsible for the observed toxicity in the wet-weather plume?

By estimating the magnitude and extent of beneficial use impairment in San Diego Bay, this project will help to establish TMDL target reduction goals and provide information for assessing appropriate margins of safety when assigning waste load and load allocations. Also, this study will provide benchmark values from which to assess progress as TMDLs on this watershed are implemented.

METHODS

General Approach

This project was completed in five integrated tasks, each associated with one of the study questions. The discharge plume was mapped based upon physical water quality parameters including salinity, temperature, and turbidity that are tracers of wet-weather discharges. The second task assessed the extent of the toxicity within the discharge plume by sampling multiple locations along the gradient of plume influence. The marine species identified during the 1998/1999 studies, the purple sea urchin (*Strongylocentrotus purpuratus*), was used as the test species. The magnitude of toxicity was assessed by conducting toxicity tests with dilution series at a site near the most concentrated part of the plume and at the in-channel site upstream of the bay. Toxicity persistence was assessed by returning to the heart of the plume at subsequent time periods and repeating the toxicity tests. Toxicity identification evaluations (TIEs) were conducted on samples from the most concentrated portion of the plume and from the in-channel sampling site upstream of the bay during the same storm events to determine the toxic constituents of concern.

Field Sampling

Plume mapping and receiving water sampling occurred during or immediately following rainfall, attempting to capture the maximum extent of the plume. A Sea-Bird Electronics pumped SBE 19 CTD (2 Hz internal recording) was used to make all physical water quality measurements. Sensors on the instrument were temperature, conductivity, pressure (Paine strain gauge, 100 psia), and a SeaTech transmissometer (660 nm, 25 cm pathlength). The pump delivered constantly flowing (18 mL/s) water over the temperature and conductivity sensors, so that slow descent or tow speeds had minimal bias on sensor measurements.

Surface water measurements were made with the CTD hung in the water using a downrigger. The downrigger submerged and stabilized the instrument at an average depth of 0.4 m while the research vessel cruised at slow speeds (< 5 knots). This configuration minimized boat turbulence and plume mixing. A differential global positioning system (dGPS) was connected to the Sea-Bird Electronics data collection system so that latitude and longitude were appended to the CTD data stream. The CTD data were collected at half-second intervals and dGPS positions were updated every two seconds.

Water column profiles were taken across shore and along shore of the Chollas Creek mouth. The sites were selected to represent the gradient of plume impact based upon measurements during the surface mapping. The profile process began by stopping the boat, raising the CTD to the surface, then lowering it to the bottom. The CTD was raised to the surface again and secured to maintain the proper depth. Surface mapping was then resumed.

At each water column profile site, surface water samples were taken for toxicity, trace metals, and total suspended solids (TSS). All water samples were immediately placed on Blue Ice in a hard plastic ice chest.

At the end of the cruise, all CTD data were stored on computer disk and backed up. Upon arrival at the laboratory (less than 24 h from the first sample collection), all water samples were stored in a refrigerator (4° C) until processed.

In-channel samples were collected from Chollas Creek at a site upstream of San Diego Bay. These samples were collected using an automated, flow-paced sampler that was triggered by increases in flow. These composite storm samples were collected by URS Greiner/Woodward-Clyde International Americas (URS/WCC) as part of the NPDES municipal stormwater permit monitoring conducted by the City of San Diego and co-permittees and as described in detail elsewhere (URS/WCC 2000).

Baseline Toxicity

All samples of stormwater were evaluated for toxicity using the purple sea urchin fertilization test (U.S. EPA 1995b). The test consisted of a 20-min exposure of sperm to the samples. Eggs were then added and given 20 min for fertilization to occur. The eggs were then preserved and examined later with a microscope to assess the percentage of successful fertilization. Toxic effects are expressed as a reduction in fertilization percentage. The purple sea urchins used in the tests were collected from the intertidal zone in northern Santa Monica Bay. The tests were conducted in glass shell vials containing 10 mL of solution at a temperature of 15° C.

The stormwater samples were adjusted to a salinity of 34 g/kg. Previous experience has shown that many sea salt mixes are toxic to sea urchin sperm. Therefore, the salinity for the sea urchin test was adjusted by the addition of hypersaline brine. The brine was prepared by freezing and partially thawing seawater. Since the addition of brine dilutes the sample, the highest stormwater concentration that could be tested for the sperm cell test was 50%. The adjusted samples were diluted with seawater to produce test concentrations ranging from 50 to 3%. Five replicates of each concentration were tested.

Two statistical parameters were calculated to describe the magnitude of toxicity in a sample: toxic units (TUs) and no observed effect concentration (NOEC). The number of toxic units provides an indication of the overall toxicity of a sample. This value is inversely proportional to the median effective concentration (EC50, concentration producing 50% reduction in fertilization). The second parameter, the NOEC, represents the highest concentration of a sample that does not cause toxicity. This parameter provides a conservative estimate of the concentration of the sample associated with the beginning of toxic effects.

Seawater control samples (0.45 µm, activated carbon filtered natural seawater from Redondo Beach) and brine control samples (50% purified water and 50% brine) were included in each test series for quality control purposes. Water quality parameters (temperature, dissolved oxygen, pH, ammonia, and salinity) were measured on the test samples to ensure that the experimental conditions were within the desired ranges and did not create unintended stress on the test organisms. In addition, a reference toxicant test was included with each stormwater test series in order to document intra-laboratory variability. Each reference toxicant test consisted of a concentration series of copper with five replicates tested per concentration. The EC50 was estimated from the data and compared to control limits based upon the cumulative mean and two standard deviations of recent experiments.

Plume Toxicity

Surface water samples from San Diego Bay collected during the plume mapping surveys were tested for sea urchin toxicity using the same test methods described for the stormwater composite samples. One sample collected from the most concentrated portion of the plume (Chollas Creek channel) was diluted with seawater and tested at concentrations ranging from 50 to 3% in order to determine the magnitude of toxicity (EC50 and TU). The remaining samples were tested at the maximum concentration available after salinity adjustment; no dilutions were prepared. The test results (percent fertilization and salinity at the time of sampling) were modeled using a logistic regression to create a mathematical function that predicted toxicity from salinity changes in the bay water samples for each runoff event. These functions were then applied to the salinity data from the plume mapping study in order to estimate the toxicity of surface water throughout the discharge plume.

Toxicity Identification Evaluations

Toxicity identification evaluations (TIEs) were conducted on stormwater (in-channel composite) and selected plume samples in order to determine which constituents were most likely to cause the observed toxic responses. The complete TIE process is generally broken into three phases. Phase I is used to characterize the toxicants present. Phase I TIE treatments are designed to selectively remove or neutralize classes of compounds (e.g., metals, non-polar organics) and thus the toxicity that may be associated with them. Phase II testing is designed to more specifically identify which chemicals in the sample are causing toxicity. Phase II analysis involves a variety of techniques, including fractionation and chemical analysis. Phase III studies are intended to confirm that the identified constituents are indeed responsible for the observed toxicity. Confirmation procedures often include statistical comparisons of observed and predicted toxicity in addition to experiments using samples spiked with the suspected toxicants. The TIE studies for the Chollas Creek samples emphasized Phase I and II testing.

Toxicant Characterization (Phase I TIEs)

A modified Phase I TIE, using methods described by the U.S. EPA (1991 and 1996), was conducted on each of the three stormwater samples to characterize toxicants present. The tests were conducted simultaneously with the baseline testing to minimize holding time and any possible associated change in toxicity. Test conditions were the same as for the baseline test, except that a reduced number of replicates were tested as recommended by U.S. EPA guidance.

The salinity of each water sample was adjusted to 34 g/kg before the application of the treatments. Four treatments were applied to each sample: particle removal, trace metal chelation, non-polar organic extraction, and chemical reduction.

Ethylenediaminetetraacetic acid (EDTA), a chelator of metals, was added to the test samples at a concentration of 60 mg/L. Sodium thiosulfate (STS), a treatment that reduces oxidants such as chlorine and also decreases the toxicity of some metals, was added to separate portions of each sample at a concentration of 50 mg/L. The EDTA and STS treatments were begun at least 1h prior to the addition of the test organisms to allow interaction with the sample.

Samples were centrifuged for 30 min to remove particle-borne contaminants. A portion of the centrifuged sample (200 to 600 mL) was passed through a 1 or 2 g Varian Bond Elut C-18 solid phase extraction column in order to remove non-polar organic compounds. The filtrate was retained for toxicity testing. The C-18 columns were sealed and stored under refrigeration for later elution during Phase II testing.

A control sample (laboratory dilution water) was included with each type of treatment to verify that the manipulation itself was not causing toxicity. The toxicity methods used to evaluate the effectiveness of the TIE treatments were the same as those used to measure baseline toxicity, except that only the two highest concentrations were tested and fewer replicates were used.

Toxicant Identification and Confirmation (Phase II and III TIEs)

The Phase II TIE tests with sea urchin sperm focused upon obtaining information to account for the effectiveness of the EDTA and C-18 treatments during the Phase I studies. These tests had three objectives: (1) to determine whether metal concentrations in the samples were sufficient to cause toxicity, (2) to investigate the effect of C-18 column treatment on trace metal toxicity, and (3) to determine whether non-polar compounds were present in toxic amounts.

The influence of trace metals was assessed by measuring the concentration of dissolved metals in the stormwater and plume samples analyzed for toxicity. Dissolved fractions of trace metals were extracted from the samples with ammonium pyrrolidine dithiocarbamate (APDC) after Bloom and Crecelius (1984). The chelated precipitate was captured on a membrane filter, which was then digested in nitric acid and subsequently analyzed using a high resolution inductively coupled plasma mass spectrometry (ICP/MS). The resulting data were compared to previously established toxicity thresholds for selected metals.

An experiment was conducted to determine whether extraction using a C-18 column altered the amount of toxicity in a sample contaminated with trace metals. Samples of filtered laboratory seawater were spiked with toxic concentrations of either copper (40 µg/L) or zinc (30 µg/L). Each sample was split into two portions, and one portion was passed through a C-18 column using the same procedure applied in previous Phase I TIE experiments. A sea urchin fertilization test was then conducted to compare the toxicity of the C-18 extracted and unaltered samples.

The presence of toxic concentrations of non-polar compounds was investigated by measuring the toxicity of solvent eluates from the Phase I C-18 columns. Each C-18 column was eluted with methanol (MeOH) followed by dichloromethane (DCM) for the February sample or with MeOH only for the March sample. The solvent eluates were exchanged into isopropanol and adjusted in volume so that when a 0.5% solution was made in seawater, a concentration factor of 2 to 3 times the original sample was achieved. This maximum concentration and two additional dilutions (50 and 25%) were tested for toxicity using the sea urchin fertilization test.

Analytical Chemistry

Water samples for trace metal analysis were centrifuged to remove particulates, extracted from seawater to concentrate target analytes and remove matrix-related interferences, and then analyzed using inductively-coupled plasma mass spectrometry (ICP-MS). Samples were centrifuged for 30 min at 3,000 x; often these samples were split with the toxicity analyses. The trace metal extraction technique followed Bloom and Crecilius (1984). The target metals were chelated out of a measured volume of well-mixed seawater using borohydride ammonium pyrrolidine dithiocarbamate (APDC) for cadmium, copper, lead and iron or using iron-palladium (Fe-Pd) for chromium and zinc. The chelated precipitate was then captured on a Nucleopore polycarbonate filter (0.45 µm pore size). The filtered precipitate was then digested using using concentrated nitric acid. Digestate was analyzed using ICP-MS following US EPA Method 200.8 (US EPA 1983).

RESULTS

Storm Event Characteristics and Sampling

Plume mapping and toxicity studies were conducted during three storm events that covered a range of rainfall and tidal conditions (Table 1, Figure 1). The first event was relatively small; rainfall amounts were less than 0.1 cm. Plume mapping activities required 3.47 hr to complete and occurred across both the ebb and flood cycle of a neap tide; tidal heights increased 0.3 m during surface water measurements. Only two samples were collected for toxicity. The first sample was very near the creek mouth and the second was collected in the bay, in an area outside of the runoff influence. No in-channel sample was collected upstream of the bay. The second event was larger with rainfall amounts of nearly 1.0 cm. The plume mapping during this event occurred exclusively during flood tide; tidal heights increased 0.7 m during the surface water measurements. Plume mapping activities required 4.72 hr to complete. Nine samples were collected for toxicity analysis. One sample was collected from the in-channel site upstream of the bay and eight samples were collected from receiving water sites that ranged from nearest the creek mouth to the open bay outside of the plume influence. The third event was the largest event sampled. Rainfall quantities exceeded 1.6 cm and plume mapping occurred exclusively during ebb tide; tidal heights decreased 1.8 m during the surface water measurements. Plume mapping activities required 5.12 hr to complete. Nine samples were also collected for toxicity analysis during this event. One sample was collected from the in-channel site upstream of the bay and eight samples were collected from receiving water sites that ranged from nearest the creek mouth to the open bay outside of the plume influence. In addition, a fourth event was targeted, but rainfall was inadequate to produce runoff.

Plume Mapping

The extent of the stormwater plume varied by size of storm, but was large enough to extend across the bay (Figures 2 through 4). The area of decreased salinity, defined as ≤ 32 practical salinity units (psu), and increased turbidity, relative to open bay water, extended from less than 0.02 km^2 during the smallest storm event to 2.25 km^2 during the second (February 12th) runoff event. The most concentrated portions of the plume were always located nearest the creek mouth, within the channel leading to the bay, and decreased away from the creek mouth as mixing and dispersion with open bay water occurred. During larger events, sufficient runoff volumes were discharged so that plumes were advected away from the Chollas Creek mouth out into the open bay. These plumes extended as far north as the Coronado Bridge and more than halfway across the bay beyond the western navigation marker located more than 2 km from the creek mouth.

Freshwater runoff plumes floated over the denser bay water and formed lenses that were thickest near the creek mouth and thinnest out near the margins (Figures 5 and 6). The depth of the plume nearest the creek mouth ranged from 2 to 4 m, depending upon the amount of rainfall (i.e., discharge volume) and overall water depth. The vertical water column structure showed that complete mixing occurred within the first 400 m of the creek mouth during the first and smallest event, and extended more than 1,500 m offshore during the second and largest runoff event. The second storm event also penetrated deepest into the water column.

Turbidity (transmissivity in beam C units) measurements also clearly defined the margins of the plume (Figures 2 through 4). Transmissivity results were similar to the salinity measures for the cross-shore water column structure; the thickest plume penetration was nearest the creek mouth, and the freshwater lensing thinned near the plume margin out in the open bay during the largest storms. Transmissivity at the margins changed up to 20% within a distance of meters. These changes were so dramatic they were visible to field crews aboard the research vessel during surveys. The only water column structure not easily resolved using turbidity measurements was an upwelling of higher salinity bay water near the creek mouth. The entrainment of deeper water is a natural feature of mixing zone dynamics. However, the upwelling was not detected using transmissivity measurements because these near-bottom waters were also turbid. It is unclear whether these bottom waters were turbid as a result of settling runoff particles or whether the turbidity was caused by the resuspension of in-place sediments as the entrainment occurred.

The water column structure in the along-shore direction showed the plume spreading asymmetrically during flood tides and symmetrically during ebb tides. The second storm, which was sampled on a flood tide, had a larger northward extent. In addition, a north-to-south long shore gradient in salinity was observed in the underlying bay waters.

Open bay salinities decreased over the wet season (Figures 2 through 6). During the first storm, open bay salinities were as high as 33.9 in January, decreasing to 33.7 in February and dropping to 32.9 in March. This result may have been due to the accumulated inputs over this time period from Chollas Creek and the other large channels that discharge to San Diego Bay including Sweetwater and Otay rivers.

Spatial Extent of Toxicity

Tests of San Diego Bay surface water samples collected during three runoff events revealed the presence of toxicity offshore of Chollas Creek. One to eight samples were collected during each runoff event. Toxicity to sea urchin sperm was detected in all samples collected within the portion of the plume containing ≥10% runoff (as determined from salinity measurements). Fertilization (normalized to the control response) in these samples ranged from 5 to 74%. The highest magnitude of toxicity (least fertilization) was found in samples taken near the mouth of Chollas Creek. Reference samples of San Diego Bay water collected from 0.3 to 1.5 km outside of the plume were non-toxic, with fertilization values of 88 to 100%.

Multiple water samples were analyzed during the second and third runoff events that showed the gradient of toxicity present corresponded with changes in water quality, as measured by salinity. The highest magnitude of toxicity (lowest fertilization) was present in the area of the plume with the lowest salinity, and the lowest magnitude of toxicity was found in those samples collected farthest from Chollas Creek.

Logistic regression analyses indicated that surface water toxicity in San Diego Bay was directly proportional to the amount of freshwater (i.e., runoff) present. Maps of toxicity created from the regression predictions show the spatial extent of the toxic portion of the plume for the second (Figure 7) and third (Figure 8) events. The toxicity plume for either event was similar in location to the discharge plume, as would be expected since salinity was the dominant factor in each map.

The boundaries of the discharge plume and the toxicity plume differed (Figures 3 and 4). In the second runoff event, the toxic portion of the plume, the region producing ≤80% fertilization, extended across 1.03 km^2 of the bay (Figure 7) and comprised approximately 50% of the physical extent of the plume, which was defined as the region of reduced salinity (≤32 psu). The size of the toxic portion of the plume measured during the third runoff event was smaller, covering an area of 0.24 km^2 (Figure 8). The physical extent of the plume during the third event was also much smaller (0.98 km^2) than observed during the second event, despite the occurrence of more rainfall in the study area during the third event (Table 3).

The estimates of the spatial extent of the toxic portion of the plume apply to the upper 0.5 m of the water column, the region from which the plume mapping data and toxicity test samples were obtained. The depth of the toxic portion of the plume was not measured directly during this study, but can be estimated from the water column profiles of salinity measured throughout the study area. These profiles show that the layer of water likely to contain toxic concentrations of runoff (salinity approximately <30 psu) is relatively thin and highly variable between stations and events (Figure 9). During the second runoff event, the toxic layer was approximately 0.6 m thick near Chollas Creek and increased in thickness to approximately 2 m as the runoff mixed to a greater extent with bay water in the outer portion of the plume. Although smaller in area during the third event, the depth of the toxic layer nearest Chollas Creek was greater (approximately 3 m) than the second event. The toxic layer decreased in thickness to approximately 1 m in the outer portion of the plume during the third event.

Magnitude of Plume Toxicity

Surface water samples collected near the mouth of Chollas Creek during the second and third runoff events, both of which were dominated by runoff (salinity <1 g/kg), had a similar magnitude of toxicity. A similar number of toxic units, 4.0 and 3.9 TUs, were present in the samples from the second and third events, respectively. The EC50s for these samples were 25 and 26%, respectively. The NOECs for these samples were 3 and 12% for the second and third events, respectively. These data indicate that strong toxic effects are expected to occur in portions of the runoff plume containing ≥25% runoff.

The overall magnitude of toxicity in the plume samples was similar to that measured in a composite sample collected from the Chollas Creek channel during each runoff event. The channel composite was slightly more toxic (5.9 TUs) than the plume sample during the second event, while the creek composite sample for the third event contained 3.4 TUs, which was not significantly different from the plume sample (Figure 10). The NOECs for the creek composites (3 and 12%) were the same as those measured for the plume samples, indicating that the threshold concentration for toxicity was similar in both types of samples.

Similarities in the magnitude of toxicity were also evaluated by comparing the dose-response curves of the creek composite sample to the toxicity of San Diego Bay surface water samples collected during each event. The toxicity of surface water samples was found to be similar to that measured in the corresponding creek composite sample diluted to contain a similar concentration of runoff (Figure 11).

Persistence of Toxicity

Repeat sampling nearest the creek mouth indicated that receiving water toxicity in San Diego Bay persisted for at least 3 days following the third (March 5) runoff event. A surface water sample collected offshore of the mouth of Chollas Creek on March 8 contained reduced salinity (27.5 g/kg) and was toxic to sea urchin sperm (60% fertilization). The fertilization response (i.e., toxicity) in this sample was similar to that measured in surface water collected from within the runoff plume on March 5 and containing a similar salinity (Figure 11). Plume mapping was not conducted during the March 8 sampling event, so the spatial extent of the remaining plume could not be determined. No repeat sampling was conducted following the second runoff event.

Identification of Toxicants

Phase I toxicity characterization tests were conducted on four samples, which included an in-channel composite and a plume sample from the second and third runoff events. The results of the EDTA and sodium thiosulfate (STS) treatments were similar for each of these samples. The EDTA eliminated the toxicity and STS was ineffective for all four samples (Figure 12). Particle removal by centrifugation was only partially effective in samples from the third event. Treatment using a C-18 solid phase extraction column removed the toxicity in three of four samples, including both of the composite samples (Figure 12).

The Phase I TIE results for EDTA, STS, and centrifugation were similar to those obtained for Chollas Creek composite samples collected and tested in 1999 and indicated that dissolved trace metals were the likely cause of toxicity. The strong effectiveness of the C-18 column treatment was not observed in 1999, however.

No toxicity was detected in solvent eluates of the C-18 columns that removed toxicity during the Phase I tests. The DCM or MeOH eluates of the columns tested at 2 to 3 times the original concentration in the aqueous sample were non-toxic to sea urchin sperm; fertilization in these samples was 93 to 100% of the control value. These results indicate that the toxicants removed by the C-18 column either had polar characteristics or had degraded during storage prior to elution.

A Phase II experiment was conducted in order to investigate the effectiveness of the C-18 column treatment on dissolved trace metals. The toxicity of seawater solutions spiked with toxic concentrations of copper or zinc was eliminated after C-18 column treatment (Figure 13). The effect was particularly noteworthy for zinc, where a solution causing a 55% reduction in fertilization was rendered non-toxic after passage through the column. These tests used the same type of column and procedures that were used in the Phase I experiments.

Each of the in-channel composite and San Diego Bay surface water samples were analyzed for dissolved trace metals in order to determine whether toxic concentrations of metals were present. Eight metals were identified as having elevated concentrations in the composite sample relative to those in surface water (Table 2). These metals included antimony, chromium, copper, iron, molybdenum, nickel, vanadium, and zinc. The average enrichment of these metals in Chollas Creek discharge (creek concentration divided by concentration in San Diego Bay) for the February 12 and March 5 events were: antimony, 75; chromium, 21; copper, 18; iron, 1,300; molybdenum, 3; nickel, 6; vanadium, 6; and zinc, 11.

Aside from iron, dissolved zinc and copper were present in the highest concentrations in samples collected from within Chollas Creek. Zinc concentrations from the most concentrated portion of the plume (essentially 100% stormwater discharge) ranged from 92 to 152 µg/L (Table 2); these concentrations were above the zinc EC50 determined from previous fertilization experiments (29 µg/L). Copper concentrations in the same samples ranged from 37 to 66 µg/L, which also exceeded the EC50 for copper (31 µg/L) measured in reference toxicant tests conducted during this study. Background concentrations of zinc and copper in the bay during this study were approximately 14 µg/L and 3 µg/L, respectively. Little is known about the sensitivity of sea urchin sperm to the other metals listed in Table 2.

Variations in dissolved zinc concentration among the San Diego Bay surface water samples showed an apparent dose response relationship with sea urchin fertilization (Figure 14). Fertilization percentage declined as zinc concentration increased, and the magnitude of effect was consistent with the dose response relationship for zinc determined from prior laboratory experiments with spiked seawater. For example, large reductions in fertilization were observed in samples containing dissolved zinc concentrations similar to or greater than the EC50 value (Figure 14). A similar plot for dissolved copper also indicated a correspondence between toxicity and concentration, but the data were more variable and did not correspond as well with the NOEC and EC50 for copper-spiked seawater (Figure 14). Many of the toxic samples contained less copper than the NOEC, indicating that the toxicity was not caused by copper. The two samples containing copper concentrations above the EC50 were highly toxic, however.

Toxic unit calculations based upon zinc and copper toxicity confirmed that these two metals were present in sufficient concentrations to cause most of the toxicity measured in the heart of the runoff plume and in the in-channel composite samples. Most of the toxicity measured in each sample was attributable to zinc, and the total amount of toxicity calculated from zinc plus copper accounted for 72 to 109% of the total toxicity measured in the samples (Figure 15).

DISCUSSION

The wet-weather events sampled from Chollas Creek generated large volumes of stormwater runoff that extended over more than 2 km^2 of San Diego Bay. These plumes were turbid and, because the freshwater discharge is less dense than seawater, they formed thin lenses of 2 to 5 m thickness on the surface of the bay. Thin stormwater plumes of large areal extent have been observed offshore other urban watersheds in southern California. Plumes extending over 4 km^2 and 3 m thickness were measured offshore Ballona Creek following storm events of 7 cm and greater (Bay *et al.* 1999). Similarly, thin plumes were measured in upper Newport Bay following storm events discharging runoff from urban areas of the San Diego Creek watershed (Lee *et al.* 1999).

Several limitations apply to the plume measurements made as part of this study. The first limitation is attempting to describe a fixed plume extent when plumes are dynamic water quality features. For example, our plume surveys lasted up to 6 h, yet plumes can shift and change in size or shape over the course of a tidal cycle. A second limitation to our plume mapping abilities was the difficulty of attempting to extrapolate our measurements to unmeasured areas. We used a kriging method to construct our plume maps. However, kriging techniques work best under steady state conditions, an assumption that was violated at times during our surveys because plumes, particularly during flooding events, are dynamic. On the other hand, we were able to find the plume margins using distinct salinity and turbidity signatures. Hence, our estimates of plume extent were verified using empirical data. Moreover, the repetitiveness of the plume extent over multiple storm events adds confidence to our assessment. In fact, the storms we measured were not extraordinarily large and a greater extent of impact may occur during larger-sized events.

Plume toxicity was directly related to toxicity measured in the Chollas Creek discharge. The magnitude of toxicity near the creek mouth was similar to the toxicity measured from within the creek. The magnitude of toxicity then decreased as the plume mixed away from the creek mouth until, reaching outside the plume margin, the toxicity was not observed. In fact, the toxicity could be predicted as a function of salinity. Further, the extent of toxicity was similar to the extent of the discharge plume after accounting for dilution of the plume with bay waters. These findings are consistent with plume toxicity measurements taken offshore of other creek mouths in southern California (Bay *et al.* 1997). Offshore of Ballona Creek, toxicity was found using the purple sea urchin test and it was in direct proportion to the amount of stormwater present in that plume.

Not only was the plume toxicity proportional to the amount of freshwater mixing, but the same constituents were identified as the toxic agents from the creek and from the plume. Zinc was identified as the primary toxicant to the purple sea urchin in Chollas Creek discharges during the 1997/1998 wet season (SCCWRP 1999) and again during this study. Zinc was also identified as the primary toxicant to the purple sea urchin in the stormwater plume from San Diego Bay that emanated from Chollas Creek during this study. However, this finding was different from other species, such as the freshwater daphnid *Ceriodaphnia*, which was sensitive to other constituents (e.g., organophosphate pesticides). We do not expect all species to be affected similarly to stormwater exposures. While we observed some very compelling evidence that Chollas Creek stormwater affected purple sea urchins, this finding may not be applicable to other marine species.

Stormwater plumes are not the only source of pollutants that generate water column toxicity in San Diego Bay. The toxicity observed in the wet-weather plume offshore Chollas Creek was greater than the toxicity observed in other 303(d) listed portions of San Diego Bay (RWQCB unpublished data). For example, purple sea urchins exposed to receiving waters sampled from the Shelter Island Yacht Harbor yielded NOECs of 20% whereas samples taken from the Chollas Creek wet-weather plume yielded NOEC values as low as 3%. Similarly, dissolved zinc and copper concentrations were as much as an order of magnitude higher in the wet-weather plume than in the yacht harbor. However, the toxicity in the Shelter Island waters persists every day of the year while the toxicity in the plume persists for at least 3 d following runoff events. Managers need to decide whether increased toxicity for shorter time periods is more important than persistent low-level toxicity.

Establishing a relationship between discharge measurements and receiving water toxicity is one of the key tools managers need to make useful environmental decisions. In this case, a TMDL for toxicity to marine organisms for Chollas Creek can be focused on two objectives that were not known prior to this study. The first objective is that trace metals, primarily zinc, can be targeted and reduced to effect a decrease in the toxicity measured in the bay. The second objective focuses on how much zinc needs to be reduced to achieve non-toxic levels in the bay. Managers have three options: (1) to reduce the amount of zinc in the discharge, (2) to reduce the total volume of discharge (which improves mixing and dilution), or (3) to combine a reduction in zinc concentration with a reduction in discharge volume. All three of these management actions will reduce toxicity, and this study provides measures of the amount of zinc or discharge volume required to achieve non-toxic levels in the bay. If the option is to reduce zinc, an estimate of what magnitude of reduction needs to occur to limit toxicity is found in this report. If the option is to reduce the discharge volume, this report also shows how much mixing and dilution needs to occur to achieve non-toxic levels in the bay. Without establishing a relationship between discharges and receiving water toxicity, the management actions selected and their endpoints would be unsubstantiated and likely inflated with a margin of safety.

CONCLUSIONS

- *Stormwater plumes from Chollas Creek extended over an area of 2 km^2 in San Diego Bay.*

  This study observed that stormwater plumes emanating from Chollas Creek extended between 0.02 and 2.25 km^2 over San Diego Bay during small to moderately-sized storm events. Plumes were easily distinguished using salinity as a conservative tracer of wet weather inputs. Turbidity was also a good tracer of the plume. Stormwater plumes formed relatively thin lenses of 1 to 3 m, floating on top of the more dense bay water.

- *Toxicity extended up to 1 km from the creek mouth and was proportional to the amount of runoff dilution.*

  This study measured toxicity using the purple sea urchin (*Strongylocentrotus purpuratus*) fertilization test in both stormwater samples taken from the creek and samples taken from the stormwater plume in San Diego Bay. This toxicity varied across the gradient of plume influence and was well correlated with the amount of stormwater present in the sample. All samples were salinity adjusted before toxicity testing, so the gradient in toxicity appears to be a function of toxicants present in the stormwater discharges.

- *The toxic part of the plume was smaller than the salinity signal.*

  Although toxicity was measured in the stormwater plume emanating from Chollas Creek, the entire plume was not toxic. In the two storms that we mapped from this study, the toxic portion of the plume was approximately 25% to 50% of the plumes' salinity signal. This reduction in the spatial extent of plume toxicity was likely due to dilution and mixing of the plume in the Bay.

- *In-channel and plume toxicity was primarily due to trace metals including zinc and copper.*

  TIEs conducted on stormwater samples from both the Creek and from the stormwater plume in the Bay identified dissolved trace metals, predominantly zinc, as the toxicant responsible for the majority of toxicity. Toxicity was eliminated by the addition of the metal chelating agent EDTA. Concentrations of dissolved zinc, and to a lesser extent copper, were high enough in the tested samples to account for the observed toxicity.

RECOMMENDATIONS

- *Since zinc was identified as a constituent of concern, sources of zinc within the watershed should be investigated.*

  This study, in combination with previous years' research, has demonstrated that zinc was responsible for the toxicity to marine organisms present in the receiving water habitat. It is recommended that sources of zinc be identified in the watershed to provide information for the development and implementation of the TMDL by regulators and stakeholders. A thorough understanding of zinc sources and how that zinc is transported to the bay will enable regulators and stakeholders to set effective allocations and efficient implementation strategies.

- *The short-term toxicity effects identified in this study should be followed-up with assessments of potential long-term effects in sediments.*

  The suspended sediments in the turbid plume measured in this study will eventually settle to the bottom of the bay with the potential to impact bay sediments. For example, monitoring at the mouth of Cholls Creek has shown an increase in sediment contamination and toxicity following the wet season relative to pre-wet season measurements (URS/WCC 2000). Also, the Bay Protection and Toxic Clean Up Program has shown an increase in sediment contamination, sediment toxicity, and impaired infaunal communities at the mouth of Chollas Creek (Fairey *et al.* 1998). The extent and magnitude of sediment contamination and toxicity should be investigated near the creek mouth to assess the potential degree of impacts due to creek discharges. Moreover, sediment TIEs should be conducted to identify the constituent(s) of concern in the contaminated sediments. These may be the same constituents as those found in the discharge plume, but not necessarily. Regardless, this information needs to be determined in order to take effective management actions to remediate benthic impacts in the bay.

- *Due to differences in sensitivity among organisms, additional species should be tested to assess if additional constituents may cause toxicity.*

  A demonstrated toxic effect was observed in the receiving water using a native species, the purple sea urchin. However, not all species respond similarly to the same constituents. For example, previous years' research showed no effect on the non-native crustacean *Mysidopsis bahia*. However, other resident species may be sensitive to other constituents in the stormwater plume. Hence, if all of the zinc was abated in the discharge, receiving water impacts may still occur. Therefore, additional testing with other species is recommended to assess the potential impact of other constituents of concern.

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TABLE 1. Summary of plume and storm event characteristics. Tide change refers to net increase or decrease in tide height during sampling. Salinity threshold was 32 practical salinity units. Threshold for toxicity was 80% of control response.

			Plume Area Based on Salinity or Toxicity Thresholds (km^2)	
Storm Date	Rainfall (cm)[a]	Tide Change (m)	Salinity	Toxicity
25 Jan 2000	<0.1	+0.3	Not measured	Not measured
12 Feb 2000	1.0	+0.7	2.25	1.03
05 Mar 2000	1.6	-1.8	0.98	0.24

[a] Measured at Lindbergh Field. Data courtesy of the National Weather Service

TABLE 2. Salinity, sea urchin toxicity (% of control fertilization), and dissolved concentration of selected metals in Chollas Creek and San Diego Bay water samples. Plume samples were collected from the portion of the plume having the lowest salinity while the bay samples were collected outside of the plume. EC50 and NOEC values for selected metals were calculated from SCCWRP fertilization experiments. The metal concentrations reflect sample dilution that occurred during salinity adjustment for toxicity testing.

	Sample	Salinity	Fertilized	Metal Concentration (µg/L)							
Date	Type	(psu)	(%)	Sb	Cr	Cu	Fe	Mo	Ni	V	Zn
	EC50					31					29
	NOEC					20-44					5-10
1/25/00	Plume	32.9	74	0.19	0.12	2.46	6	8.92	1.24	2.03	16.50
1/25/00	Bay	33.8	94	0.14	0.16	3.21	2	8.61	0.91	2.04	11.40
2/12/00	Creek	0	6	17.56	2.68	51.20	2,184	25.80	10.72	11.14	150.80
2/12/00	Plume[a]	0	18	3.45	1.93	36.88	1,752	14.6	8.75	12.57	92.00
2/12/00	Bay[a]	32.4	92	0.18	0.15	3.08	1	8.95	0.94	2.06	13.80
3/5/00	Creek	0	10	8.32	3.36	63.00	3,080	25.20	12.44	11.28	146.00
3/5/00	Plume	0	8	6.20	3.30	65.60	3,260	26.40	13.78	13.44	152.20
3/5/00	Bay[a]	32.6	100	0.16	0.14	3.22	3	9.44	10.42	2.00	14.30
3/8/00	Plume	27.5	60	0.24	0.33	3.73	8	11.54	1.99	3.66	26.06

[a] Mean of two samples for this entry, all other values represent single samples.

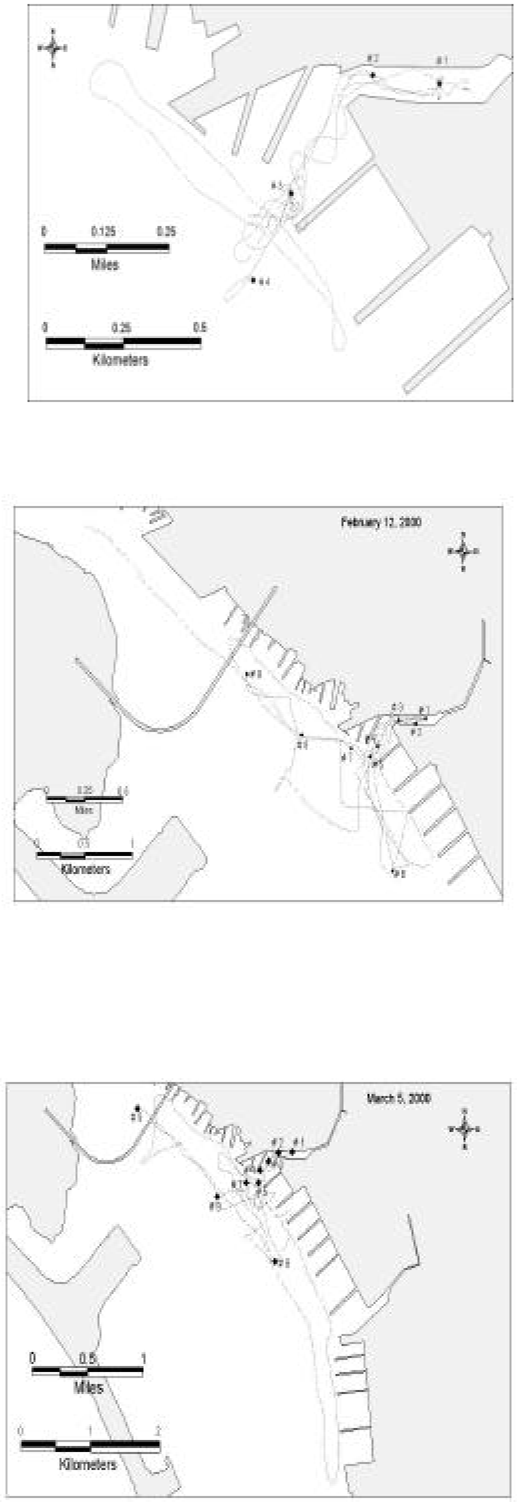

FIGURE 1. Towpaths for surface plume mapping offshore Chollas Creek during three separate storm events (January 25, February 12, and March 5, 2000). Numbers represent locations where vertical water column profiles were conducted and samples for toxicity were collected.

insert Figure 2 here

insert figure 3 here

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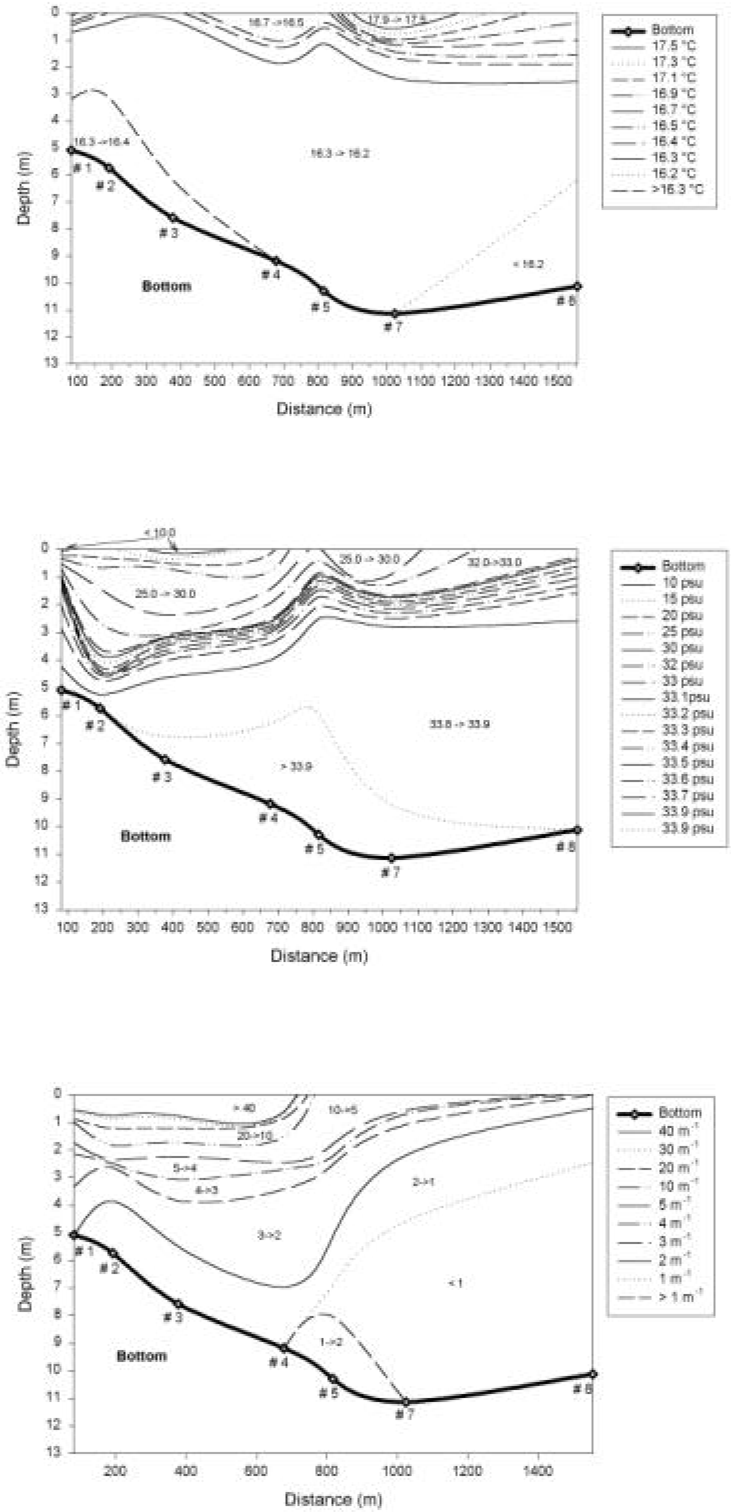

FIGURE 5. Temperature (°C), salinity (practical salinity units, psu), and turbidity (Beam C attenuation per meter) in cross-section moving offshore from the Chollas Creek mouth into San Diego Bay during the February 12, 2000 storm event.

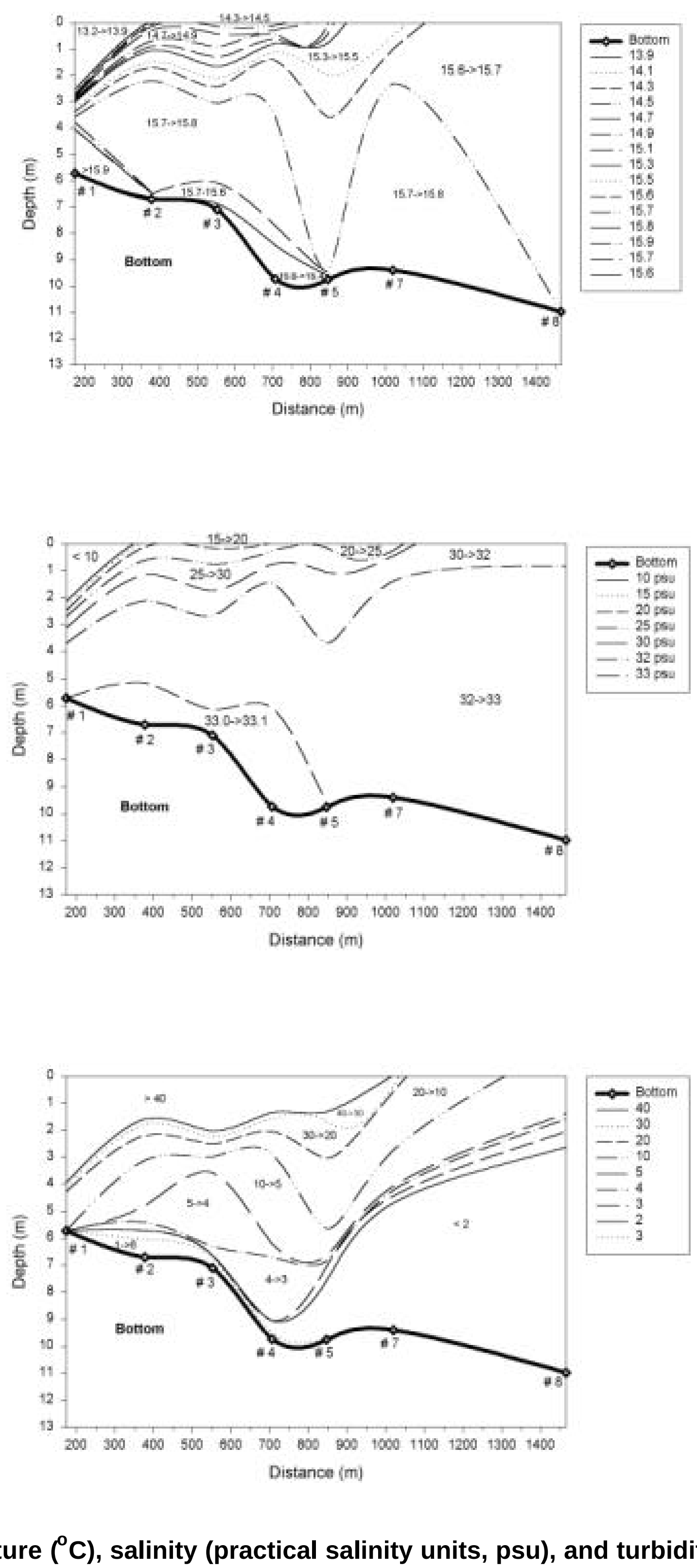

FIGURE 6. Temperature (°C), salinity (practical salinity units, psu), and turbidity (Beam C attenuation in meters) in cross-section moving offshore from the Chollas Creek mouth into San Diego Bay during the March 5, 2000 storm event.

insert figure 7 here

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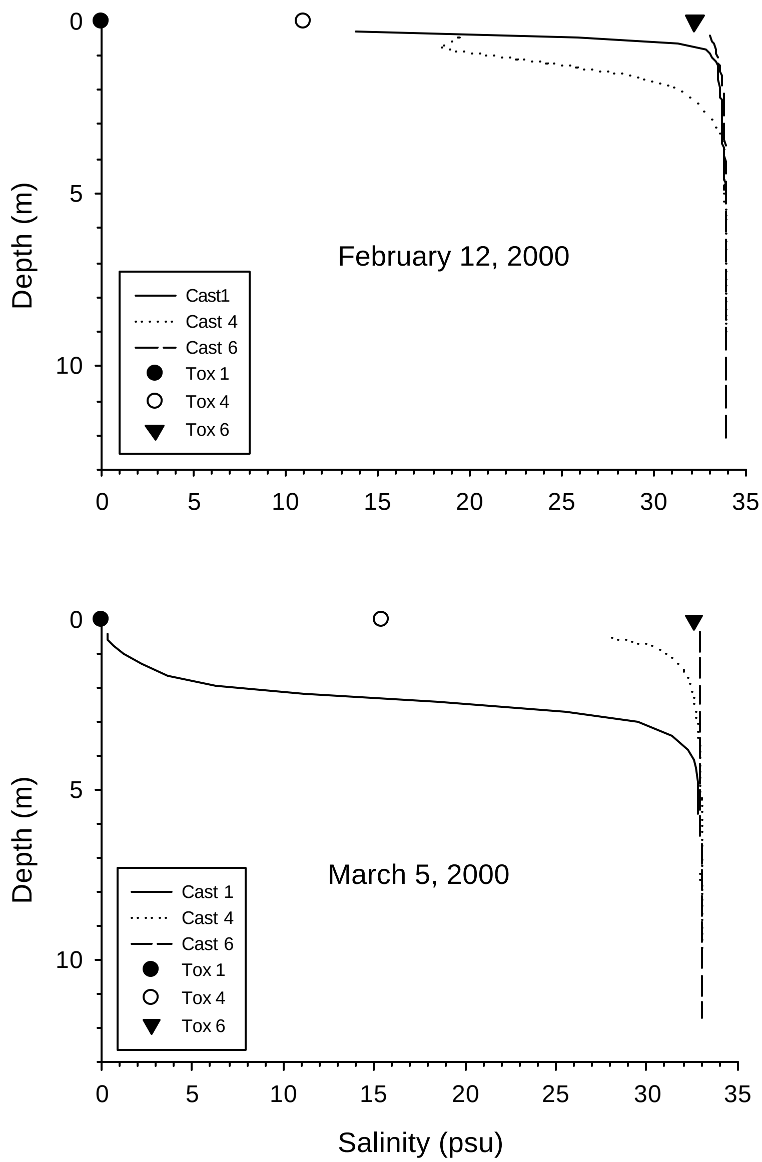

FIGURE 9. Change in salinity with depth for selected stations in San Diego Bay. Lines indicate salinity from CTD casts and symbols show salinity in surface water samples collected for toxicity analysis. Station 1 = near Chollas Creek Mouth; Station 4 = ~0.2 km offshore of Chollas Creek; Station 6 = outside of discharge plume.

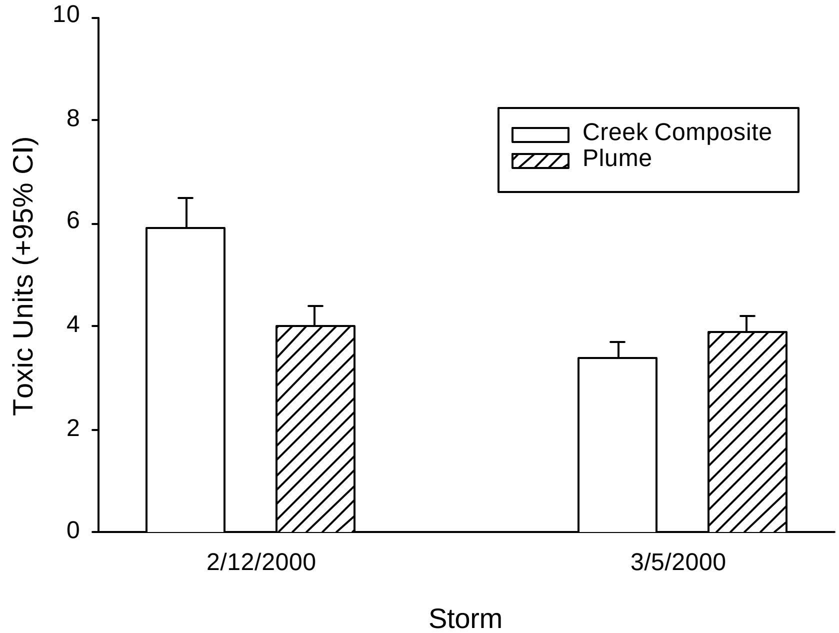

FIGURE 10. Comparison of the magnitude of toxicity to sea urchins in Chollas Creek composite and San Diego Bay plume samples.

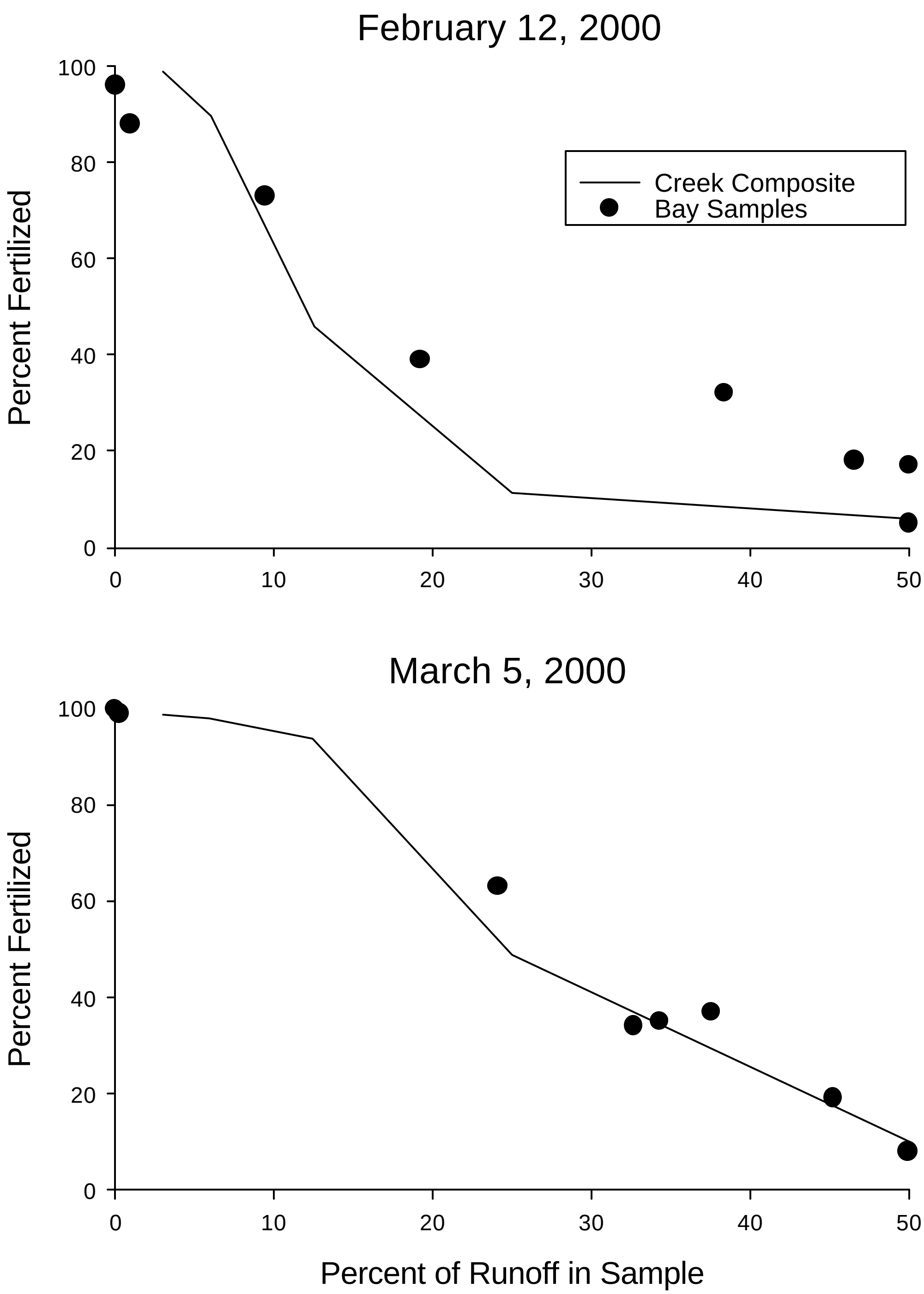

FIGURE 11. Comparison of sea urchin toxicity in San Diego Bay surface water samples to the dose-response curve obtained for composite samples obtained from Chollas Creek.

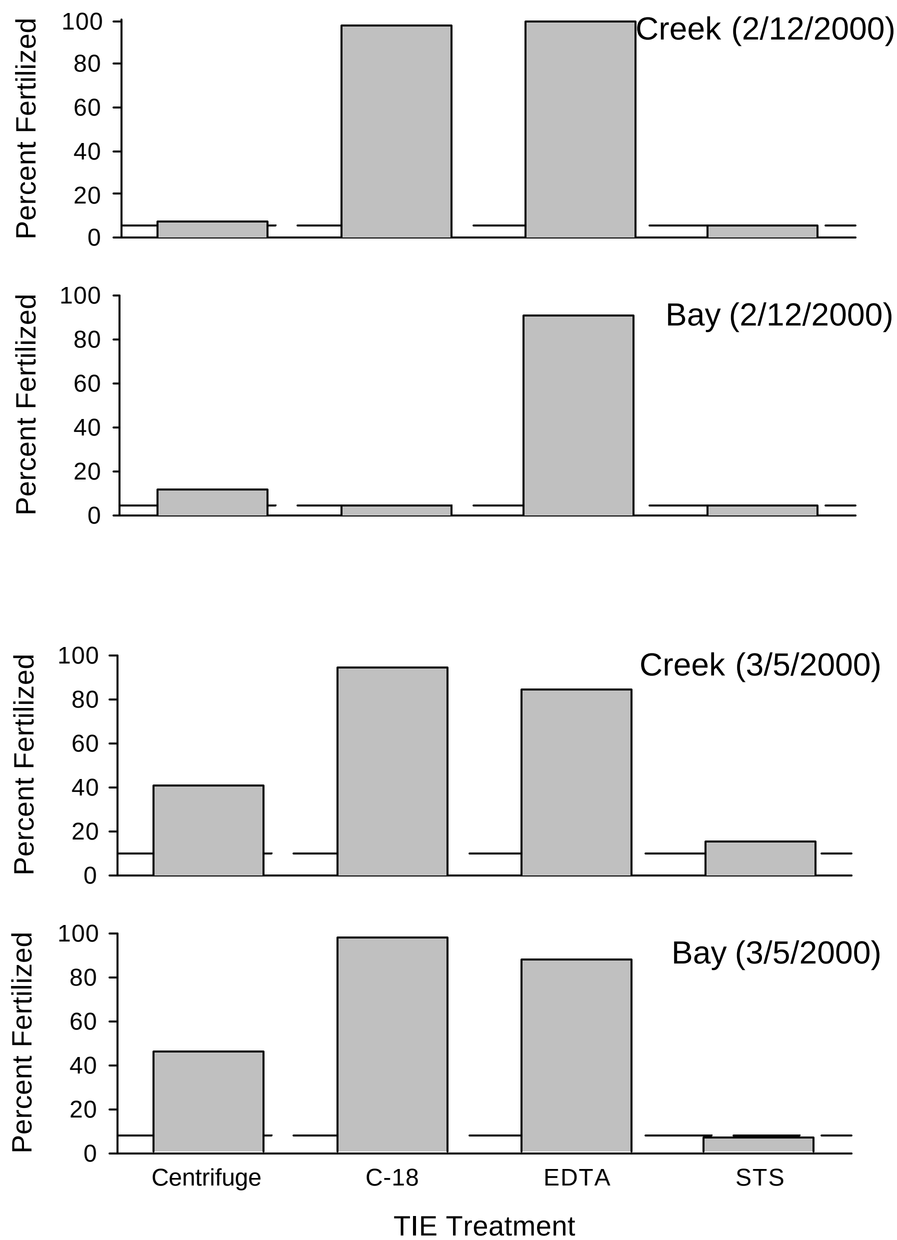

FIGURE 12. Summary of toxicity characterization results for Chollas Creek stormwater composite samples and bay surface water samples taken near the mouth of the creek. Each sample tested contained 50% runoff. The baseline toxicity (prior to TIE treatment) is indicated by the dashed line.

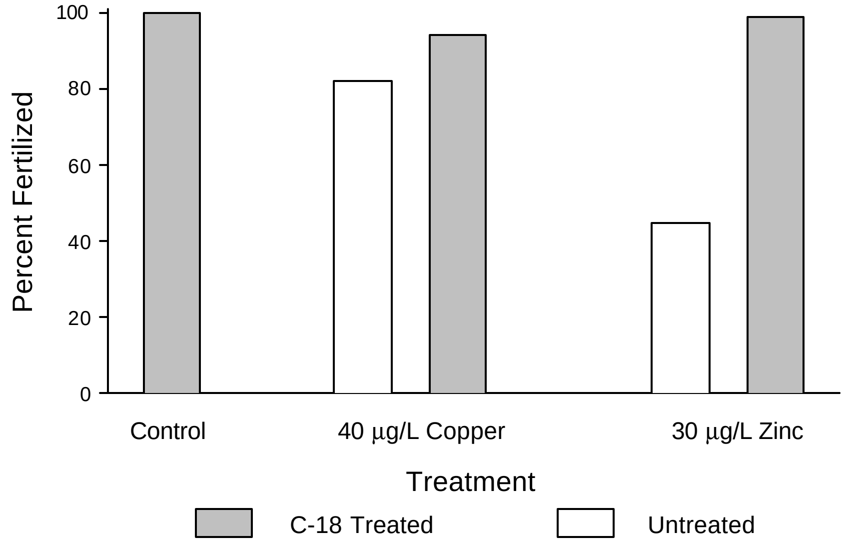

FIGURE 13. Effect of C-18 column treatment on the toxicity of metal-spiked seawater to sea urchins.

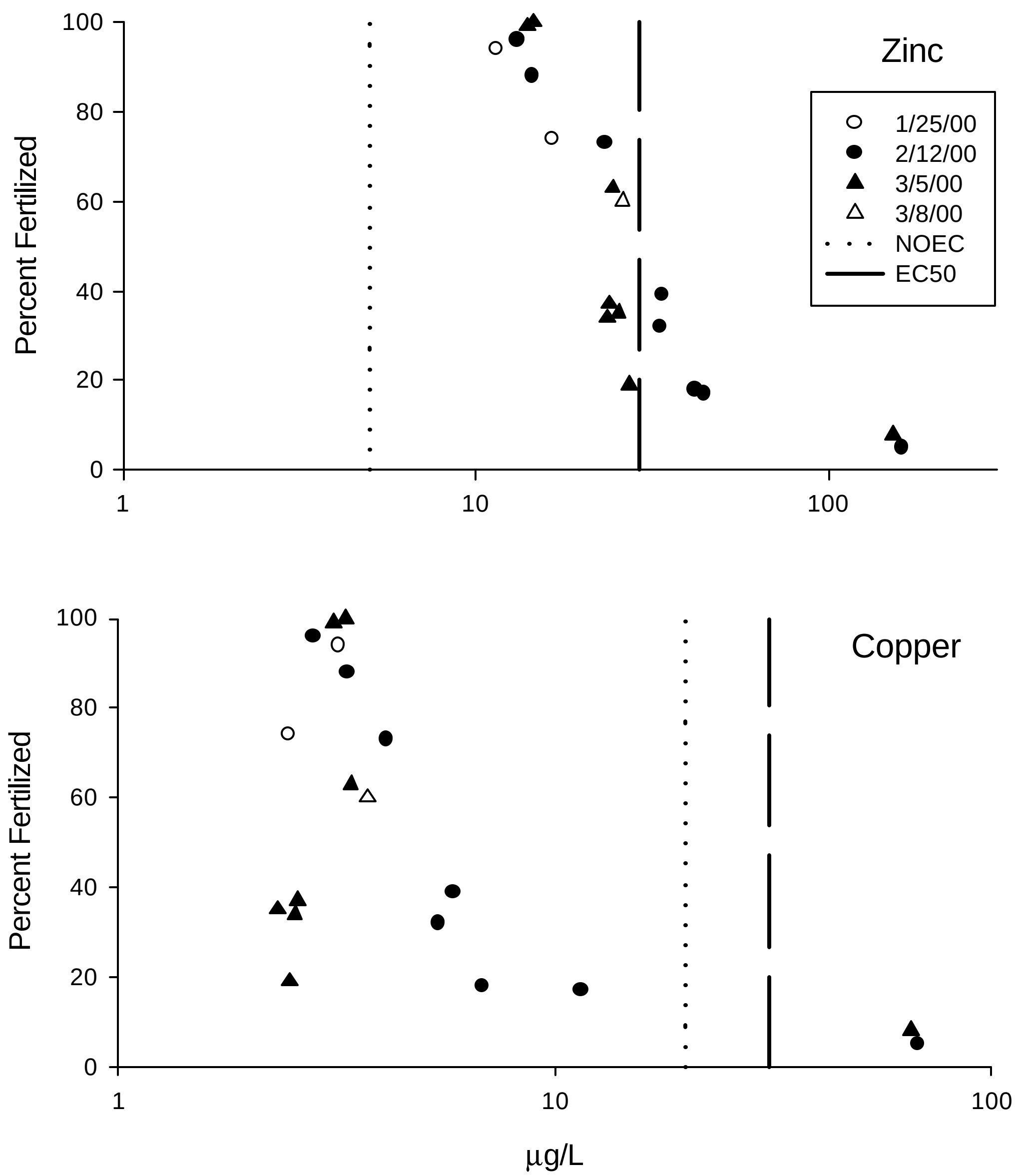

FIGURE 14. Comparison of sea urchin toxicity to dissolved metal concentrations in San Diego Bay surface water samples collected during three storm events. Reference lines indicate the NOEC and EC50 for each metal, which was determined from laboratory experiments.

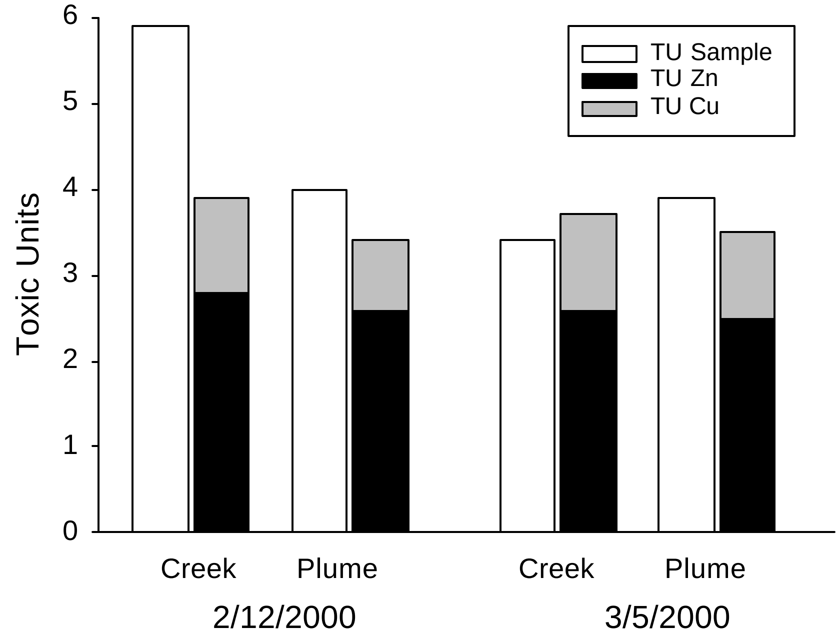

FIGURE 15. Comparison of toxic units (TUs) measured in Chollas Creek or plume samples and toxic units predicted from dissolved metals concentration.

APPENDIX A

Toxicity Test Results

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Wet Weather Receiving Water

Sample Collected: 1/25/00
Test Initiated: 1/26/00 Test Ended: 1/26/00 Experiment Number: S424

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Different from Control
CCSW01260001	Control Seawater	97	5.1	5	
CCBK01260001	Brine Control 50%	93	12.0	5	
CCBK01250001	Travel Blank	81	17.1	5	
CCRW01250010	Station 1 100%	50	20.8	5	*
CCRW01250010	Station 1 50%	91	9.4	5	
CCRW01250010	Station 1 25%	98	2.5	5	
CCRW01250080	Station 8 100%	100	0.9	5	
CCRW01250080	Station 8 50%	NC	NC	NC	
CCRW01250080	Station 8 25%	NC	NC	NC	

NC= Not counted. The next highest concentration was similar to the mean control value.

Station 1: NOEC= 50% EC50 >100%
Station 8: NOEC >100% EC50 >100%

The test met acceptability criteria for control fertilization (70% or greater), however the reference toxicant had high variability precluding the calculation of a copper EC50.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Station 1 100%	8.26	na	33.3	16.1	0.06
Station 8 100%	8.30	na	34.1	16.1	0.56
Test Min	8.01	na	33.1	16.1	0.00
Test Max	8.30	na	34.1	16.1	0.56

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Copper reference toxicant

Sample Collected: 1/25/00
Test Initiated: 1/26/00 Test Ended: 1/26/00 Experiment Number: S425

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Different from Control
CCSW01260002	Seawater Control	83	13.7	5	
CCRF01260001	9.5 ug/l Cu	50	33.6	5	NT
CCRF01260002	13.9 ug/l Cu	29	24.2	5	NT
CCRF01260003	20.4 ug/l Cu	37	19.4	5	NT
CCRF01260004	30.0 ug/l Cu	11	5.1	5	NT
CCRF01260005	44.0 ug/l Cu	1	1.3	5	NT
CCRF01260006	65.0 ug/l Cu	0	0.5	5	NT

NT= Significance testing not performed.

The test met acceptability criteria for control fertilization (70% or greater), but the very high variability associated with the lower concentrations precludes calculating meaningful NOEC or EC50 values.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Copper Ref.					
Test Min	8.18	na	33.5	16.1	0.13
Test Max	8.25	na	33.6	16.1	0.13

na= not analyzed.

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Copper reference toxicant

Sample Collected: 2/13/00
Test Initiated: 2/13/00 Test Ended: 2/13/00 Experiment Number: S427

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Different from Control
CCSW01260002	Seawater Control	99	0.5	4	
CCRF01260001	9.5 ug/l Cu	98	0.9	5	
CCRF01260002	13.9 ug/l Cu	100	0.6	4	
CCRF01260003	20.4 ug/l Cu	99	0.5	5	
CCRF01260004	30.0 ug/l Cu	95	3.8	5	
CCRF01260005	44.0 ug/l Cu	65	10.0	4	*
CCRF01260006	65.0 ug/l Cu	33	13.3	4	*

Evidence of contamination of exposure vials led to one replicate being discarded from the control, 13.9, 44.0 and 65.0 ug/l concentrations.

NOEC= 30.0 ug/L EC50= 55.5 ug/l

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Copper Ref.					
Test Min	8.18	na	33.0	14.7	na
Test Max	8.22	na	33.7	14.7	na

na= not analyzed.

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Chollas Creek Wet Weather Sample Baseline and TIE

Sample Collected: 2/13/00
Test Initiated: 2/13/00 Test Ended: 2/13/00 Experiment Number: S428

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW02130001	Control	98	1.7	3	
CCBK02130001	Brine Control 50%	NA	NA	NA	
CCBK02130001	Brine Control 25%	NA	NA	NA	
CCFL02120090A	Chollas Ck Flow 50%	6	4.5	5	*
CCFL02120090A	Chollas Ck Flow 25%	11	7.9	5	*
CCFL02120090A	Chollas Ck Flow 12.5%	45	6.1	4	*
CCFL02120090A	Chollas Ck Flow 6%	88	4.6	3	*
CCFL02120090A	Chollas Ck Flow 3%	97	0.7	2	
CCBK02130002	EDTA Blank 60 mg/L	96	-	1	NT
CCFL02120090A	Chollas Flow EDTA 60 mg/l 50%	100	0.7	2	NT
CCFL02120090A	Chollas Flow EDTA 60 mg/l 25%	NC	NC	0	
CCBK02130003	STS Blank 50 mg/l	99	-	1	NT
CCFL02120090A	Chollas Flow STS 50 mg/l 50%	6	5.0	3	NT
CCFL02120090A	Chollas Flow STS 50 mg/l 25%	NC	NC	0	
CCBK02130004	Centrifuge Blank	99	-	1	NT
CCFL02120090A	Chollas Flow Centrifuged 50%	8	10.4	3	NT
CCFL02120090A	Chollas Flow Centrifuged 25%	NC	NC	0	
CCBK02130004	C-18 Column Blank	97	1.4	2	NT
CCFL02120090A	Chollas Flow C-18 Treated 50%	98	0.6	3	NT
CCFL02120090A	Chollas Flow C-18 Treated 25%	NC	NC	0	

NA= Brine control were made improperly so that salinity was very high, therefore not analyzed.
NC= Samples not evaluated microscopically.
NT= Significance testing not performed.

There was evidence of contamination of the exposure vials, therefore, replicates that had fertilization values of 25 percentage points or below highest values were removed. Since TIE treatments had only 3 reps, removed samples only if difference was more than 50 points.

Chollas Flow Sample NOEC= 3% EC50= 17.0%

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Chollas Ck 50%	8.08	na	31.6	14.7	0.14
Test Min	7.90	na	29.7	14.7	0.00
Test Max	8.23	na	32.4	14.7	0.14

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Station 1 Wet Weather Sample Baseline and TIE

Sample Collected: 2/13/00
Test Initiated: 2/13/00 Test Ended: 2/13/00 Experiment Number: S429

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Different from Control
CCSW02130003	Control	93	-	1	
CCRW02120001	Station 1 50%	5	5.5	5	*
CCRW02120001	Station 1 25%	45	1.2	3	*
CCRW02120001	Station 1 12.5%	85	5.2	3	*
CCRW02120001	Station 1 6%	85	7.8	2	*
CCRW02120001	Station 1 3%	99	0.0	2	
CCBK02130002	EDTA Blank 60 mg/L	90	-	1	NT
CCRW02120001	Station 1 EDTA 60 mg/l 50%	91	1	3	NT
CCRW02120001	Station 1 EDTA 60 mg/l 25%	NC	NC	0	
CCBK02130003	STS Blank 50 mg/l	86	-	1	NT
CCRW02120001	Station 1 STS 50 mg/l 50%	5	3	3	NT
CCRW02120001	Station 1 STS 50 mg/l 25%	4	-	1	NT
CCBK02130004	Centrifuge Blank	2	3	3	NT
CCRW02120001	Station 1 Centrifuged 50%	12	18	3	NT
CCRW02120001	Station 1 Centrifuged 25%	19	-	1	NT
CCBK02130006	C-18 Column Blank	34	29	2	NT
CCRW02120001	Station 1 C-18 Treated 50%	5	1	3	NT
CCRW02120001	Station 1 C-18 Treated 25%	46	46	3	NT

NC= Samples not evaluated microscopically.
NT= Significance testing not performed.

There was evidence of contamination of the exposure vials, therefore, replicates that had fertilization values of 25 percentage points or below highest values were removed. Since TIE treatments had only 3 reps, removed samples only if difference was more than 50 points.

Station 1 NOEC= 3% EC50= 25.0%

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Station 1 50%	8.19	na	32.5	14.7	0.00
Test Min	7.93	na	31.6	14.7	0.00
Test Max	8.23	na	33.0	14.7	0.14

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Wet weather receiving water samples

Sample Collected: 2/13/00
Test Initiated: 2/13/00 Test Ended: 2/13/00 Experiment Number: S430

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW02130004	Control Seawater	99	0.4	5	
CCTB02120000	Travel Blank	100	0.5	4	
CCLB02120000	Laboratory Blank	100	0.5	5	
CCRW02120002	Station 2	17	3.6	5	*
CCRW02120003	Station 3	18	13.9	5	*
CCRW02120004	Station 4	32	8.9	5	*
CCRW02120005	Station 5	72	12.1	4	*
CCRW02120006	Station 6	87	5	4	*
CCRW02120007	Station 7	39	11	5	*
CCRW02120008	Station 8	95	4	5	

There was evidence of contamination of the exposure vials, therefore, replicates that had fertilization values of 25 percentage points or below highest values were removed.

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample		pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Receiving Water						
	Test Min	8.05	6.8	31.4	14.7	0.00
	Test Max	8.18	7.3	32.7	14.7	0.15

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Copper reference toxicant

Sample Collected: 2/22/00
Test Initiated: 2/22/00   Test Ended: 2/22/00   Experiment Number: S431

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus*   Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCRT02130001	Seawater Control	98	1.3	5	
CCRT02130002	9.5 ug/l Cu	99	0.9	5	
CCRT02130003	13.9 ug/l Cu	97	1.1	5	
CCRT02130004	20.4 ug/l Cu	97	0.9	5	
CCRT02130005	30.0 ug/l Cu	94	2.6	5	
CCRT02130006	44.0 ug/l Cu	94	1.1	5	
CCRT02130007	65.0 ug/l Cu	69	12.4	4	*

Evidence of contamination of exposure vials led to one replicate being discarded from the 65.0 ug/l concentration.
NOEC= 44.0 ug/l   EC50 > 65.0 ug/L

The test met acceptability criteria for control fertilization (70% or greater), but the EC50 was outside of control chart limits.

Water quality analysis not performed.

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Wet weather Chollas Creek and receiving water samples (RETEST)

Sample Collected: 2/12/00
Test Initiated: 2/22/00 Test Ended: 2/22/00 Experiment Number: S432

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW02220002	Control	96	2.1	5	
CCBK02220001	Brine Control 50%	97	1.5	5	
CCBK02220002	Brine Control 25%	96	2.1	2	
CCFL02120090A	Chollas Ck Flow 50%	52	11.1	5	*
CCFL02120090A	Chollas Ck Flow 25%	91	1.8	5	*
CCFL02120090A	Chollas Ck Flow 12.5%	96	1.9	5	
CCFL02120090A	Chollas Ck Flow 6%	98	0.5	5	
CCFL02120090A	Chollas Ck Flow 3%	96	1.5	5	
CCRW02120001	Station 1 50%	45	4.6	5	*
CCRW02120001	Station 1 25%	93	0.4	5	*
CCRW02120001	Station 1 12.5%	97	0.5	5	
CCRW02120001	Station 1 6%	97	1.1	5	
CCRW02120001	Station 1 3%	95	5.6	5	

Chollas Creek Flow NOEC= 12.5% EC50= 53.3%
Station 1 NOEC= 12.5% 50.0%

The test met acceptability criteria for control fertilization (70% or greater), but the reference toxicant EC50 was outside of control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Chollas Creek 50%	8.17	6.7	30.8	15.0	0.05
Station 1 50%	8.21	6.4	31.0	15.0	0.08
Test Min	8.09	6.1	30.2	15.0	0.00
Test Max	8.21	7.1	32.6	15.0	0.08

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Chollas Creek Wet Weather Sample Baseline and TIE

Sample Collected: 3/5/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S433

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Different from Control
CCSW03070001	Control	99	0.5	5	
CCBK03070001	Brine Control 50%	98	2.3	5	
CCBK03070002	Brine Control 25%	NC	NC	0	
CCFL03050090A	Chollas Ck Flow 50%	10	4.6	5	*
CCFL03050090A	Chollas Ck Flow 25%	49	8.9	5	*
CCFL03050090A	Chollas Ck Flow 12.5%	94	7.3	5	
CCFL03050090A	Chollas Ck Flow 6%	98	1.2	5	
CCFL03050090A	Chollas Ck Flow 3%	99	0.8	5	
CCBK03070001	EDTA Blank 60 mg/L	60	11.4	3	NT
CCFL03050090A	Chollas Flow EDTA 60 mg/l 50%	85	7.4	3	NT
CCFL03050090A	Chollas Flow EDTA 60 mg/l 25%	NC	NC	0	
CCBK03070002	STS Blank 50 mg/l	99	1.0	3	NT
CCFL03050090A	Chollas Flow STS 50 mg/l	15	5.1	3	NT
CCFL03050090A	Chollas Flow STS 50 mg/l	NC	NC	0	
CCBK03070003	Centrifuge Blank	99	0.6	3	NT
CCFL03050090A	Chollas Flow Centrifuged	41	22.5	3	NT
CCFL03050090A	Chollas Flow Centrifuged	NC	NC	0	
CCBK03070004	C-18 Column Blank	92	6.7	3	NT
CCFL03050090A	Chollas Flow C-18 Treated	95	4.0	3	NT
CCFL03050090A	Chollas Flow C-18 Treated	NC	NC	0	

NC= Samples not evaluated microscopically.
NT= Significance testing not performed.

Chollas Creek Flow NOEC= 12.5% EC50= 29.4%

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Chollas Creek 50%	na	6.2	na	15.0	0.11
Test Min	7.80	6.1	32.8	15.0	0.02
Test Max	8.30	6.8	33.7	15.0	0.11

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Station 1 Wet Weather Sample Baseline and TIE

Sample Collected: 3/5/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S434

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW03070002	Seawater Control	99	0.8	5	
CCRW03050001	Station 1 50%	8	1.9	5	*
CCRW03050001	Station 1 25%	36	15.7	5	*
CCRW03050001	Station 1 12.5%	82	23.0	5	
CCRW03050001	Station 1 6%	99	0.9	5	
CCRW03050001	Station 1 3%	100	0.5	5	
CCRW03050001	Station 1 EDTA 60 mg/l 50%	88	3.5	3	NT
CCRW03050001	Station 1 EDTA 60 mg/l 25%	NC	NC	0	
CCRW03050001	Station 1 STS 50 mg/l 50%	7	4.0	3	NT
CCRW03050001	Station 1 STS 50 mg/l 25%	NC	NC	0	NT
CCRW03050001	Station 1 Centrifuged 50%	46	16.8	3	NT
CCRW03050001	Station 1 Centrifuged 25%	NC	NC	0	
CCBK03070005	C-18 Column Blank	98	1.7	3	NT
CCRW03050001	Station 1 C-18 Treated 50%	98	0.6	3	NT
CCRW03050001	Station 1 C-18 Treated 25%	NC	NC	0	

NC= Samples not evaluated microscopically.
NT= Significance testing not performed.

Station 1 NOEC= 12.5% EC50= 25.7%

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Station 1 50%	8.30	6.1	33.1	15.0	0.18
Test Min	7.81	6.1	33.0	15.0	0.00
Test Max	8.30	7.4	33.7	15.0	0.18

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Wet weather receiving water samples

Sample Collected: 3/5/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S435

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW03050003	Control Seawater	100	0.4	5	
CCTB03050098	Travel Blank	99	1.3	5	
CCLB03050099	Laboratory Blank	100	0.5	5	
CCRW03050002	Station 2	19	5.4	5	*
CCRW03050003	Station 3	37	6.7	5	*
CCRW03050004	Station 4	35	7.3	5	*
CCRW03050005	Station 5	34	7.4	5	*
CCRW03050006	Station 6	99	1	5	
CCRW03050007	Station 7	63	8	5	*
CCRW03050008	Station 8	100	0	5	*

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Receiving Water					
Test Min	8.10	6.7	32.3	15.0	0.03
Test Max	8.30	7.6	33.7	15.0	0.21

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: C-18 column eluates

Sample Collected: 2/12/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S436

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates
CCSW03070003	Control Seawater	99	0.5	5
CCBK03070006	Isopropanol Blank 0.25%	NC	NC	0
CCBK03070006	Isopropanol Blank 0.5%	100	0.6	3
CCFL02120090A	Chollas Ck C-18 MeOH Eluate 0.5X	NC	NC	0
CCFL02120090A	Chollas Ck C-18 MeOH Eluate 1X	NC	NC	0
CCFL02120090A	Chollas Ck C-18 MeOH Eluate 2X	97	4.4	3
CCFL02120090A	Chollas Ck C-18 MeCl2 Eluate 0.5X	NC	NC	0
CCFL02120090A	Chollas Ck C-18 MeCl2 Eluate 1X	NC	NC	0
CCFL02120090A	Chollas Ck C-18 MeCl2 Eluate 2X	93	3.6	3
CCRW02120001	Station 1 C-18 MeOH Eluate 0.5X	NC	NC	0
CCRW02120001	Station 1 C-18 MeOH Eluate 1X	NC	NC	0
CCRW02120001	Station 1 C-18 MeOH Eluate 2X	100	0.6	3
CCRW02120001	Station 1 C-18 MeCl2 Eluate 0.5X	NC	NC	0
CCRW02120001	Station 1 C-18 MeCl2 Eluate 1X	NC	NC	0
CCRW02120001	Station 1 C-18 MeCl2 Eluate 2X	99	0.6	3
CCBK03070007	Blank C-18 MeOH Eluate 0.5X	NC	NC	0
CCBK03070007	Blank C-18 MeOH Eluate 1X	NC	NC	0
CCBK03070007	Blank C-18 MeOH Eluate 2X	80	4.0	3
CCBK03070008	Blank C-18 MeCl2 Eluate 0.5X	NC	NC	0
CCBK03070008	Blank C-18 MeCl2 Eluate 1X	NC	NC	0
CCBK03070008	Blank C-18 MeCl2 Eluate 2X	63	5.5	3
CCBK03070009	Manifold Blank 2X	99	1.5	3

NC= Samples not evaluated microscopically.

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Test Min	8.00	5.8	33.4	15.0	na
Test Max	8.20	6.7	33.7	15.0	na

na= not analyzed

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: Copper reference toxicant

Sample Collected: 3/7/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S437

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW03070005	Seawater Control	100	0.5	5	
CCRT03070001	9.5 ug/l Cu	98	1.9	5	
CCRT03070002	13.9 ug/l Cu	93	6.9	5	
CCRT03070003	20.4 ug/l Cu	93	11.7	5	
CCRT03070004	30.0 ug/l Cu	83	9.6	5	*
CCRT03070005	44.0 ug/l Cu	40	15.9	5	*
CCRT03070006	65.0 ug/l Cu	4	3.5	5	*

NOEC= 20.4 ug/l EC50= 40.8 ug/l

The test met acceptability criteria for control fertilization (70% or greater), and the EC50 was within control chart limits.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
Copper Ref.					
Test Min	8.10	6.2	33.5	15.0	0.00
Test Max	8.10	6.4	33.6	15.0	0.00

Toxicity Data Summary

Project: Chollas Creek Plume
Sample Description: C-18 column eluates

Sample Collected: 2/12/00
Test Initiated: 3/7/00 Test Ended: 3/7/00 Experiment Number: S436

Test Method: Purple Sea Urchin Fertilization Test (EPA/600/R-95/136)
Species: *Strongylocentrotus purpuratus* Laboratory: SCCWRP
Supervising Technician: Darrin Greenstein

Sample Code	Sample	Mean %Fertilized	Standard Deviation	Number of Replicates	Significantly Reduced from Control
CCSW03140001	Seawater Control	100	0.4	5	
CCBK03140001	Brine Control	99	1.2	5	
CCRT03140001	Copper 40 ug/l	82	5.3	3	NT
CCRT03140002	Zinc 30 ug/l	45	8.4	3	NT
CCBK03140002	Metal C-18 Column Blank	100	0.6	3	NT
CCRT03140001	Copper 40 ug/l C-18 Treated	94	7.6	3	NT
CCRT03140002	Zinc 30 ug/l C-18 Treated	99	0.0	3	NT
CCBK03140003	Brined C-18 Column blank	99	1.5	3	NT
CCFL03050090	Chollas Ck Brined Centrifuged 50%	38	12.4	3	NT
CCFL03050090	Chollas Ck Brined C-18 Treated 50%	100	0.6	3	NT
CCBK03140004	Unbrined C-18 Column blank	100	0.0	3	NT
CCFL03050090	Chollas Ck Unbrined Centrifuged 50%	43	8.6	3	NT
CCFL03050090	Chollas Ck Unbrined C-18 Treated 50%	100	0.6	3	NT
CCBK03140005	Elution blank	100	0.6	3	NT
CCBK03140006	Methanol blank 0.5%	100	0.6	3	NT
CCBK03140006	Methanol blank 1.0%	100	0.6	3	NT
CCFL03050090	Chollas Creek Eluate 0.75X	NC	NC	0	
CCFL03050090	Chollas Creek Eluate 1.5X	NC	NC	0	
CCFL03050090	Chollas Creek Eluate 3X	96	4.4	3	NT
CCRW03050001	Station 1 Eluate 0.75X	NC	NC	0	
CCRW03050001	Station 1 Eluate 1.5X	NC	NC	0	
CCRW03050001	Station 1 Eluate 3X	93	6.1	3	NT
CCRW03080001	Station 1 Post rain Sample 15.2%	60	13.9	5	*
CCRW03080001	Station 1 Post rain Sample 12.5%	97	2.3	5	*
CCRW03080001	Station 1 Post rain Sample 6%	100	0.4	5	
CCRW03080001	Station 1 Post rain Sample 3%	NC	NC	0	
CCFL03050090	Chollas Ck C-18 1st DIW wash 2.4X	100	0.0	3	
CCFL03050090	Station 1 C-18 1st DIW wash 2.4X	99	1.2	3	

NC= Samples not evaluated microscopically.
NT= Significance testing not performed.

Station 1 Post rain Sample NOEC= 6% EC50= 16.0%

The test met acceptability criteria for control fertilization (70% or greater). No reference toxicant exposure was performed.

Toxicity summary for experiment S436 continued.

Sample characteristics (range among treatments during test):

Sample	pH	Dissolved Oxygen (mg/L)	Salinity (g/kg)	Temp. (°C)	Total Ammonia (mg/L)
.					
Test Min	7.90	6.8	31.9	15.0	na
Test Max	8.10	7.8	35.2	15.0	na

na= not analyzed

APPENDIX B

Chemistry Results

Analytical chemistry results for creek and bay samples.

Sample ID	Sample Date	Sample description	Salintiy (psu)	TSS (mg/L	Dilution of sample for toxicity	Trace Metals (µg/L)																	
						Al	Sb	As	Cd	Cr	Co	Cu	Fe	Pb	Mn	Mo	Ni	Se	Ag	Tl	Sn	V	Zn
CCRW01250010A	Jan. 25, 2000	Near Mouth RW	32.9	NA	1	1.9	0.2	1.4	0.3	0.1	0.2	2.5	6.5	0.1	19.6	8.9	1.2	ND	0.3	ND	0.1	2.0	16.5
CCRW01250080A	Jan. 25, 2000	Outside Plume RW	33.8	NA	1	2.1	0.1	1.5	0.7	0.2	0.1	3.2	2.3	0.1	8.2	8.6	0.9	ND	0.1	ND	ND	2.0	11.4
CCRW02120001A	Feb. 12, 2000	Near Mouth RW	0.0	137	0.5	110.8	5.2	ND	ND	3.4	40.8	68.0	3220.0	0.6	17.7	27.6	15.1	ND	ND	ND	ND	16.5	161.8
CCRW02120002A	Feb. 12, 2000	Plume RW	0.0	142	0.5	460.0	1.8	3.1	ND	0.5	ND	5.8	284.0	1.3	10.8	1.6	2.4	ND	ND	ND	ND	8.6	22.2
CCRW02120003A	Feb. 12, 2000	Plume RW	5.0	156	0.55	26.5	0.3	2.0	0.2	0.5	0.5	3.8	32.2	0.5	11.9	2.5	2.6	ND	0.0	ND	ND	6.7	23.0
CCRW02120004A	Feb. 12, 2000	Plume RW	11.0	48	0.58	10.2	0.3	2.2	0.2	0.4	0.5	3.2	13.7	0.3	21.9	3.9	2.1	ND	0.0	ND	ND	5.8	19.4
CCRW02120005A	Feb. 12, 2000	Plume RW	28.9	23	0.85	11.5	0.2	1.7	0.2	0.2	0.2	3.5	5.3	0.2	14.5	7.8	1.3	ND	0.0	ND	ND	2.6	19.8
CCRW02120006A	Feb. 12, 2000	Outside Plume RW	32.2	9	1	3.2	0.2	1.4	0.2	0.1	0.1	3.4	1.7	0.1	14.5	9.3	1.0	ND	0.1	ND	ND	2.1	14.5
CCRW02120007A	Feb. 12, 2000	Plume RW	24.4	9	0.77	6.7	0.3	1.8	0.3	0.3	0.3	4.5	5.5	0.2	28.8	7.5	1.7	ND	0.1	ND	ND	3.6	26.0
CCRW02120008A	Feb. 12, 2000	Outside Plume RW	32.5	9	1	3.1	0.2	1.5	0.2	0.2	0.1	2.8	1.2	0.1	11.3	8.6	0.9	ND	0.2	ND	ND	2.0	13.1
CCFL02120090	Feb. 12, 2000	Creek Sample	0.0	131	0.5	155.8	17.6	4.0	ND	2.7	3.3	51.2	2184.0	0.7	17.2	25.8	10.7	ND	2.2	ND	ND	11.1	150.8
CCRW03050001A	Mar. 5, 2000	Near Mouth RW	0.0	283	0.5	78.0	6.2	ND	ND	3.3	4.0	65.6	3260.0	ND	15.0	26.4	13.8	ND	ND	ND	ND	13.4	152.2
CCRW03050002A	Mar. 5, 2000	Plume RW	5.6	467	0.55	13.8	0.4	4.7	0.4	0.7	0.3	2.5	12.0	0.3	24.0	15.6	2.5	ND	1.8	ND	ND	8.3	27.3
CCRW03050003A	Mar. 5, 2000	Plume RW	12.8	317	0.62	43.7	0.3	4.0	0.4	0.6	0.3	2.6	52.3	0.4	24.4	14.8	2.2	ND	0.3	ND	ND	6.8	23.9
CCRW03050004A	Mar. 5, 2000	Plume RW	15.4	257	0.65	43.9	0.3	3.6	0.4	0.5	0.3	2.3	44.1	0.3	21.7	11.2	2.1	ND	0.1	ND	ND	5.9	25.4
CCRW03050005A	Mar. 5, 2000	Plume RW	16.6	243	0.66	81.9	0.3	3.6	0.5	0.5	0.3	2.5	86.6	0.4	22.1	12.8	2.8	ND	0.0	ND	ND	5.8	23.6
CCRW03050006A	Mar. 5, 2000	Outside Plume RW	32.6	9	1	3.4	0.2	1.5	0.3	0.2	0.1	3.1	4.2	0.1	11.8	9.5	0.9	ND	0.0	ND	ND	2.0	14.0
CCRW03050007A	Mar. 5, 2000	Plume RW	22.1	51	0.75	13.1	0.3	3.2	0.3	0.5	0.2	3.4	9.7	0.2	15.7	12.0	1.7	ND	0.0	ND	ND	4.2	24.4
CCRW03050008A	Mar. 5, 2000	Outside Plume RW	32.7	6	1	3.4	0.2	1.6	0.2	0.1	0.3	3.3	1.4	0.1	10.6	9.4	19.9	ND	0.0	ND	ND	2.0	14.6
CCFL03050090A	Mar. 5, 2000	Creek Sample	0.0	318	0.5	174.4	8.3	ND	ND	3.4	3.5	63.0	3080.0	0.2	6.8	25.2	12.4	ND	ND	ND	ND	11.3	146.0
CCRW0380001	Mar. 8, 2000	Near Mouth RW	27.5	0.2	0.85	5.6	0.2	2.6	1.0	0.3	0.4	3.7	7.9	0.1	81.0	11.5	2.0	ND	0.0	ND	ND	3.7	26.1

ND = not detected