May 8, 2013
Item No. 7
Supporting Document No. 7

Schwall, Kristin@Waterboards

From:	Snyder, Barry <barry.snyder@amec.com>
Sent:	Monday, March 11, 2013 4:45 PM
To:	Schwall, Kristin@Waterboards; Mata, Michelle@Waterboards
Cc:	Sharon Cloward; Stransky, Chris
Subject:	Comments on Tentative Order No. R9-2013-0026; NPDES Permit No.CAG719001; General Waste Discharge Requirements for Discharges from Boatyards and Boat Maintenance Facilities Adjacent to Surface Waters within the San Diego Region
Attachments:	Boatyard Draft NPDES Permit Comments_SDPTA.pdf

Dear Kristin and Michelle-

Thank you for the opportunity to provide comments on Tentative Order No. R9-2013-0026; draft NPDES Permit No.CAG719001; General Waste Discharge Requirements for Discharges from Boatyards and Boat Maintenance Facilities Adjacent to Surface Waters within the San Diego Region. I am submitting these comments on the draft Boatyard NPDES Permit on behalf of the San Diego Port Tenants Association and San Diego Bay Boatyards. Please feel free to call or e-mail me if you have any questions regarding these comments. Thank you for your consideration.

Respectfully,

Barry Snyder

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TENTATIVE ORDER R9-2013-0026
GENERAL WASTE DISCHARGE REQUIREMENTS FOR DISCHARGES
FROM BOATYARDS AND BOAT MAINTENANCE AND REPAIR FACILITIES
TO SURFACE WATERS WITHIN THE SAN DIEGO REGION

Section-Specific Comments:

#	Page	Section	Topic	Comments
1	E-3	Attachment E II. Monitoring Locations	Storm Water Monitoring Locations	On Table E-1 of the draft permit, Nielsen Beaumont Marine is required to monitor "SW-NMB" at "A representative sample location for the discharge of storm water to America's Cup Harbor, San Diego Bay." In fact, the new yard design at the upgraded Nielsen Beaumont Marine facility prevents all stormwater discharges to America's Cup Harbor. Based upon this fact, it is requested that the description that Nielsen Beaumont Marine discharges storm water to America's Cup Harbor be deleted from the general permit. In fact, other San Diego Bay boatyards have also been retrofitted so that they do not have a discharge to the Bay. This fact should be considered and Table E-1 revised accordingly.
2	NA	NA	No Exposure Certification (NEC) option in the General Permit	The July 16, 2012, General NPDES Permit for Storm Water Discharges Associated with Industrial Activities includes an option for a facility to apply for a Conditional Exclusion - No Exposure Certification (NEC) (http://www.swrcb.ca.gov/water_issues/programs/stormwater/docs/industrial/2012npdesgenprmt/permit_igp_72012.pdf). The NEC Requirements are described on pages 58-62. Section C. NEC Industrial Materials and Activities - Storm-Resistant Shelter Not Required, states, "To qualify for NEC coverage, a Storm-Resistant Shelter is not required for the following: 5. Any Industrial Materials and Activities that are <u>protected within a secondary containment structure that will not discharge storm water to waters of the United States</u>. The design of Nielsen Beaumont Marine (in particular) is such that the entire boatyard facility is protected within a secondary containment structure (i.e. berm) that will not discharge storm water to waters of the United States. Consequently, it is requested that Conditional Exclusion - No Exposure Certification (NEC) language be added to Tentative Order No. R9-2013-0026; NPDES Permit No.CAG719001 so that a boatyard, it they choose, can apply for a NEC exclusion.

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3	I-2	Attachment I	Consistency in the use of the Term "Tier" versus "Category"	The term "Category" is used throughout the draft NPDES Permit to describe the two types of boatyard facilities cover by this permit as well as the monitoring requirements for each. Please note that in Section I – Boatyard Annual Checklist, these facilities are referred to as Tier I and II. Please revise Section I to be consistent with the sections of the permit.
4	15	Order IV.A.	Chronic toxicity testing for storm water	To reiterate many recent comments submitted to the State Board in 2011 on the Draft Statewide Toxicity Policy, the Administrative Draft of the San Diego Boatyard Permit, and other Policies and Permits related to storm water monitoring in California (i.e. Areas of Special Biological Significance [ASBS] Special Protections), ***chronic toxicity testing of end-of-pipe storm water prior to entering a marine receiving water environment is inappropriate.*** Additional details backing up this statement are provided in an attached White Paper (ATTACHMENT I) (Stransky 2013) and are summarized below: • Conducting chronic toxicity tests on a sample that would normally pass within several hours to a day at most will undoubtedly lead to an overestimation of toxicity and in no way reflects the real exposure and dynamics that occur in marine receiving waters during and after a storm event. • Freshwater runoff entering a marine environment needs special consideration, as undiluted freshwater alone is toxic to marine species. Any contaminant pulses that a marine species will be exposed to will occur only after the storm water has mixed in the marine environment. • Adding brine or salts to a freshwater sample alters the properties of storm water in unknown ways and results in a sample that no marine animal would ever be exposed to in the environment. This contrasts sharply with situations where storm water enters a freshwater receiving water environment where animals indeed could be exposed to undiluted storm water for extended durations without succumbing physiologically to a salt imbalance. • Acute toxicity tests with mysid shrimp (*Americamysis bahia*) are recommended and have proven to be sensitive and able to cost effectively identify problematic runoff sources to receiving water environments. Expensive chronic toxicity tests are not required for this assessment at end-of-pipe. • Based on substantial storm water toxicity data collected to date across the State, there is recognition that surface runoff resulting from a transient short-term pulse will

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				frequently elicit both acute and chronic toxicological response in a discharge, even at facilities with stringent BMPs in place. Although limited studies have been published, available data collected in receiving waters (RW) at the point of discharge during a storm event have found limited acute or chronic toxic responses regardless of effects observed in adjacent outfalls. One of the most comprehensive studies published to date with concurrent storm water end of pipe and RW monitoring was performed by the Navy in San Diego Bay (Katz et al. 2006) and found limited toxicity in the receiving waters directly in front of an outfall during several storm events (< 1% of samples tested, n = 202). Only a few chronic tests using mussel embryo development showed effects in the receiving water; none were acutely toxic to mysid shrimp or topsmelt. On the other hand, discreet grab and composite storm water samples from concurrently tested adjacent outfalls were often toxic. Almost all showed an effect on mussel embryo development. Real time continuous *in situ* monitoring during the study in 2006 and a prior study (Katz and Rosen, 2005) also found toxicity in end-of-pipe samples, but no toxicity in bay samples directly in front of the monitored outfall. These results, along with extensive plume mapping performed as a part of these studies in San Diego Bay suggest that the relatively small magnitude and ephemeral nature of these outfall discharges were sufficient to explain the removal of toxicity of the storm discharge once it reaches the bay. • Based on the above results, and current proposed end-of-pipe chronic toxicity testing requirements, accelerated monitoring and follow-up Toxicity Identification Evaluations (TIEs) will be required on nearly every end-of-pipe discharge sample regardless of the actual potential for effects and magnitude of impact in the receiving water. The cost to proceed down this route is nearly impossible to fathom. • The State Board has previously concurred that chronic toxicity tests are an invalid measure to assess impacts of storm water on receiving waters due to the intermittent nature of storm water runoff and short duration (See attached letter (ATTACHMENT II) from the State Board regarding a petition of waste discharge requirements for Continental Maritime and NASSCO, Order WQ-98-07). • The Numeric Actions Levels (NAL) limits for chemistry in the Tentative Order are based on <u>acute</u> criteria. • Chronic toxicity tests are meaningful and recommended in RW samples in front of a

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				discharge of interest as required in Section V. • Simultaneous testing of both effluent and RW samples provides a number of substantial benefits. This is consistent with recent State of California Special Protections requirements for discharges to ASBS. The RW is the area of interest for potential biological effects. If effects are observed in the RW, measurements in the effluent can help track sources. If effects are observed in the RW, but not the adjacent effluent, then the source of toxicity is likely from elsewhere. If the RW is not toxic at the immediate point of discharge, compliance is achieved regardless of effluent toxicity. Acute only testing of end-of-pipe stormwater has been proven to be sensitive and will provide a meaningful cost-effective connection to any effects that may or may not be observed in the immediate receiving water. Delete chronic methods for end-of-pipe storm water and replace with *acute.*
5	E-2	Attachment E. MRP – Section I.A.	General Monitoring Provisions	All *effluent* samples shall be taken at the monitoring locations specified below and, unless otherwise specified, before the monitoring flow joins or is diluted by any other waste stream, body of water, or substance. *Receiving water monitoring shall occur in the mixing zone approximately 1 foot below the surface immediately in front of a monitored discharge*. Monitoring locations shall not be changed without notification to and the approval of the San Diego Water Board. The proposed receiving water monitoring sampling location is consistent with new protocols for monitoring ASBS in the 2012 State of California Special Protections Requirements
6	E-4	Attachment E. MRP – Section III	Discharge Monitoring	Add the following Section for clarity: *B. Monitoring Locations and Frequency* *Effluent samples shall be collected prior to the point of discharge, at the designated monitoring location for the effluent as specified in Tables E-1 and E-2. At minimum the sample shall consist of a single grab collected during the first four hours of runoff. A composite of several grab samples collected during the period when a runoff occurs is recommended if possible to better characterize discharged storm water effluent over the entire runoff event. Sampling methods should be the same for both analytical chemistry and toxicity analyses.* *Monitoring results shall be submitted annually with the annual report, as specified in Section VIII*

#	Page	Section	Topic	Comments
				of this MRP.
7	E-4	Attachment E. MRP – Section III. Table E-3	Toxicity sampling frequency for stormwater	Replace chronic with *acute* for stormwater effluent testing (See Comment # 4).
8	E-4	Attachment E. MRP – Section III. Table E-3	Acute toxicity sampling frequency for stormwater	Add *Composite* Sample as an option in the Table under sample type. Recommend grab as a minimum requirement, but a composite sample is preferred for TSS, settleable solids, COD, BOD, metals, and toxicity
9	E-6	Attachment E. MRP IV.A.1	Sensitive Species Screening	This paragraph states that a "three-species sensitivity screening shall be conducted during the first sample collection under the permit." The following text states that "a minimum of four single-concentration toxicity tests shall be performed for each species used." This seems conflicting and needs clarification. Based on a history of species sensitivity screens conducted in both storm water and receiving waters in San Diego Bay, the embryo larval development test will most likely always be the most sensitive test species of the proposed three. *Based on information available now, a single three-species screen during each permit cycle seems plenty sufficient and resource conscious.*
10	E-6	Attachment E. MRP IV.A.2	Giant Kelp Tests	The proposed plant species, giant kelp, is not found growing in San Diego Bay. Furthermore, the reproductive spores can also be difficult and dangerous to collect for storm water testing since they are found at the bottom of the plant and need to be collected offshore by SCUBA within 24 hours of testing. Small craft advisories, strong currents, potentially dangerous levels of bacteria for divers to enter the water, and limited visibility are common during and just after storms in southern California. Unfortunately there is no other commonly used/suitable marine west coast marine plant species that can be used for storm water monitoring. *A recommendation for the third species in lieu of giant kelp would be to include a chronic exposure using the mysid shrimp Americamysis bahia.* This species is already commonly used for acute testing of storm water around San Diego Bay,

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				and this would also provide a more direct comparison to proposed continued acute exposures using this species for end-of-pipe monitoring.
11	E-10	Attachment E. MRP – Section IV	Toxicity Requirements	Chronic toxicity tests in end-of-pipe stormwater are inappropriate for discharges to marine environments. Suggest acute tests only with mysid shrimp (*Americamysis bahia*) in end-of-pipe stormwater. See Comment #4 for rationale. Chronic tests are meaningful in marine receiving water samples in front of a discharge as required in Section V.
12	E-11	Attachment E. MRP – Section V, Table E-5	Receiving Water Monitoring Requirements	Addition of chronic toxicity monitoring is now included in the Tentative Order, but only one time each permit cycle. • Understanding and mitigating impacts to the receiving waters is the ultimate goal, thus monitoring efforts need to be focused here. • With such infrequent monitoring it will be impossible to assess any trends over time and whether or not implemented BMPs are effective at improving water quality. • Concurrent chronic tests in the receiving water with end-of-pipe acute tests are proposed to identify connections between the two as described above in Comment #1. • Recently adopted storm water monitoring efforts in California for coastal Areas of ASBS place a strong emphasis on the receiving waters for compliance determinations. • A greater emphasis on monitoring of receiving waters as opposed to storm water at the end-of-pipe is also included in both the final Los Angeles Municipal Separate Storm Sewer System (MS4) Permit (Order No. R4-2012-0175) and the current draft San Diego Municipal Stormwater Permit (Tentative Order R9-2013-0001). Chronic toxicity testing is required, but only in the receiving waters below end-of-pipe discharges.
13	A-2	Attachment A - Definitions	Add Acute toxicity	Add acute toxicity tests for end-of-pipe monitoring and the following definition: *Acute Toxicity Tests* *Acute toxicity tests measure the lethal effects of a discharge or ambient water sample over short time periods (up to 96 hours using standard EPA protocols).*

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References:

Katz C. and G. Rosen. 2005. Evaluating Storm Water Impacts- Monitoring the Receiving Environment Using a Floating Bioassay Laboratory System. Oceans Conference, Proceedings of the MTS/IEEE, September 17-23.

Katz, C., G. Rosen, and E. Arias. 2006. Storm Water Toxicity Evaluation Conducted at Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base, San Diego, and Naval Station North Island. Technical Report 1938, May 2006. SSC San Diego.

Stransky, C., 2013. Stormwater Sampling and Toxicity Testing White Paper - Boatyard and Other Industrial Discharges to Marine Receiving Water Environments in San Diego, March 11, 2013.

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ATTACHMENT I

San Diego Port Tenants Association

Storm Water Sampling and Toxicity Testing White Paper

Boatyard and Other Industrial Discharges to Marine Receiving Water Environments in San Diego

March 11, 2013

Chris Stransky

Introduction

Assessing receiving water impacts due to storm water runoff poses many challenges due to the extreme dynamic nature of storm events and resulting discharges, especially in southern California. Thorough and appropriately applied methods are needed to accurately characterize water quality impacts during runoff events. Important considerations include decisions regarding where to sample and which parameters to monitor. Understanding and mitigating impacts to the receiving waters is the ultimate goal, thus monitoring efforts need to be focused here. Furthermore, freshwater runoff entering a marine environment needs special consideration, as undiluted freshwater alone is toxic to marine species. Recently adopted storm water monitoring efforts in California for coastal Areas of Special Biological Significance (ASBS) place a strong emphasis on the receiving waters for compliance determinations. Compliance in ASBS, as outlined in the latest Special Protections document (State Board Resolution No. 2012-0012), is based on a comparison of data between discharge receiving water locations and pre-designated reference locations. Comparisons are also conducted in the receiving waters pre- and post-storm to assess whether storm water runoff is causing potential impairment. A greater emphasis on monitoring of receiving waters as opposed to storm water at the end-of-pipe is also included in both the final Los Angeles Municipal Separate Storm Sewer System (MS4) Permit (Order No. R4-2012-0175) and the current draft San Diego Municipal Stormwater Permit (Tentative Order R9-2013-0001). Chronic toxicity testing is required, but only in the receiving waters below end-of-pipe discharges.

As highlighted so well in the storm water addendum to the State of California's recently developed Policy for Toxicity and Assessment Control (June 2012), and in many published papers elsewhere, it takes comprehensive and sound monitoring methods to truly understand potential receiving water effects due to both point and non-point storm water sources, and ultimately evaluate long term trends and BMP (best management practices) effectiveness when employed. These points are critical to: 1) knowing if there really is a problem worth spending significant monitoring and BMP efforts on; and 2) whether we can translate the results from implementing BMPs to measurable success over time. The discussion below relates specifically to proposed end-of-pipe and receiving water storm water toxicity monitoring requirements in the tentative NPDES permit for boatyards in San Diego Bay (Tentative Order R9-2013-0026), but is relevant and applies to most other storm water monitoring programs as well.

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Sampling Considerations for Toxicity Tests

Receiving Waters

Toxicity monitoring should be included in receiving waters adjacent to storm water discharges for all boatyard and other industrial dischargers, along with the physical and chemical analyses already proposed. Toxicity testing of the receiving water was added to the tentative Order for San Diego Boatyards, but only one set of chronic tests is currently required during the life of the Permit. With such infrequent monitoring it will be impossible to assess any trends over time and whether or not implemented BMPs are effective at improving water quality. Requirements for ASBS Special Protections and the Los Angeles and San Diego MS4 Permits require testing of two to three receiving water samples per year.

It is recommended that salinity be recorded in the field for any samples collected to ensure a receiving water sample is mixed and influenced by storm water close to the discharge. For storm water discharges entering marine receiving waters, if possible it is recommended that samples be collected at the low salinity tolerance range for the species being tested (26-30 parts per thousand [ppt] for species used following EPA's toxicity methods for the West Coast, EPA 600-R-95-136). This is equivalent to a worst case sample any marine animal would be exposed to for a chronic duration, without facing a certain death due to freshwater alone. This difference from discharges that end up in freshwater receiving waters is important to consider where animals in this case could potentially be exposed to undiluted storm water for chronic time-frames. Another option for consideration is to collect end-of-pipe storm water from a discharge of interest and add water collected at the same time from the nearby receiving water to an appropriate test salinity that the marine test species can tolerate.

Outfall Monitoring

Determining the source and loading of contaminants to receiving waters is clearly important. Chemical and toxicological monitoring of selected outfalls is thus needed. Chronic toxicity tests of storm water at the end-of-pipe, however, is not appropriate or needed as discussed further below (Storm Water Toxicity Exposures Section). The State of California has in fact previously deemed chronic toxicity tests an invalid end-of-pipe measure to assess impacts of storm water on receiving waters due to the intermittent nature of storm water runoff and short duration (See attached letter from the State Board regarding a petition of waste discharge requirements for Continental Maritime and NASSCO, Order WQ-98-07). Proposed chronic toxicity tests were replaced with acute tests for end-of-pipe storm water samples.

Current proposed physical and chemical analyses in the Tentative Order for San Diego Boatyards, in addition to a single acute toxicity test, is more than sufficient to help identify problematic sources where impaired adjacent receiving waters are observed. Chronic toxicity tests are over-conservative for short-term storm water pulses and very expensive to conduct. These valuable resources are much better spent on understanding impacts in the receiving water itself.

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Sample Representativeness

Another big concern relates to the current focus in the Tentative San Diego Boatyard Permit on collecting single grab samples during the first part of a storm, which represents just a snapshot of the dynamics that occur during any storm event from minute to minute. Collection of more representative composite samples in both storm water effluents and receiving waters needs serious consideration and is a requirement in the draft MS4 Permit in San Diego as an example. From the variability routinely observed (as shown and referenced in the storm water guidance section of the State's 2012 Policy for Toxicity and Assessment Control), collection and analysis of single grab samples is difficult at best to draw any conclusions on, and has limited meaning from both a compliance perspective and scientifically. Furthermore, the acceptable time period for the collection of a "first-flush" grab sample has been extended from within 1-hour of initial runoff to within 4-hours of initial runoff in the tentative San Diego Boatyard and San Diego Navy facility permits. Anyone looking to enhance their chance of compliance will surely target the 4th hour. How meaningful and protective will this be? We certainly need to have better characterization of what is occurring in the receiving water throughout a storm if we really are going to understand effects, prioritize and efficiently manage BMPs, and determine whether or not they are working and providing sufficient protection once implemented.

<u>Storm Water Toxicity Exposures</u>

The discussion above leads further to the concern of conducting *chronic* toxicity tests on a salted or brined up freshwater water sample that will be entering a marine environment. Again, any pulses that a marine critter will be exposed to will occur only after the storm water has mixed in the marine environment. Adding brine and salts to a freshwater sample alters the properties of storm water in unknown ways and results in a sample that no animal would ever be exposed to in the environment. This again contrasts with situations where storm water enters a freshwater receiving water environment. Unfortunately marine critters won't ever have a little bag of brine or salt to save them.

Based on personal experience and other studies, this zone of initial dilution is typically quite small for most outfalls in San Diego Bay – a mixed freshwater signal that exists very close to the surface and near outfalls (a meter or so out and 1 to 2 feet below the surface outside of which salinities are typically above 28 ppt during a runoff event). Plume mapping in front of outfalls in San Diego Bay found maximum concentrations of storm water between 2% and 14% under various conditions over a 3 year period (Katz et. al. 2006 (SPAWAR); report attached). Dilution and residence time, of course can vary substantially based on the size of storm and watershed drainage area, but it's not difficult to get out there and take a few measurements with a field meter during a rain event to gain a decent understanding of site-specific dynamics.

Available testing results to date have found that storm water samples tested using chronic marine invertebrate embryo and egg fertilization tests very often result in a significant response relative to concurrent laboratory controls; however, in almost all cases there has been little to no effect once the samples are diluted 25 or 50% from a highest testable concentration (typically 50-60% storm water when brine is added). Such concentrations of storm water are still much greater than that any marine animal will ever encounter without succumbing to the effects of freshwater alone. In fact almost half of the hundreds of grab sample tests at end-of-pipe locations monitored over many years by the Navy in San Diego have shown acute effects to mysid shrimp, which thus provides a good sensitive indicator. A majority of this data; however, should be qualified since most are single grab samples taken at various times throughout any given event, and very few if any trends have been possible to discern after years of sampling. At the same time, however, in those few "special study" cases where concurrent receiving water tests have been conducted, there have only been a few receiving water samples that have shown chronic effects to embryo development or sea urchin egg fertilization (only 3% of 65 samples tested in the study conducted by Katz et al. (2006) at four Naval Bases in San Diego Bay). In contrast almost all of the chronic embryo development tests in the end-of-pipe storm water showed a significant effect relative to concurrent controls. A summary of this extensive toxicity dataset in San Diego between 2002 and 2005 is provided at the end of this paper for reference. The graph compares the frequency of toxicity observed in samples collected at end-of-pipe (first-flush and storm duration composites), and adjacent bay receiving waters using one chronic test (bivalve embryo development), and two acute tests (Pacific topsmelt and mysid shrimp *A. bahia* survival). Real time continuous *in situ* monitoring during the study in 2006 and a prior study (Katz and Rosen, 2005) also found toxicity in end-of-pipe samples, but no toxicity in bay samples directly in front of the monitored outfall. Based on these results and current proposed end-of-pipe chronic toxicity testing requirements in the Tentative San Diego Boatyard permit, accelerated monitoring and follow-up Toxicity Identification Evaluations (TIEs) will be required on nearly every end-of-pipe discharge sample regardless of the actual potential for effects and magnitude of impact on the receiving water. The cost to proceed down this route will be extraordinary.

There is considerable concern that we could very well end up on a path that will divert significant funds and time to what ends up being a misguided effort in many cases. Continuing to conduct acute toxicity tests at the end-of-pipe is recommended as an indicator, but also including a concurrent acute or chronic test in the receiving water directly in front of an outfall for connectivity and compliance determination. An effect in both provides much greater confidence that we have a location worth spending the extra follow-up effort on if good monitoring methods are used. Analytical chemistry alone at end-of-pipe, however, should also be sufficient to identify problematic discharges at most sites, as long as toxicity is performed in the receiving water. Such approaches, with more testing effort in the receiving water and more thorough sampling methods, will indeed cost more per event at any given location, but the information will be much more meaningful and valuable in the end.

A final disconnect worth pointing out in the Tentative Boatyard Order is the current application of *acute* Numeric Action Levels (NALs) at end-of-pipe while including a simultaneous chronic toxicity test method in the same sample which has the potential to cause effects at concentrations well below the current NAL (i.e. a median effect concentration of approximately 10-15 parts per billion [ppb] copper for the chronic *Mytilus* test versus. a copper acute NAL of 33 ppb). Acute NALs at the end-of-pipe make perfect sense given the acute nature of storm water runoff. The same reasoning and consistency should apply to toxicity.

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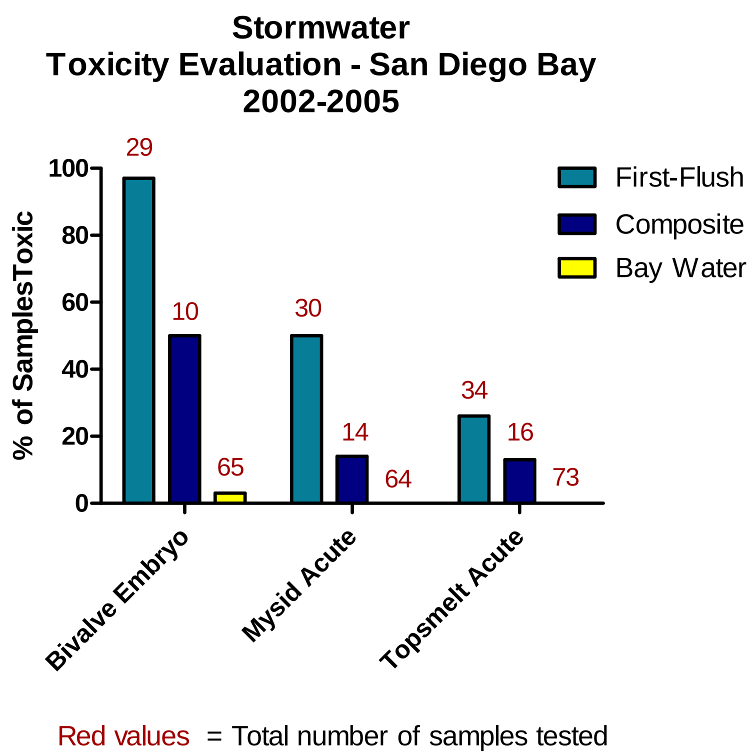
Site Prioritization

Prioritization of sites to put forth the extra effort will be important to consider. All it takes is a quick survey around facilities and receiving waters during a storm event to initially screen areas that should be prioritized. Land use knowledge is critical. Our collective ability to sample every permitted outfall out there and conduct good sampling techniques is impossible with available resources. This very well could also be considered environmentally irresponsible given the excessive use of disposable supplies, chemicals, and fuel required for a shot gun approach that provides limited useful data. Prioritization is an additional topic that needs serious consideration and additional discussion.

Conclusion

Willingness to engage in efforts to conduct more meaningful and thorough compliance monitoring at fewer prioritized locations is critical and can readily be accomplished through a regulatory framework with the monitoring suggestions provided herein. The willingness and ability to do so by the stakeholders will depend on perceived benefits versus NPDES compliance costs. Uncertainty as to whether follow up BMP activities are needed and actually making a difference when implemented is a major concern. The feedback I have received from those we support and others suggests all are more than willing to invest in more focused monitoring that will effectively and efficiently answer the important questions posed in the Permits; as opposed to monitoring just to fulfill a compliance check box. Several storm water NPDES Permits are headed in this direction already following extensive research, commenting periods, and careful consideration. Requirements in the Boatyard Permit will be precedent setting and should carefully re-consider the applicability and need for chronic toxicity tests at the end-of-pipe, enhanced monitoring of the receiving waters, and more representative sample collection methodologies as discussed herein.



Graphical summary created from data provided in the following document:

Katz, C., G. Rosen, and E. Arias. 2006. Stormwater toxicity evaluation conducted at Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Station North Island. SSC San Diego, Tech. Rept. # 1938, May 2006.

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TECHNICAL REPORT 1938
May 2006

Storm Water Toxicity Evaluation Conducted at Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island

C. Katz
G. Rosen
E. Arias

SSC San Diego

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TECHNICAL REPORT 1938
May 2006

Storm Water Toxicity Evaluation Conducted at Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island

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EXECUTIVE SUMMARY

BACKGROUND

This report describes results of a study to evaluate the toxicity of industrial storm water discharges from U.S. Navy facilities bordering San Diego Bay. The study was conducted to support a request from the San Diego Regional Water Quality Control Board to develop a scientifically based acute toxicity threshold for industrial storm water discharges that can be applied to National Pollutant Discharge Elimination System (NPDES) permits. Current NPDES storm water permits at Navy facilities include a toxicity requirement that states: "*…undiluted storm water runoff associated with industrial activity shall not produce less than 90% survival 50% of the time, and not less than 70% survival, 10% of the time, using standard test species and protocol*." This requirement is based on Whole Effluent Toxicity (WET) testing that the Environmental Protection Agency (EPA) identifies as "a useful parameter for assessing and protecting against impacts upon water quality and designated uses caused by the aggregate toxic effects of the discharge of pollutants" (EPA, 1991a). Thus, the study focused on the use of WET test methods and data evaluations.

GOAL

The goal of this study was to develop a robust dataset of storm water and receiving water toxicity that can be used to support a scientifically based acute toxicity threshold for industrial storm water discharges from Navy facilities. The technical approach used three simultaneous measurement components to evaluate industrial storm water toxicity and impacts to San Diego Bay waters. The three components included the following:

1. Toxicity and chemistry measurements in storm water (end-of-pipe)
2. Toxicity and chemistry measurements in receiving waters
3. Storm water plume mapping

SAMPLING

The study evaluated storm discharges and receiving waters during 11 storm events from 2002 to 2005. Data were collected from 14 drainage areas at Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island. The drainage areas monitored were representative of the various industrial activities occurring on all four bases.

A total of 136 discrete samples were collected during this study, including 51 first-flush (collected during the first hour of flow) and flow-weighted composite storm water samples. It also included 85 receiving water samples collected immediately outside outfalls before, during, and after storm events. A total of 333 toxicity tests were performed on these samples.

Samples were analyzed using multiple toxicity testing endpoints, including the two acute tests allowed in the permit, 96-hour survival of *Atherinops affinis* (topsmelt) larvae, and *Americamysis bahia* (mysid) juveniles. An additional toxicity endpoint evaluated the 48-hour normal embryo-larval development of *Mytilus galloprovincialis* (mussel), an indigenous species to San Diego Bay. This mussel test provides one of the most sensitive endpoints available for evaluating marine waters. These three test species were also used in a Toxicity Identification Evaluation (TIE) to identify the causative agents of toxicity. Samples were analyzed for a range of contaminants of concern, including a suite of total and dissolved metals, polynuclear aromatic hydrocarbons, polychlorinated biphenyls, and chlorinated pesticides. Seventeen plume mapping surveys, including an on-site floating bioassay laboratory study, were conducted before, during, and after storm events.

RESULTS

Toxicity and Chemistry Measurements in Storm Water. The study established that acute storm water toxicity measured at the end-of-pipe was highly variable, spanning the full range of impact, from 0 to 100% survival of topsmelt and mysids. The toxicity of first-flush storm water samples, representing the discharge at one moment in time, was higher than in composite samples that were representative of the entire discharge. First-flush samples failed to meet the 90% survival requirement in the NPDES permit 58% of the time. Composite samples failed 25% of the time. However, the 90% survival requirement in the permit does not follow WET data evaluation methods in identifying when a sample is acutely toxic or not. When using WET methods, including t-testing and consideration of method variability, 30% (versus 58%) of first-flush samples and 7% (versus 25%) of composite samples were identified as acutely toxic. The toxicity identification evaluation and chemistry data identified copper and zinc as the primary toxicants of concern, although surfactants were identified in some samples.

Toxicity and Chemistry Measurements in Receiving Waters. Less than 1% of 202 receiving water toxicity tests exhibited toxicity. The lack of relationship between the measurements of toxicity in first-flush samples with toxicity observed in the receiving environment was a result of limited receiving water exposure conditions.

Storm Water Plume Mapping. The mapping surveys and the special floating bioassay study clearly showed that Navy storm water discharges and their influence on receiving waters were limited in magnitude, minimal in their spatial extent, and very short-lived. Thus, toxicity measured in first-flush storm water overestimates the exposure conditions measured in the receiving water and thereby overestimates the potential for toxic impacts.

SUMMARY

In summary, this study provides one of the most extensive datasets on storm water runoff conducted, effectively characterizing the bounds of variability inherent in these types of discharges and their impacts to receiving water quality. Using multiple lines of evidence, the data showed that first-flush storm water can be acutely toxic, primarily as a result of copper and zinc concentrations in the discharge. The total storm discharge, represented by composite samples, was generally less toxic and had lower contaminant concentrations. Most importantly, there was no relationship between toxicity measured in storm water and toxicity measured in the receiving water. These results show that WET testing on storm water as required in the permit cannot be used to infer toxicity in the receiving environment.

RECOMMENDATIONS

This study was conducted to support a scientifically based acute toxicity threshold for storm water discharges. To ensure that an acute toxicity threshold for storm water discharges will accurately identify and be protective of water-quality impacts in the receiving environment, the proposed Navy alternative toxicity threshold should include the following:

- The use of appropriate EPA WET test methods and data evaluation when declaring a test result as toxic
- Acknowledgement of WET method variability and considerations of minimum detection limits in declaring toxic results
- Consideration of realistic exposure conditions when using WET testing to infer toxicity in the receiving water

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LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
BAT	Best Available Technology Economically Achievable
BCT	Best Conventional Pollutant Control Technology
BMP	Best Management Practice
CCC	Criteria Continuous Concentration
CMC	Criteria Maximum Concentration
CNRSW	Commander Navy Region Southwest
CoCs	Contaminants of Concern
COMP	Composite
CVAA	Cold Vapor Atomic Absorption Spectrometry
CVAF	Cold Vapor Atomic Fluorescence Spectrometry
DDT	Dichlorodiphenyltrichloroethane
DOC	Dissolved Organic Carbon
DQO	Data Quality Objectives
EC50	Effect Concentration (50%)
EDTA	Ethylenediaminetetraaceticacid
EPA	Environmental Protection Agency
ERM	Effects Range Mean
FF	First-flush
FIAS	Flow Injection Atomic Spectrometer
GFAA	Graphite Furnace Atomic Absorption Spectrometry
HMW	High Molecular Weight
HSB	Hypersaline brine
ICP/MS	Inductively Coupled Plasma/Mass Spectrometry
ICP-OES	Inductively Coupled Argon Plasma Optical Emission Spectrometer
LC50	Lethal Concentration (50%)
LMW	Low Molecular Weight
LOEC	Lowest-Observable-Effect-Concentration
MBAS	Methylene Blue Activated Substances
MDL	Method Detection Limit
MESC	Marine Environmental Survey Capability
NAB	Naval Amphibious Base Coronado

NAV	Naval Station San Diego
NAVFACENGCOM	Naval Facilities Engineering Command
NFESC	Naval Facilities Engineering Service Center
NI	Naval Air Station North Island
NOEC	No Observed Effect Concentration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-point Source
NS&T	National Status and Trends
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PMSD	Percent Minimum Significant Difference
PSU	Practical Salinity Units
PWC	Public Works Center
RF	Radio Frequency
RSD	Relative Standard Deviation
SSC San Diego	Space and Naval Warfare Systems Center San Diego
SUB	Naval Submarine Base San Diego
SWRMC	South West Regional Maintenance Center
TAC	Test Acceptability Criteria
TIE	Toxicity Identification Evaluation
TMDL	Total Maximum Daily Load
TPCB	Total Polychlorinated Biphenyl
TSS	Total Suspended Solids
TU_A	Acute Toxic Unit
UVF	Ultra-Violet Fluorescence
WET	Whole Effluent Toxicity
WQS	Water Quality Standard

1. INTRODUCTION

This report describes results of a study to evaluate the toxicity of industrial storm water discharges from U.S. Navy facilities bordering San Diego Bay. The study was conducted by the Environmental Sciences and Applied Systems Branch at the Space and Naval Warfare Systems Center San Diego (SSC San Diego) at the request of Commander Navy Region Southwest (CNRSW). The request was made after CNRSW received a National Pollutant Discharge Elimination System (NPDES) permit (CA0109363) from the San Diego Regional Water Quality Control Board for the Naval Submarine Base San Diego on 11 September 2002, with the following two provisions:

1. *"For the Submarine Base facility, effective 4 years after the adoption of this Order, in a 96-hour static or continuous flow bioassay (toxicity) test, undiluted storm water runoff associated with industrial activity shall not produce less than 90% survival 50% of the time, and not less than 70% survival, 10% of the time, using standard test species and protocol."*
2. *"During the 4-year period before the effective date of the toxicity limit set forth in paragraph a of this Specification, the U.S. Navy shall conduct a study of the toxicity in storm water discharges from all areas of SUBASE which industrial activities are undertaken and shall recommend a scientifically valid survival rate for acute exposure to discharges of storm water from industrial areas at SUBASE. The study may include a Toxicity Identification Evaluation (TIE), or a Toxicity Reduction Evaluation (TRE)."*

These same requirements were adopted within the NPDES permits for three other Navy facilities on the bay: Naval Station San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island, which were permitted during the next 6 months.

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2. BACKGROUND

The toxicity requirement in the permits is based on Whole Effluent Toxicity (WET) testing. WET testing was identified by the Environmental Protection Agency (EPA) as “a useful parameter for assessing and protecting against impacts upon water quality and designated uses caused by the aggregate toxic effects of the discharge of pollutants” (EPA’s Technical Support Document for Water Quality-based Toxics Control [EPA, 1991a]). On the basis of results obtained in EPA’s Complex Effluent Toxicity Testing Program and other reviewed studies (cited in EPA, 1991a), the EPA concluded that the control of toxicity is a valid approach for protecting ambient water quality and receiving water impact. They also concluded that “impact from toxics would only be suspected where effluent concentrations after dilution are at or above toxicity effect concentrations.” WET testing has been applied to mixing of continuous industrial discharges with receiving waters, but does not provide direction on its application for short exposure discharges such as those produced by storm water. The current permits do not consider if storm water effluent concentrations after dilution are at or above toxicity effect concentrations.

The permit requirement is based on short-term or acute toxicity testing. Acute WET tests use standardized protocols to evaluate short-term toxicity by exposing test organisms for 96-hour or less and measuring lethality as the endpoint. Tests also exist that are designed to evaluate chronic toxicity, which is typically defined as a longer term test in which sublethal effects such as fertilization, growth, or reproduction are measured on very sensitive life stages of test organisms (e.g., embryos). In WET tests, a chosen test species is exposed to an effluent sample (often at various levels of dilution) within a test chamber for a specified duration. At the end of the exposure period, the test effect (lethality, development, etc.) is evaluated and compared to results in a control sample to determine if the effluent was toxic or not. The current permits do not consider comparisons to control samples as a means of establishing when a sample is toxic or not toxic.

Various quality assurance/quality control (QA/QC) measures are applied to WET methods to minimize test method variability and ensure that the tests produce meaningful results. These measures apply to effluent sampling and handling, test organism source and condition, test conditions, instrument calibration, replication, the use of reference toxicants, recordkeeping, and data evaluations. Test method variability is a key component when evaluating toxicity data and declaring the result as toxic or non-toxic. Guidance on method variability and the use of minimum significant difference (MSD) was developed by EPA in 2000 (EPA, 2000). The MSD represents the smallest difference that can be distinguished between the response of the control organisms and the response of the organisms exposed to the effluent. As such, the MSD is a minimum detection limit for toxicity tests. The current permit requirement does not consider test method variability.

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3. STUDY GOAL

The goal of this study was to develop a robust dataset of storm water and receiving water toxicity that can be used to support a scientifically based acute toxicity threshold for industrial storm water discharges from Navy facilities. Implicit in this goal is the requirement that the toxicity threshold accurately ensures protection against impacts upon receiving water quality and its designated uses. To meet this goal, the study included an extensive characterization of storm water toxicity and its causes. It also included a comparable characterization of surrounding receiving waters, including an evaluation of exposure conditions. Together, these data were used to assess toxicity thresholds based on the observed relationship between toxicity measured in storm water discharges and in receiving waters. To ensure that the widest range of conditions was represented, measurements were made during multiple storm events from multiple drainage areas and in waters adjacent to all four Navy bases. Multiple toxicity endpoints and a suite of contaminants of concern (CoCs) were evaluated in storm water and receiving waters. Receiving water conditions around each base were evaluated before, during, and after storm events to evaluate exposure conditions and the spatial and temporal extent of storm water plumes.

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4. TECHNICAL APPROACH

The technical approach used three simultaneous measurement components to evaluate industrial storm water toxicity and impacts to San Diego Bay waters. The three components included toxicity and chemistry measurements in storm water, toxicity and chemistry measurements in receiving waters, and storm water plume mapping. These lines of evidence are shown schematically in Figure 1 and graphically in Figure 2. The goal of conducting these measurements simultaneously was to be able to directly relate observations made in storm discharges to water quality impacts observed in the receiving environment.

The first component was to collect storm water samples before their discharge (end-of-pipe) into the receiving environment and analyze them for toxicity and chemistry. Two types of storm water samples were collected; first-flush (FF) storm water samples, collected during the first hour of flow as required in the permits, and flow-weighted composite (COMP) samples, acquired throughout an entire storm event. These discrete samples were analyzed for multiple toxicity endpoints, including two acute tests allowed in the NPDES permit: 96-hour survival of *Atherinops affinis* (topsmelt) larvae and *Americamysis bahia* (mysid) juveniles. An additional toxicity endpoint evaluated was the 48-hour normal embryo-larval development of *Mytilus galloprovincialis* (mussel), an indigenous species to San Diego Bay. This mussel test provides one of the most sensitive endpoints available for evaluating marine waters. The storm water samples were also analyzed for a suite of CoCs, including total and dissolved metals, polynuclear aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and chlorinated pesticides that included dichlorodiphenyltrichloroethane (DDT) and its metabolites, and isomers of chlordane. Ancillary measurements included dissolved organic carbon (DOC) and total suspended solids (TSS). A Toxicity Identification Evaluation (TIE) was also conducted to evaluate the causative agents of observed toxicity.

One goal of these measurements was to evaluate the magnitude of toxicity as measured in first-flush samples as required in the NPDES permit and compare it to the magnitude of the toxicity represented by the discharges of an entire storm event represented by composite samples. A second goal was to evaluate the magnitude of the contaminants of concern relative to acute water quality standards to help identify the toxic agents.

The second measurement component was to collect and analyze receiving water samples for toxicity and chemistry. Discrete samples were collected immediately outside the points of storm water discharge before, during (simultaneous with storm water sample collection), and after storm events. Samples were also collected a distance away from the discharge points to evaluate gradients of impact in the receiving water. Bay samples were analyzed for the same toxicity endpoints and CoCs as the storm water samples. The goal of this measurement component was to evaluate the magnitude of toxic response directly in the receiving water resulting from the storm water discharges. This approach eliminates extrapolating exposure conditions and integrates impacts from all sources, not just storm water. CoCs measured in receiving waters were also compared to chronic water quality standards to assess their role in observed toxicity.

The third measurement component was to evaluate exposure conditions in receiving waters by mapping the spatial and temporal distribution of storm water plumes as they mixed with bay waters. Receiving waters were monitored outside outfalls for seawater salinity, temperature, turbidity, and ultraviolet oil fluorescence (UVF) before, during (simultaneous with storm water sample collection), and after storm events using the Navy's Marine Environmental Survey Capability (MESC), a real-time data acquisition and processing system. These data were used to evaluate plume magnitude and extent as a function of time to better understand the exposure conditions produced by storm discharges.

A variation on the three simultaneous measurement components was to deploy a shipboard bioassay laboratory system immediately outside an outfall to conduct receiving water toxicity testing under actual exposure conditions. The MESC onboard the RV ECOS was used as the measurement and data acquisition platform. Simultaneous toxicity and chemistry measurements were conducted as on all other occasions but in this instance, bay water toxicity analyses were performed by exposing organisms directly to actual receiving water conditions outside the outfall for the test duration. The goal of this one-time effort (Special Floating Bioassay Study) was to measure the actual exposure conditions present outside a storm water discharge location, compare toxicity results using standard laboratory measurements with those made *in situ*, and to evaluate its time-varying toxic and chemical impact on the receiving water.

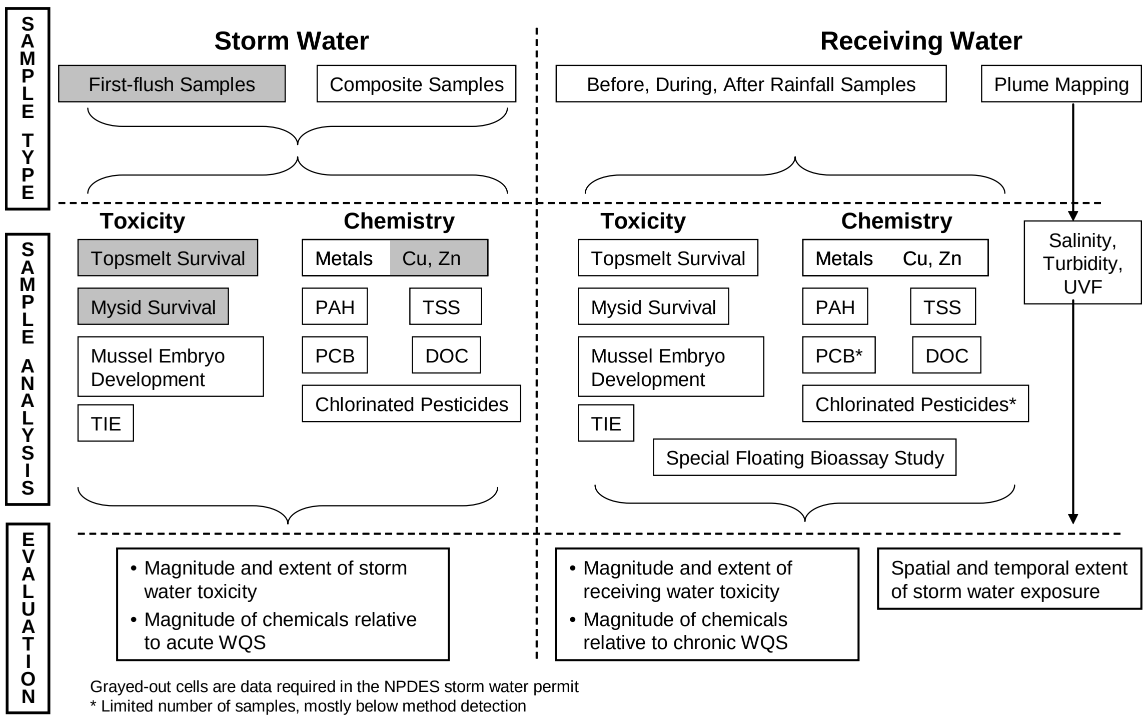

Figure 1. Schematic of technical approach that included simultaneous toxicity and chemistry measurements in storm water, toxicity and chemistry measurements in receiving waters, and storm water plume mapping.

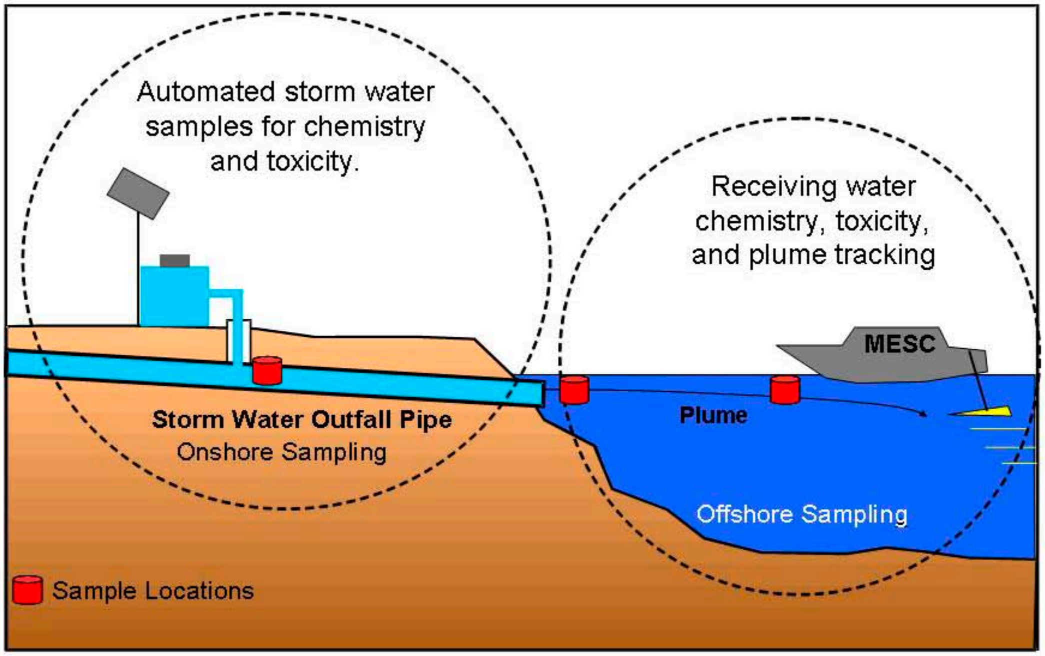

Figure 2. Graphical schematic for the technical approach that included simultaneous toxicity and chemistry measurements in storm water, toxicity and chemistry measurements in receiving waters, and storm water plume mapping. Receiving water sampling was conducted using the Marine Environmental Survey Capability (MESC).

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5. TECHNICAL REVIEW

A technical team was put together to help guide the sampling design and plans, and also evaluate results. The team included participants from the City of San Diego (Ruth Kolb), Port of San Diego (Eileen Maher), Southern California Coastal Water Research Project (Ken Schiff), Southwest Marine Shipyard (Shaun Halvax), U.S. Environmental Protection Agency (EPA) Region IX (Debra Denton), and U.S. Fish and Wildlife Service (Scott Sobiech). In addition to reviewing and commenting on sampling plans, the team met mid-way through the project to review results and provide comments and guidance on continuing work. Periodic project briefs and discussions with Regional Water Board staff were also conducted during the first 2 years of the project. Three of the technical review team members provided comments on the draft version of this report. Comments and responses to comments from these reviews along with those from two independent reviewers are included in Appendix I of this report.

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6. METHODS

6.1 SAMPLING SUMMARY

The toxicity investigation was conducted by SSC San Diego during the October through May wet seasons from 2002 through 2005. During that time, 11 storms were sampled with rainfall totals ranging from 0.1 inch up to a record 3.4 inches (Table 1). A 12th sampling event captured only a pre-storm condition. Antecedent dry periods (rainfall <0.1 inch) ranged from 5 days up to a record dry period of 6 months (183 days), which was captured during the first-flush of the year storm SDB4. A total of 14 different industrial storm water drainage areas were sampled at four bases including four piers (Table 1). The drainage areas sampled ranged in size from 0.5 to 75 acres. The four bases included Naval Station San Diego (NAV), Naval Submarine Base San Diego (SUB), Naval Amphibious Base Coronado (NAB), and Naval Air Station North Island (NI) (Figure 3).

A total of 136 samples were collected and analyzed for toxicity and/or chemistry, though not every sample was analyzed for all components. Table 1 summarizes the samples collected and the analyses performed in chronological order. These tables, organized by base, are repeated in Appendix A. The sampling total was comprised of 51 storm water samples collected from the end-of-pipe (outfall) and included 33 first-flush samples (as required in the permit) and 18 full-storm, flow-weighted composite samples. The total also included 85 bay samples collected immediately outside outfalls before (27), during (35), and after (23) storm events. These bay sampling locations were nominally sited directly outside the point of discharge. At most locations, the samples were collected in the top 2 feet of the water column within a few feet of the discharge point. At a few sites, the outfall discharged under a pier or onto the shoreline before reaching the bay. In these few instances, bay samples were collected up to 50 feet away from the actual discharge point. The exact sampling locations are described later under each site description. Several receiving water samples were also collected from stations located a short distance away from the outfall discharge to see if a gradient in chemistry or toxicity could be detected. Seventeen plume mapping surveys were conducted before, during, or after storm events (Figure 4). Note that discrete samples collected during the SDB4 storm event were collected during the first 0.1-inch rainfall, though a total of 1.7 inches of rain fell during the next 3 days. Plume mapping was conducted during the later part of the rainfall event. Plume mapping was conducted only before and during (not after) storms SDB6 and SD7 because of logistical constraints.

The amounts and type of data collected during each storm sampling event varied with available resources, storm specifics, logistical constraints, and particular data needs. In a couple of instances, the sampling was opportunistic to capture a particular type of sample(s) such as the first-flush of the year sample or to capture a unique bay condition after a large amount of rainfall had occurred. In some instances, the sampling was limited to a single type of sample to meet a specific data need such as during the TIE sampling. The special floating bioassay study was also conducted during one storm (SDB45) event to monitor bay conditions outside an outfall for 96 hours to evaluate toxicity under true exposure conditions (Katz and Rosen, 2005). While the amount and type of data collected for each storm varied, the overall data collection was designed to meet the project goal of producing a robust dataset to characterize storm water toxicity and impacts to San Diego Bay.

The acronyms listed for each base above were used to uniquely identify samples collected from each base. The full sample identifier consisted of the base name acronym, sample location based on outfall number, storm event name, and sample type. Base name acronyms were described above.

However, the acronyms used by the toxicity laboratory performing the TIE were slightly different. An introductory description of the differences is provided in the TIE reports provided in Appendices E and F. The differences were as follows: NAV = NAVSTA, SUB = SUBASE, NAB = NAB, and NI = NASNI. Sample locations included storm water outfalls (OF), receiving water samples (Bay), or pier samples (PR). Storm events were given a unique identifier (Table 1). Sample types included first-flush (FF), composite (Comp), and bay samples collected before (PRE), during (DUR), and after (AFT) storm events (SDB1, SDB2…). Examples for sample naming conventions used throughout the study and included in the data appendices are as follows:

NAV-OF9-SDB1-FF = Naval Station San Diego Outfall 9, Storm SDB1, First-Flush

NAB-BAY9-SDB4-AFT = Naval Amphibious Base Coronado, Bay sample outside outfall 9, Storm SDB4, After storm

Table 1. Chronological summary of storms sampled, rainfall totals, antecedent dry period, and type of sampling. Discrete samples collected during the SDB4 storm event were collected during the first 0.1 inch of rainfall, as noted in the table, though mapping surveys started a day later with additional rainfall amounts.

Start Date	Storm Event	Navy Base	Rainfall Total (inches)	Antecedent Dry Period (days)*	Sampling
07 November 2002	SDB1	NAV	0.23	60	Onshore, Offshore, Mapping
24 February 2003	SDB2	NAV/SUB	0.99	10	Onshore, Offshore, Mapping
11 December 2003	SDB2A	SUB	0.00	NA	Offshore
02 February 2004	SDB3	SUB	0.46	8	Onshore, Offshore, Mapping
18 February 2004	TIE1	NAV/SUB	0.19	14	Onshore
26 February 2004	TIE1A	SUB	>3	NA	Offshore
17 October 2004	SDB4	NAV/SUB/NAB/NI	0.1	183	Onshore, Offshore, Mapping+
27 October 2004	SDB45	NAV	3.4	5	Onshore, Offshore, Mapping
10 January 2005	SDB5	NAV/SUB/NAB/NI	>6	NA	Offshore
10 February 2005	SDB6	NAB/NI	1.6	12	Onshore, Offshore, Mapping
19 March 2005	TIE2	NAB/NI	0.07	13	Onshore, Offshore
27 April 2005	SDB7	NAB/NI	0.44	34	Onshore, Offshore, Mapping

* Previous rainfall < 0.1", amount typically required to generate flow.

+ Mapping surveys were started a day later when a larger storm developed

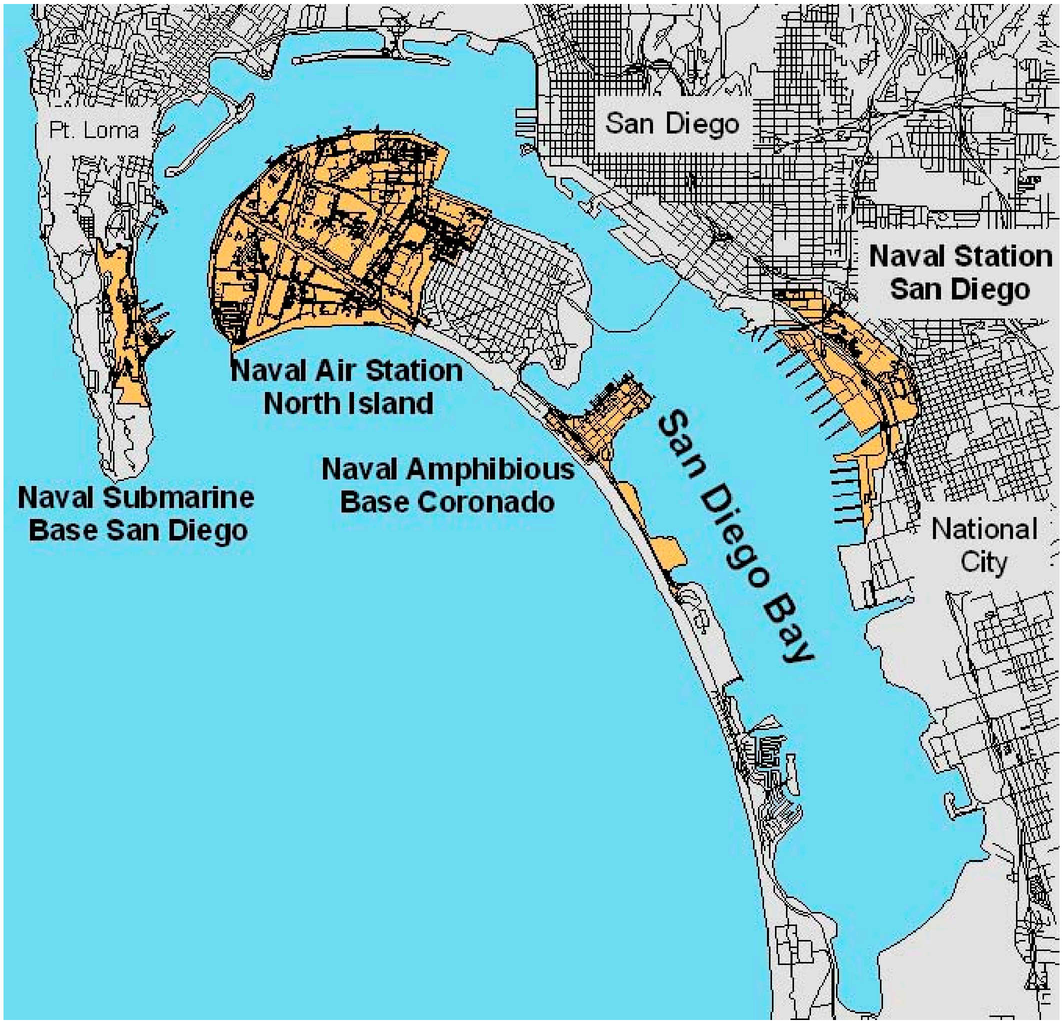


Figure 3. Navy bases bordering San Diego Bay sampled during the study, including Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island.

Table 2. Chronological sampling and analysis summary. An “X” denotes analysis performed. Sample naming conventions were described above.

Sample Dates	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
11/7/2002	NAV	SDB1	OF 9	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	OF 11	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	OF 14	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	Bay	PRE				X			X			
	NAV	SDB1	Bay 9	PRE	X	X	X		X					
	NAV	SDB1	Bay 9	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 9	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 11	PRE	X	X	X		X					
	NAV	SDB1	Bay 11	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 11	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 14	PRE	X	X	X		X					
	NAV	SDB1	Bay 14	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 14	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 14A	PRE	X	X	X		X					
	NAV	SDB1	Bay 14A	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 14A	AFT	X	X	X	X	X		X			
2/24/2003	NAV	SDB2	PR 5	FF	X	X	X	X	-		X	X		
	NAV	SDB2	PR 5	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	PR 6	FF	X	X	X	X	-		X	X		
	NAV	SDB2	PR 6	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 9	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 9	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 11	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 11	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 14	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 14	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	Bay 9	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 9	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 9	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	AFT	X	X	X	X	-		X			
	SUB	SDB2	OF 11B	FF	X	X	X	X	-		X	X		
	SUB	SDB2	OF 24	FF	X	X	X	X	-		X	X		
	SUB	SDB2	OF 26	FF	X	X	X	X	-		X	X		
	SUB	SDB2	Bay 11B	PRE	X	X	X	X	-		X			
	SUB	SDB2	Bay 11B	DUR	X	X	X	X	-		X			
	SUB	SDB2	Bay 24	DUR	X	X	X	X	-		X			
	SUB	SDB2	Bay 26	DUR	X	X	X	X	-		X			
12/11/2003	SUB	SDB2A	Bay 11B	PRE	X	X	X							
	SUB	SDB2A	Bay 23CE	PRE	X	X	X							
	SUB	SDB2A	Bay 26	PRE	X	X	X							
2/2/2004	SUB	SDB3	OF 11B	FF	X	X			X	X	X			X
	SUB	SDB3	OF 11B	COMP	X	X	X	X	X	X	X	X	X	
	SUB	SDB3	OF 23 C&E	FF	X	X	X		X	X	X			X
	SUB	SDB3	OF 23 C&E	COMP	X	X	X	X	X	X	X	X	X	
	SUB	SDB3	OF 26	FF	X	X	X		X	X	X			X
	SUB	SDB3	OF 26	COMP	X	X		X	X	X	X	X	X	X
	SUB	SDB3	Bay 11B	PRE	X	X	X		X	X	X			X
	SUB	SDB3	Bay 11B	DUR	X	X	X		X	X	X			X
	SUB	SDB3	Bay 11B	AFT	X	X	X		X	X	X			X
	SUB	SDB3	Bay 23 C&E	PRE	X	X	X		X	X	X			X
	SUB	SDB3	Bay 23 C&E	DUR	X	X	X		X	X	X			X
	SUB	SDB3	Bay 23 C&E	AFT	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26	PRE	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26	DUR	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26	AFT	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26A	PRE	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26A	DUR	X	X	X		X	X	X			X
	SUB	SDB3	Bay 26A	AFT	X	X	X		X	X	X			X

- Lost

Table 2. Chronological sampling and analysis summary. An “X” denotes analysis performed. Sample naming conventions were described above. (cont)

Sample Dates	Base	Storm	Outfall	Sample Type	Menidia	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
2/18/2004	NAV	TIE1	OF 9	FF	X	X	X	T						
	NAV	TIE1	OF 11	FF	X	X	X	T						
	NAV	TIE1	OF 14	FF	X	X	X	T						
2/18/2004	SUB	TIE1	OF 11B	FF	X	X	X	T						
	SUB	TIE1	OF 23 C&E	FF	X	X	X	T						
	SUB	TIE1	OF 26	FF	X	X	X	T						
2/26/2004	SUB	TIE1A	Bay 11B	AFT			X							
	SUB	TIE1A	Bay 23 C&E	AFT			X							
	SUB	TIE1A	Bay 26	AFT			X							
10/17/2004	NAV	SDB4	OF 14	FF	X	X	X		X					X
	ALL+	SDB4	Bay	PRE	X	X	X		X					X
	NAV	SDB4	Bay 14	DUR	X	X	X		X					X
10/17/2004	SUB	SDB4	OF 11B	FF	X	X	X		X					X
	SUB	SDB4	Bay 11B	DUR	X	X	X		X					X
10/17/2004	NAB	SDB4	OF 9	FF	X	X	X		X					X
	NAB	SDB4	Bay 9	DUR	X	X	X		X					X
10/17/2004	NI	SDB4	OF 23A	FF	X	X	X		X					X
	NI	SDB4	Bay 23A	DUR	X	X	X		X					X
10/26/2004	NAV	SDB45	OF 14	FF	X	X	X	X	X	X	X	X	X	
	NAV	SDB45	OF 14	COMP		X	X	X	X	X	X	X	X	
	NAV	SDB45	Bay 14	PRE	X	X	X		X	X				X
	NAV	SDB45	Bay 14	DUR1*	X	X	X		X	X				X
	NAV	SDB45	Bay 14	DUR2					X	X				X
	NAV	SDB45	Bay 14	DUR3					X	X				X
	NAV	SDB45	Bay 14	DUR4					X	X				X
	NAV	SDB45	Bay 14	AFT1					X	X				X
	NAV	SDB45	Bay 14	AFT2					X	X				X
	NAV	SDB45	Bay 14	AFT3					X	X				X
1/10/2005	NAV	SDB5	Bay 14	AFT	X	X	X							
	SUB	SDB5	Bay 11B	AFT	X		X							
	NAB	SDB5	Bay 9	AFT	X	X	X							
	NI	SDB5	BAY 23A	AFT			X							
	na	SDB5	Downtown	AFT	X	X	X							
2/10/2005	NAB	SDB6	OF 9	FF	X	X	X		X	X	X	X	X	X
	NAB	SDB6	OF 9	COMP	X	X	X	X	X	X	X	X	X	
	NAB	SDB6	OF18	FF	X	X	X		X	X	X	X	X	X
	NAB	SDB6	OF 18	COMP				X	X	X	X	X	X	
	NAB	SDB6	Bay 9	PRE	X	X	X		X	X	X	X	X	X
	NAB	SDB6	Bay 9	DUR	X	X	X		X	X	X	X	X	X
	NAB	SDB6	Bay 18	PRE	X	X	X		X	X	X	X	X	X
	NAB	SDB6	Bay 18	DUR	X	X	X		X	X	X	X	X	X
	NI	SDB6	OF 23A	FF	X	X	X		X	X	X	X	X	
	NI	SDB6	OF 26	FF	X	X	X		X	X	X	X	X	X
	NI	SDB6	OF 26	COMP	X	X	X	X	X	X	X	X	X	
	NI	SDB6	BAY 23A	PRE	X	X	X		X	X	X	X	X	X
	NI	SDB6	BAY 23A	DUR	X	X	X		X	X	X	X	X	X
	NI	SDB6	Bay 26	PRE	X	X	X		X	X	X	X	X	X
	NI	SDB6	Bay 26	DUR	X	X	X		X	X	X	X	X	X
3/19/2005	NAB	TIE2	OF 9	FF	X	X	X	T						
	NAB	TIE2	OF 18	FF	X	X	X	T						
	NAB	TIE2	Bay 9	DUR	X	X	X							
	NAB	TIE2	Bay 18	DUR	X	X	X							
	NI	TIE2	OF 23A	FF	X	X	X	T						
	NI	TIE2	OF 26	FF	X	X	X	T						
	NI	TIE2	Bay 23A	DUR	X	X	X							
	NI	TIE2	Bay 26	DUR	X	X	X							
4/27/2005	NAB	SDB7	OF 9	FF	X				X	X	X			X
	NAB	SDB7	OF 9	COMP	X			X	X	X	X	X	X	
	NAB	SDB7	OF 18	FF	X				X	X	X			X
	NAB	SDB7	OF 18	COMP	X			X	X	X	X	X	X	
	NAB	SDB7	Bay 9	PRE	X		X		X	X	X			X
	NAB	SDB7	Bay 9	DUR	X		X		X	X	X			X
	NAB	SDB7	Bay 18	PRE	X		X		X	X	X			X
	NAB	SDB7	Bay 18	DUR	X		X		X	X	X			X
	NI	SDB7	OF 23A	FF	X			X	X	X	X	X	X	
	NI	SDB7	OF 26	FF	X				X	X	X			X
	NI	SDB7	OF 26	COMP	X			X	X	X	X	X	X	
	NI	SDB7	BAY 23A	PRE	X		X		X	X	X			X
	NI	SDB7	BAY 23A	DUR	X		X		X	X	X			X
	NI	SDB7	Bay 26	PRE	X		X		X	X				X
	NI	SDB7	Bay 26	DUR	X		X		X	X	X			X

+ Taken off SSC-SD Pier
* *ex situ* toxicity
T Analyzed by toxicity lab

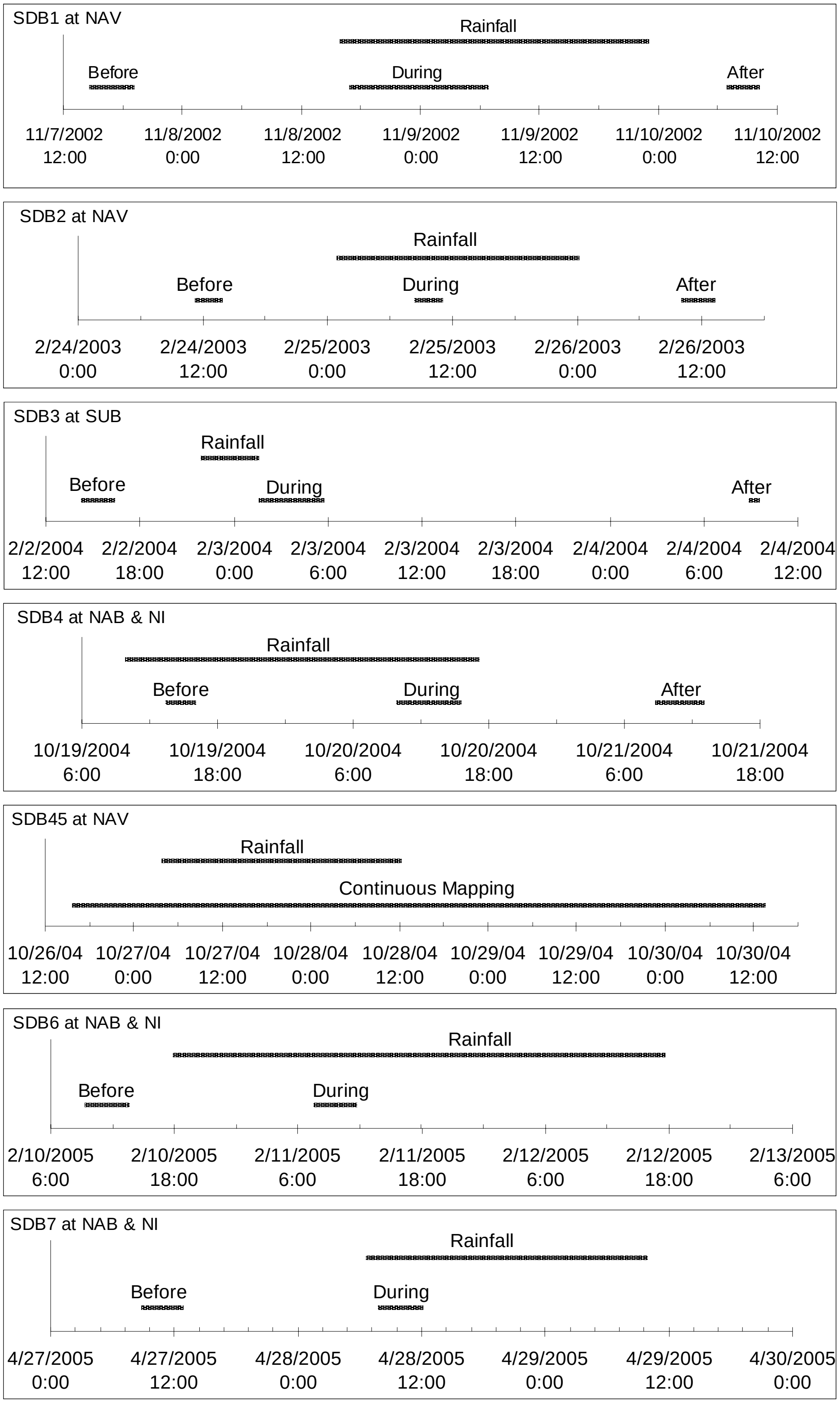


Figure 4. Summary timetable of 17 plume mapping surveys conducted before, during, and after rainfall events. The floating bioassay system was deployed during the SDB45 storm event.

6.2 MONITORING SITES

The drainage areas evaluated at each base were chosen on the basis that they contain some industrial activities as identified by the CNRSW Water Program Manager, Mr. Rob Chichester. All industrial drainage areas implement best available technology economically achievable (BAT) for toxic and non-conventional pollutants and best conventional pollutant control technology (BCT) for conventional pollutants through the use of Best Management Practices (BMP) as required in the Navy's Storm Water Pollution Prevention Plan. Placement of the monitoring site within a drainage area was based on the ability to safely access the site at all times, that the physical configuration of the outfall was appropriate for automated monitoring equipment and for measuring flow, and that the site was minimally impacted from tide water intrusion. Because most, if not all, storm drain outfalls at these bases are subject to tide water intrusion, most monitoring sites were moved upstream from their point of discharge to the bay to minimize the likelihood of tidal intrusion during sampling. Though the monitoring sites were placed upstream of the discharge point, they still represented over 90% of the drainage area. Even though sites were moved upstream of their discharge point, most remained affected by tidal intrusion during high tides. In all, the drainage areas represented about 221 acres. This area is approximately 10% of the total industrial acreage at these bases (Table 3). The drainage areas were all made up of greater than 90% impervious surface. The following sections describe the specific drainage acreages monitored at each of the four bases.

Table 3. Storm water outfall monitoring site sampling acreages.

Monitoring Site	Drainage Area (acres)	Sampled Area (acres)	Area Sampled (%)
NAV			
Outfall 9	16.6	15.4	93%
Outfall 11	30.8	28.0	91%
Outfall 14	53.3	49.1	92%
Pier 5	1.7	1.7	100%
Pier 6	1.9	1.9	100%
Total	104.3	96.1	92%
SUB			
Outfall 11B	21.3	19	90%
Outfall 23C	0.7	0.7	100%
Outfall 23E	0.5	0.5	100%
Sierra Pier 26	2.5	2.5	100%
November Pier 24	0.7	0.7	Not known
Total	25.8	23.7	92%
NAB			
Outfall 18	6.3	6.3	100%
Outfall 9	5.3	5.3	100%
Total	11.6	11.6	100%
NI			
Outfall 23A	5.7	5.7	100%
Outfall 26	73.9	68.0	92%
Total	79.6	73.7	93%

6.2.1 Naval Station San Diego Sites

Naval Station San Diego is located on the eastern shore of mid-San Diego Bay (Figure 3). The base is just south of downtown San Diego and adjacent to National City. The base is the largest surface force support installation in the nation, providing shore support, living quarters, and pier-side berthing services for approximately 60 Pacific Fleet Surface Force ships. The base has approximately 50 tenant commands, the three largest of which include the Public Works Center (PWC), the South West Regional Maintenance Center (SWRMC), and the Fleet Training Center. The base population is more than 35,000 military and 7,000 civilians.

The facility is composed of approximately 1029 acres, about 90% of which is made up of impervious surface. Its 14 piers provide about 12 miles of berthing space. There are 38 industrial drainage areas on the base. Most of these drainages directly discharge to San Diego Bay. Approximately 280 acres are identified as having industrial activities that include fuel storage and dispensing, hazardous substance storage, materials storage, metal fabrication, painting, a recycling collection center, repair and maintenance (general), sandblasting, a scrap metal yard, ship support services, vehicle repair and maintenance. Well over 50% of base acreage is paved roads or used for parking.

CNRSW chose five drainage areas to represent industrial storm water discharges to the center pier area region. This region is due for a sediment Total Maximum Daily Load (TMDL) evaluation in the near future, and the data derived from this study were planned for use in that investigation. Figure 5 shows the five drainage areas, their outfalls, drainage conveyance systems, and sampling locations. Two of the drainages include piers that have multiple drains along their entire length. Table 3 shows the drainage areas for each area. Figure 6 shows an example mapping track used to evaluate the magnitude and extent of storm water plumes in the receiving water. The 104 acres of drainage area evaluated represents about 37% of the base’s total acreage identified as industrial. About 90% of the drainage areas evaluated were actually monitored by placing sampling locations close to where the outfalls discharge to the bay. The following paragraphs describe each monitoring site setup. The drainage areas sampled do not have any storm water run-on from non-Navy sources.

Outfall 9. Outfall 9 (OF9) enters the bay just north of Pier 5. The monitoring location was at the corner of Bainbridge and Brinser Streets, just north of the Graving Dock, about 100 feet from the discharge point through the quay wall. The outfall drains 16.6 acres, virtually all of which is impervious surface. This monitoring location was estimated to effectively sample 93% of the drainage area. Industrial facilities in this drainage area include the SWRMC shops: auxiliary machine shop, maintenance shops, and transportation and maintenance shop. The outfall is tidally influenced with bay water reaching the monitoring location at a tide stage of 3.8 feet. The pipe diameter on the upstream side of the catch basin was 20 inches, though silt covered the bottom 3.4 inches.

Onshore monitoring equipment was set up on the sidewalk next to a bus stop shelter, with the rain gauge placed on top of the shelter (Figure 7). Sensor cables and a sample line were run across the sidewalk under a mound of mortar where it entered into a curb drain that met with the main flow line. The outfall was accessible through a manhole in the middle of the street. The sensors were placed ~3 feet upstream of the manhole and catch basin opening, with the flow sensor pointing upstream to optimize its signal strength. The sensors were placed on top of the silted in section and area-flow calculations were adjusted to account for this altered pipe area. Offshore samples were collected immediately outside the discharge pipe as it came through the quay wall, within 2 feet of the pipe opening.

Outfall 11. Outfall 11 (OF11) enters the bay between Piers 5 and 6. The monitoring location was located at the western corner of Building 84 at the Graving Dock, about 500 feet from the discharge point through the quay wall. The outfall drains ~31 acres, all of which is impervious surface. This monitoring location was estimated to effectively sample 91% of the drainage area. When the Graving Dock is active, about half, 40% the area, is sealed from draining to this outfall as a result of storm water best management practices (BMP). Industrial facilities in this drainage area include an SWRMC corrosion control shop, antenna repair shop, and maintenance shop, and PWC ship-to-shore shops. The outfall is tidally influenced, with bay water reaching the monitoring location at a tide stage of 4.3 feet. The pipe diameter was 36 inches, though the bottom 3.3 inches was covered with gravel.

Onshore monitoring equipment was set up next to Building 84, with the rain gauge placed on top of the building (Figure 8). The outfall was accessible through a grated catch basin next to the building. The sensors were placed ~ 3 feet upstream of the catch basin opening, with the flow sensor pointing upstream to optimize its signal strength. The sensors were placed on top of the gravel section and area-flow calculations were adjusted to account for this altered pipe area. When the Graving Dock was active, the catch basin opening was well sealed around the sensor and sampling lines. Offshore samples were collected immediately outside the discharge pipe as it came through the quay wall, within 2 feet of the pipe opening.

Outfall 14. Outfall 14 (OF14) enters the bay between Piers 6 and 7. The monitoring site was located in a large parking lot bordering Wooden Street across from the Defense Logistics Agency Building, about 650 feet from the discharge point through the quay wall. The outfall drains ~53 acres, virtually all of which is impervious surface. This location was estimated to effectively sample 92% of the drainage area. Industrial facilities in this drainage area include a PWC vehicle maintenance and a divers' storage facility. The outfall is tidally influenced with bay water reaching the monitoring location at a tide stage of 3 feet. The pipe diameter on the upstream side of the catch basin was 36 inches, though the bottom 1.6 inches was covered with gravel.

Onshore monitoring equipment was set up inside concrete barriers placed around the manhole (Figure 9). The sensors were placed ~ 3 feet downstream of the manhole opening, with the flow sensor pointing upstream to optimize its signal strength. The sensors were placed on top of the gravel section and area-flow calculations were adjusted to account for this altered pipe area. Offshore samples were collected immediately outside the discharge pipe as it came through the quay wall, within 2 feet of the pipe opening. This site was monitored during the special floating bioassay study (SD45). Bay samples were also collected at a station, designated 14A, approximately 500 feet out from the outfall pipe.

Pier 5. Pier 5 (PR5) is approximately 1,260 feet long and 60 feet wide, with a total surface area of 1.7 acres. Storm water drains through ~ 350 separate concrete scuppers along the sides of the crowned pier. The high number of drains did not lend itself to autosampling, so samples were manually collected from about 20% of the drains along the entire length of the pier and composited to obtain a sample representative of the entire pier. Standard operations on the pier include material handling of sanitary waste, bilge water waste, loading equipment and supplies, drum and hazardous waste removal, recycling bins, and trash collection. The drains were not tidally influenced. Offshore samples were not collected that were specific to the pier discharge, though plume mapping was conducted around the pier area.

Pier 6. Pier 6 (PR6) is approximately 1375-feet long and 60-feet wide, with a total surface area of 1.9 acres. Storm water drains through ~ 120 separate small drains imbedded in the concrete surface. The high number of drains did not lend itself to autosampling, so samples were manually collected from about 20% of the drains along the entire length of the pier and composited to obtain a sample representative of the entire pier. Standard operations on the pier include the same material handling operations already discussed for Pier 5 above. Offshore sampling was conducted around the outside of the pier. The drains were not tidally influenced. Offshore samples were not collected that were specific to the pier discharge, though plume mapping was conducted around the pier area.

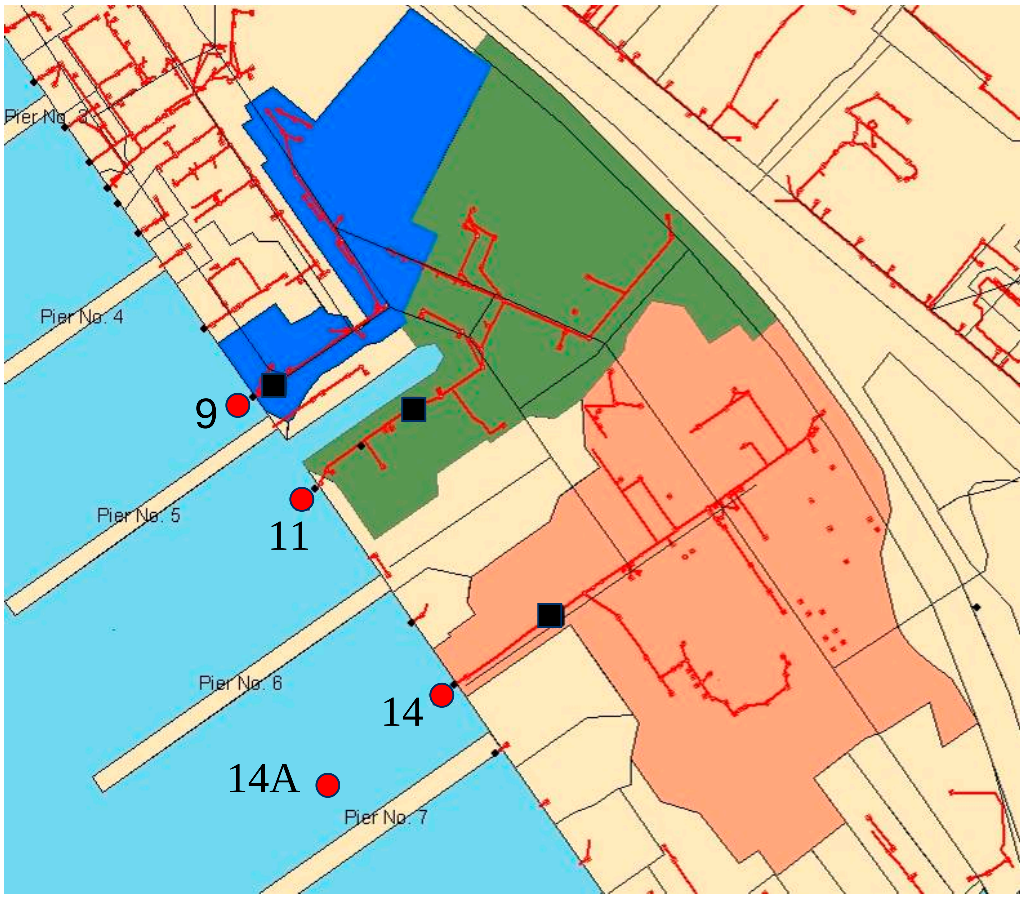


Figure 5. Detail of Naval Station San Deigo drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water locations are identified by the red circles and labeled with the associated outfall number. Drains along Piers 5 and 6 were also monitored. Position of offshore sampling locations is approximate because of the map scale.

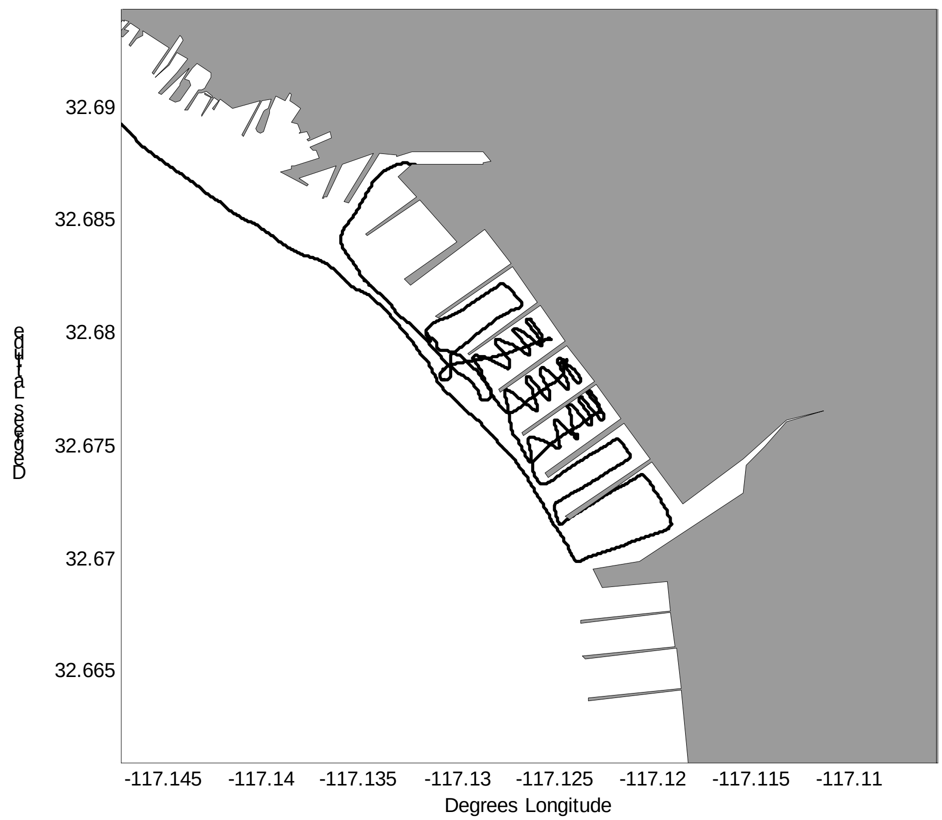


Figure 6. Example storm water plume mapping track used during storm event SDB1 at Naval Station San Diego. The track was repeated before, during, and after storm events. All plume mapping tracks are shown in Appendix G.

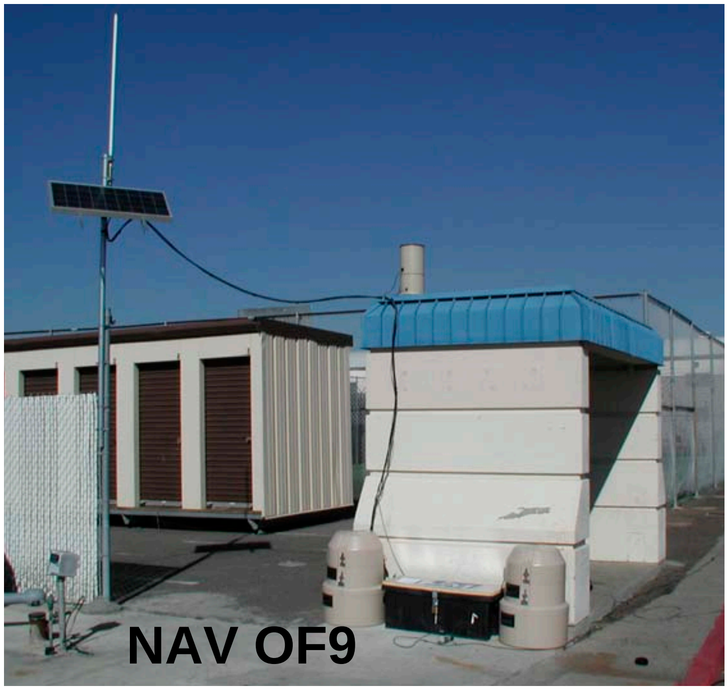


Figure 7. Naval Station San Diego storm water monitoring location for outfall 9. Automated samplers, rain gauge, power and communications systems are also shown.

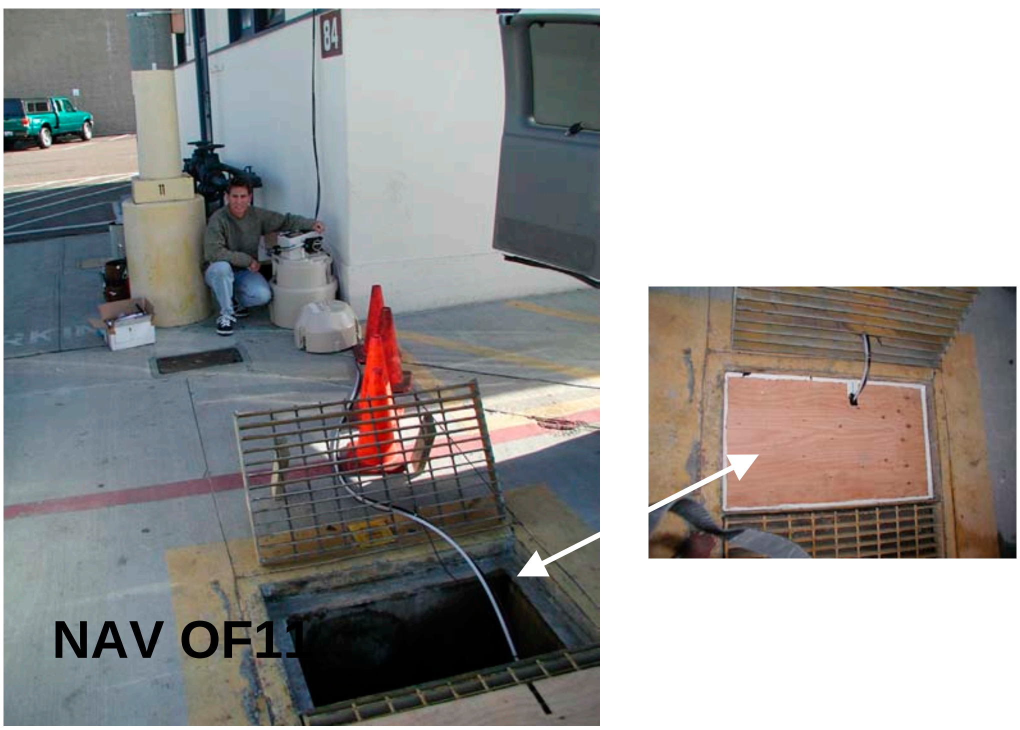


Figure 8. Naval Station San Diego storm water monitoring location for outfall 11. The rain gauge was placed on top of Building 84 in the background. The solar power panel and RF link were attached to the light pole next to the building. The short distance between the building and the grate was secured by traffic cones to protect the sample line and cabling. The inset at the right shows plywood covering the catch basin when the Graving Dock was active.

Figure 9. Naval Station San Diego storm water monitoring location for outfall 14. The site was located in a parking lot about 650 feet from the discharge point through the quay wall. The barriers were provided by the base to provide a secure monitoring area.

6.2.2 Naval Submarine Base San Diego

Naval Submarine Base San Diego is on the Point Loma peninsula, which forms the western boundary of the entrance to San Diego Bay from the Pacific Ocean. The base provides pier-side berthing and support services for submarines of the U.S. Pacific Fleet. The base is home to Commander, Third Fleet; Commander, Submarine Squadron Eleven; Commander, Submarine Development Squadron Five; and Commander, Military Sealift Command Pacific, as well as six attack submarines, the Third Fleet Flagship, and Submarine Training Center Detachment.

The base comprises 316 acres, but the majority of the industrial facilities are on approximately 30 acres around its pier area (Figure 10). Most of this acreage is made up of impervious surface. The base has three main piers identified as November, Mike, and Sierra. There are 11 different industrial drainage areas on the base. Industrial activities on the base include a fuel depot, hazardous substance storage, materials storage, a recycling collection center, repair and maintenance (general), ship support services, an air compressor, and a steam plant. A high percentage of the base is paved roads or used for parking. The drainage areas sampled do not have any storm water run-on from non-Navy sources.

Five drainage areas were chosen by CNRSW to represent industrial storm water discharges from the base. Figure 10 shows the drainage areas, their outfalls, drainage conveyance systems, and sampling locations. Two of the drainages include piers that have multiple drains along their entire length. Table 3 shows the drainage areas for each area. Figure 11 shows an example mapping track used to evaluate the magnitude and extent of storm water plumes in the receiving water. A total of 26 acres of industrial drainage area was evaluated. About 90% of the drainage areas evaluated were actually monitored by placing sampling locations close to where the outfalls discharge to the bay. The following paragraphs describe each monitoring site setup.

Outfall 11B. Outfall 11 (OF11) enters the bay under Sierra Pier. The monitoring location was located at the northeast corner of the base's parking structure, approximately 280 feet from its discharge point under Sierra Pier. The outfall drains about 21 acres, nearly all of which is impervious surface. This location was estimated to effectively sample 90% of the drainage area. Industrial facilities in this drainage area include an air compressor plant, fire fighting facility, wet trainer, and waterfront operations storage. The outfall is tidally influenced with bay water reaching the monitoring location at a tide stage of ~ 4.1 feet. The pipe diameter was 26 inches.

Onshore monitoring equipment was set up in a parking space enclosed by barriers similar to Naval Station San Diego outfall 14 (Figure 9). The rain gauge was placed on the ground within a few feet of the sampling system. The outfall was accessible through a grated catch basin. Monitoring sensors were placed ~ 3 feet downstream of the catch basin opening, with the flow sensor pointing upstream to optimize its signal strength. Offshore samples were collected at the northwest corner of Sierra Pier. This sampling position was approximately 50 feet away from the discharge pipe, which enters underneath the pier.

Outfall 23CE. Outfalls 23C and 23E (OF23CE) were sampled together. These drainage areas are roughly 0.5 acres, each of impervious surface, and are next to each other along the waterfront north of Mike Pier (Figure 10). The waterfront edges of these areas are bermed by about a ½-foot-high asphalt curb. A pipe with a ball valve extends through the berm in each area. The valve can be manually opened to allow storm water to flow over the rip-rap border before its entry to the bay, though it usually remains closed. The onshore monitoring location was located on the bay side of the two valves. The two valves were tied together using Teflon® tubing connected to an automated sampler. The autosampler system was used to manually collect storm water samples from the two sites and to measure rainfall. Industrial facilities in this drainage area include a bilge and oily wastewater treatment system, periscope maintenance facility, and a ship spares storage area. The outfall was not tidally influenced. The pipe diameter going through the berm was approximately 3 inches. Offshore samples were collected from the surface water within 5 feet of the rip-rap that forms the base borders and half-way between the two discharge locations.

Outfall 24, November Pier. Outfall 24 (OF24) is one of many drains located along the length of November Pier. Because the pier was not numbered, the designator for this outfall was its outfall (OF) number rather than its pier number (PR), as was used at Naval Station San Diego. The sampling location used to manually collect one first-flush storm water sample was approximately 170 feet out on the north side of the pier. The pier is approximately 540 feet long and 60 feet wide, with a total surface area of ~ 0.7 acres. The area of the pier represented by the single sampling location is not known. Standard operations on the pier include material handling of sanitary waste, bilge water waste, loading equipment and supplies, drum and hazardous waste removal, recycling bins, and trash collection. The drains were not tidally influenced. The pier drain was sampled by pumping water as it flowed across a Teflon® sheet using a peristaltic pump with Teflon® tubing. Offshore samples were collected off the side of the pier below the drain using the same pumping system. A float was attached to the tubing to ensure the sample was collected at a depth of 2 feet.

Outfall 26, Sierra Pier. Outfall 26 (OF26) is one of many drains located along the length of Sierra Pier. Because the pier was not numbered, the designator for this outfall was its outfall (OF) number rather than its pier number (PR), as was used at Naval Station San Diego. The center drain at the 525-foot marker collected first-flush storm water samples. Full-storm composite samples were manually collected from about 20% of the drains along the entire length of the pier and composited to obtain a sample representative of the entire pier, which at approximately 1000-feet long by 110-feet wide, has a total surface area of ~2.5 acres. Samples were pumped from plastic funnel inserts that had a siphon tube that allowed water to flow through the drain while maintaining a constant 0.5-L volume.

Standard operations on the pier include material handling of sanitary waste, bilge water waste, loading equipment and supplies, drum and hazardous waste removal, recycling bins, and trash collection. Offshore sampling was conducted off the side of the pier immediately to the west of the ARCO dry dock. The drains were not tidally influenced. Offshore sampling was conducted immediately next to the south side of the pier adjacent to the ARCO dry dock. An additional sample was also collected at a site designated 26A, approximately 100 feet out from the end of Sierra Pier.

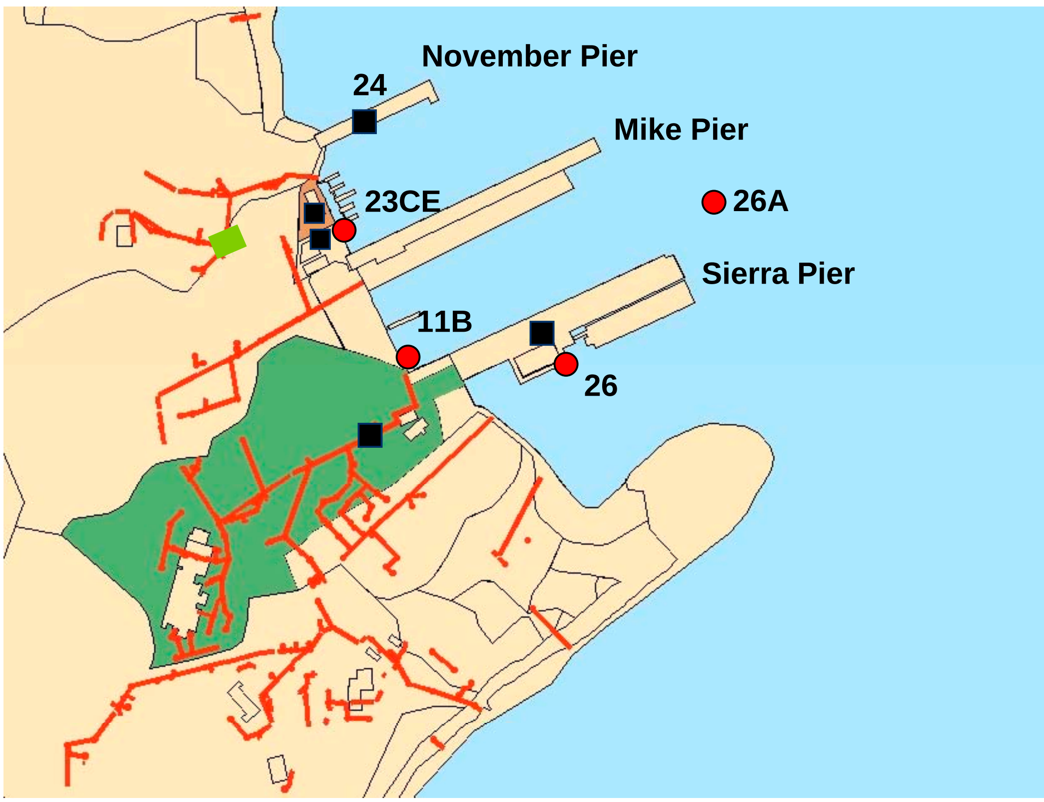


Figure 10. Detail of Naval Submarine Base San Diego drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares, though samples were also collected from multiple drains along Sierra Pier for composite samples. Receiving water sample locations are identified by the red circles and labeled with the associated outfall number. Position of offshore sampling locations is approximate because of the map scale.

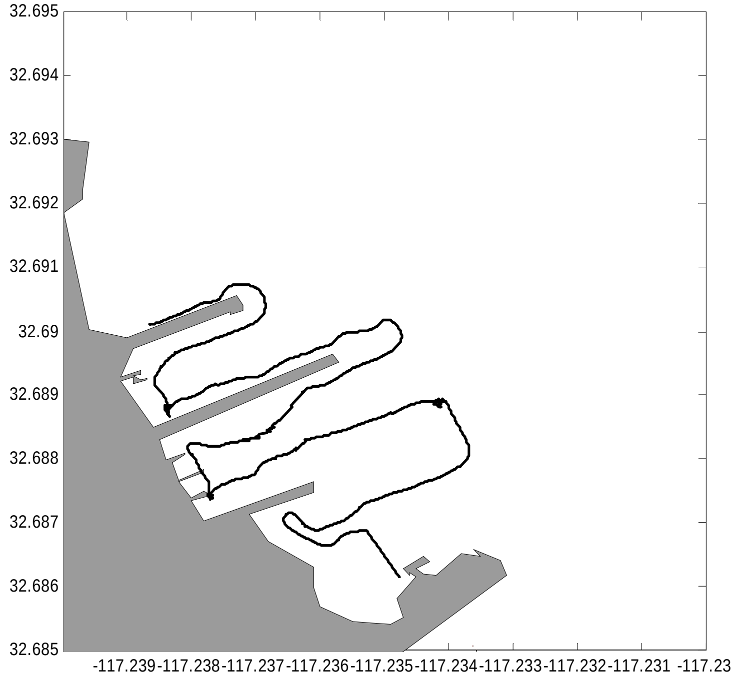


Figure 11. Example storm water plume mapping track used during storm event SDB2 at Naval Submarine Base San Diego. The track was repeated before, during, and after storm events. All plume mapping tracks are shown in Appendix G.

6.2.3 Naval Amphibious Base Coronado Sites

Naval Amphibious Base Coronado is on a strip of land that juts into the bay from the west side at about its midpoint from the mouth (Figure 3). The base is a major shore command, supporting 27 tenant commands, and is the West Coast focal point for special and expeditionary warfare training and operations. The amphibious base houses Commander Naval Surface Force, U.S. Pacific Fleet, responsible for the training, maintenance and crews of the approximately 90 ships of the Pacific Fleet, and Commander Naval Special Warfare Command, U.S. Pacific Fleet. Also located there are most of the Naval Expeditionary and Naval Special Warfare units of the Pacific Fleet as well as the Navy Parachute Team, the Leap Frogs.

The base currently occupies ~1,000 acres, including 257 beach-front acres leased from the State of California along the Pacific Ocean. The majority of the Activity is on a rectangular-shaped area constructed with fill material extending from the original peninsula into the bay. The topography of the Activity is very flat, with an average elevation of about 10 feet above mean sea level. Most of the acreage is made up of impervious surface. The drainage areas sampled do not have any storm water run-on from non-Navy sources.

The base has 53 industrial drainage areas. Approximately 88 acres are identified as having industrial activities that include fuel storage and dispensing, hazardous substance storage, materials storage, a recycling collection center, repair and maintenance (general), ship support services, an air compressor, and a steam plant. A high percentage of the base is paved roads or used for parking.

CNSRW chose two drainage areas to represent industrial storm water discharges from the base. Figure 12 shows the drainage areas, their outfalls, drainage conveyance systems, and sampling locations. Figure 13 shows an example mapping track used to evaluate the magnitude and extent of storm water plumes in the receiving water. The nearly 12 acres of drainage area evaluated represents about 14% of the base's total acreage identified as industrial. The entire drainage areas were evaluated by placing sampling locations at the end of the discharge pipes. Offshore sampling was conducted immediately outside the pipe discharge to the bay. The following paragraphs describe each monitoring site setup.

Outfall 9. Outfall 9 (OF9) enters the bay near the southeast corner of the base in a barge maintenance yard. The outfall drains ~ 5.3 acres, all of which is impervious surface. The monitoring site was right along the quay wall (Figure 14), thus sampling was representative of the entire drainage area other than what might discharge as sheet runoff. Industrial facilities in this drainage area include an abrasive blast facility and a boat-fitting and sail-loft building. The outfall is tidally influenced with bay water reaching the monitoring location at a tide stage of 4.8 feet. The pipe diameter was 13 feet. Monitoring sensors were placed ~ 3 feet upstream of the end of the pipe with the flow sensor pointing upstream. Offshore sampling was conducted immediately outside the discharge pipe as it came through the quay wall.

Outfall 18. Outfall 18 (OF18) enters the bay near the northwest corner of the base in a small grassy area along the beach (Figure 15). The outfall drains ~6.3 acres, most of which is impervious surface. The monitoring site was at the end of the outfall pipe that exited the rip-rap at the shore edge. Thus, sampling was representative of the entire drainage area other than what might discharge as sheet runoff. Industrial facilities in this drainage area include a vehicle and boat maintenance facility and a hazardous materials storage and handling area. The outfall was tidally influenced, with bay water reaching the monitoring location at a tide stage of 6.4 feet, a very high tide condition. The pipe diameter was 18 feet. A funnel with a siphon tube was attached at the end of the outfall pipe to provide a consistent volume for the sampling pump (Figure 16). Monitoring sensors were placed ~ 3 feet upstream of the end of the pipe, with the flow sensor pointing upstream. Offshore sampling was conducted immediately outside the region of rip-rap. During the SDB4 and TIE2 rain events, samples were collected from shore within 5 feet of the discharge. During the SDB6 and SDB7 sampling events, the samples were collected by boat and because of shallow water, the distance from the discharge was between 30 and 50 feet away.

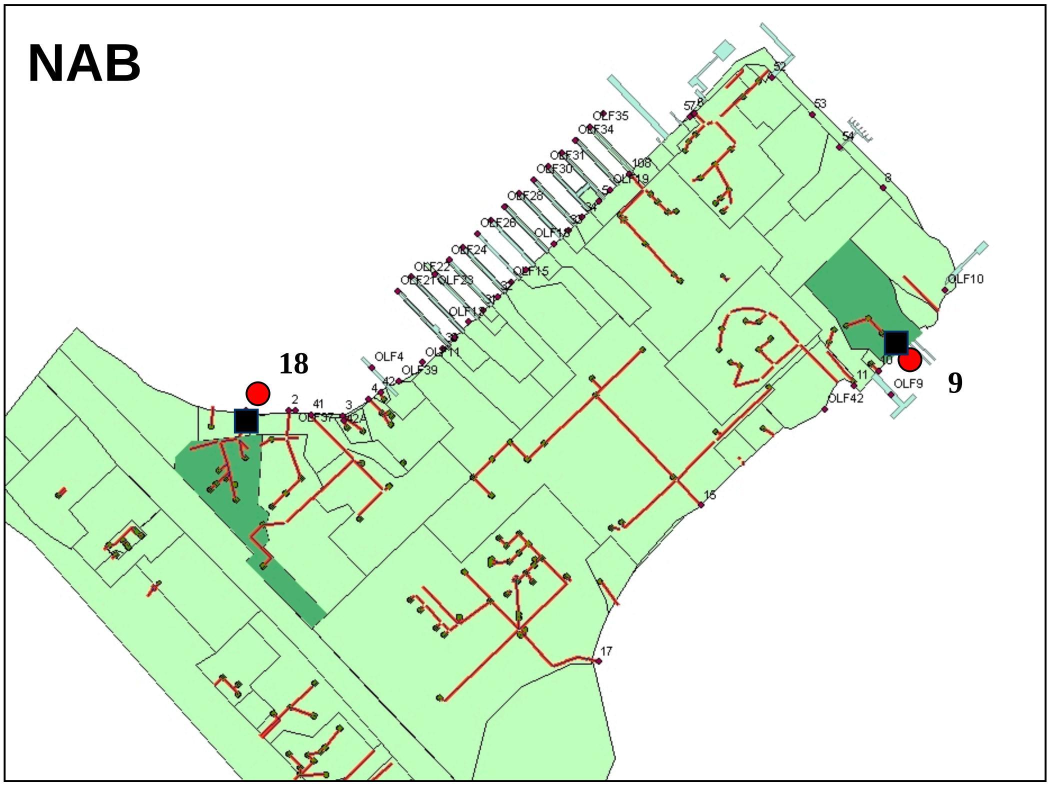


Figure 12. Detail of Naval Amphibious Base Coronado drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water sample locations are identified by the red circles and labeled with the associated outfall number. Position of offshore sampling locations is approximate because of the map scale.

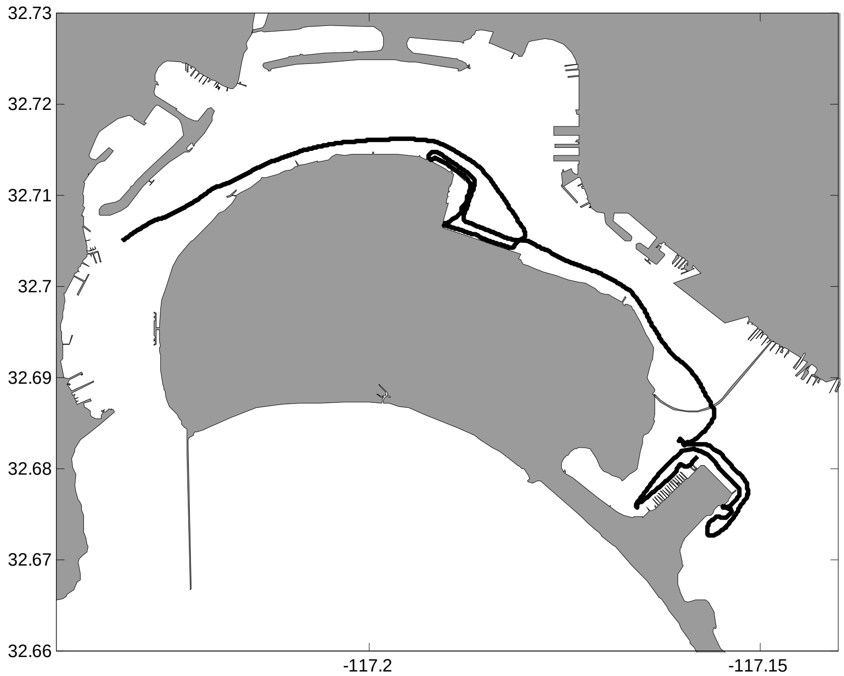


Figure 13. Example storm water plume mapping track used before storm event SDB6 for Naval Amphibious Base Coronado and Naval Air Station North Island. The track was repeated before and during storm events. All plume mapping tracks are shown in Appendix G.

Figure 14. Naval Amphibious Base Coronado storm water monitoring location for outfall 9. The site was located in a barge maintenance area right at the quay wall.

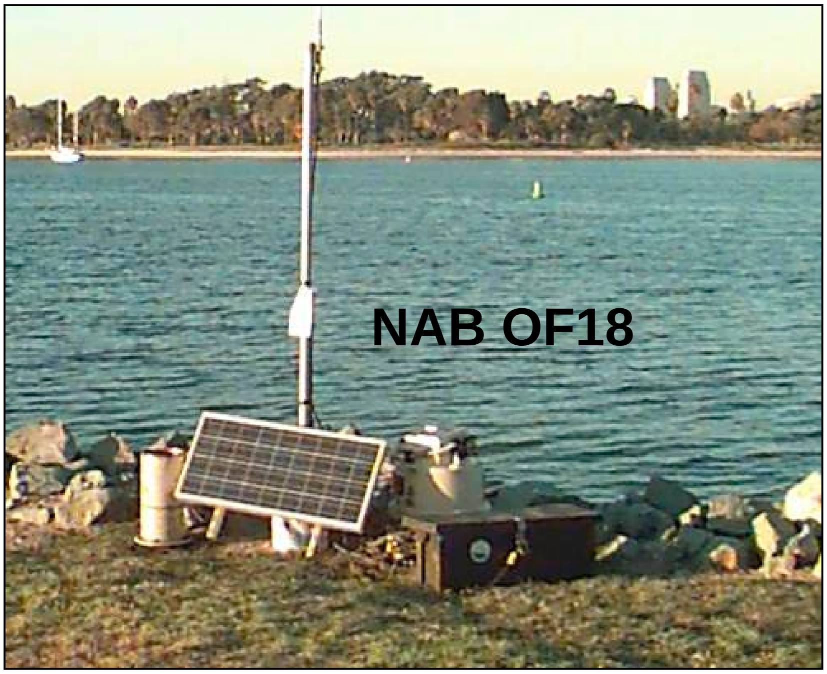


Figure 15. Naval Amphibious Base Coronado storm water monitoring location for outfall 18. The site was located within a small grassy area along a beach bordering the bay.

Figure 16. Sampling setup at Naval Amphibious Base Coronado outfall 18. Storm water was sampled as it flowed through the funnel setup, which maintained a continuous 0.5-L volume using the attached siphon tube.

6.2.4 Naval Air Station North Island Sites

Naval Air Station North Island is the bulk of the land mass that forms the western perimeter of San Diego Bay (Figure 3). The Air Station is headquarters for six major military flag staffs, including Commander Naval Air Force, U.S. Pacific Fleet, responsible for maintenance and training of all naval aircraft and aircraft carriers in the Pacific Fleet; Commander Third Fleet, responsible for the defense of the western approaches to the U.S. and the direction of joint, combined, intertype, and fleet exercises in the eastern Pacific; Commanders Carrier Group One and Seven; and Commanders Cruiser Destroyer Group One and Five. With all the ships in port, the population of the base is over 30,000 active duty, selected reserve military, and civilian personnel.

The base occupies 2,800 acres, of which 2,400 acres are land area and 400 acres are water (tidelands around the island). Approximately 80% of the base land area is impervious to storm water. There are 54 industrial drainage areas on the base. Approximately 2,040 acres are identified as having industrial activities that include fuel storage and dispensing, hazardous substance storage, materials storage, metal fabrication, painting, a recycling collection center, repair and maintenance (general), sandblasting, a scrap metal yard, ship support services, aircraft support and maintenance facilities, and vehicle repair and maintenance.

CNRSW chose two drainage areas to represent industrial storm water discharges to the center pier area region. Figure 17 shows the two drainage areas, their outfalls, drainage conveyance systems, and sampling locations. Table 3 shows the drainage areas for each area. Figure 13 shows an example mapping track used to evaluate the magnitude/extent of storm water plumes in the receiving water. The nearly 80 acres of drainage area evaluated represents about 4% of the base's total industrial acreage. About 93% of the drainage areas evaluated were actually monitored by placing sampling locations close to where the outfalls discharge to the bay. Sampled drainage areas do not have any storm water run-on from non-Navy sources. The following describe each monitoring site setup.

Outfall 23A. Outfall 23A (OF23A) enters the bay along the north–south carrier pier. The outfall was located in a parking area behind the Port Operations building, adjacent to one of the carrier piers (Figure 17). Because the catch basin grate was located in a thoroughfare, the site was sampled manually. The outfall drains ~5.7 acres, all of which is impervious surface. The monitoring site was representative of the entire drainage area. Industrial facilities in this drainage area include a waterfront operations facility and a boom storage facility. It is not known whether bay water tidally influences the outfall, as this event was not observed during sampling events. The pipe diameter was estimated as 18 feet (the grating was not removed). Offshore sampling was conducted immediately outside the discharge pipe as it came through the quay wall along the carrier pier.

Outfall 26. Outfall 26 (OF26) enters San Diego Bay at the corner formed by two carrier piers (Figure 17). The monitoring site was along the fence line that secured a steam plant (Figure 18). The outfall drains ~74 acres, which is impervious surface. Samples collected at this monitoring site were representative of about 92% the entire drainage area. Industrial facilities include aircraft maintenance hangars, a PWC storage warehouse, a spray paint booth and sandblasting facility, an air compressor plant, and a Navy primary standards laboratory flow calibration facility. The outfall is tidally influenced, with bay water reaching the monitoring location at a tide stage of 3.2 feet. The pipe diameter was 48 inches. Monitoring sensors were placed ~ 3 feet upstream of the manhole, with the flow sensor pointing upstream. Offshore sampling was conducted as close to the discharge pipe as it came into the bay through the quay wall and rip-rap along the shoreline. During the SDB4 and TIE2 rain event, samples were collected from shore within 5 feet of the discharge. During the SDB6 and SDB7 sampling events, the samples were collected by boat and because of shallow water, the distance from the discharge was between 30 and 50 feet away.

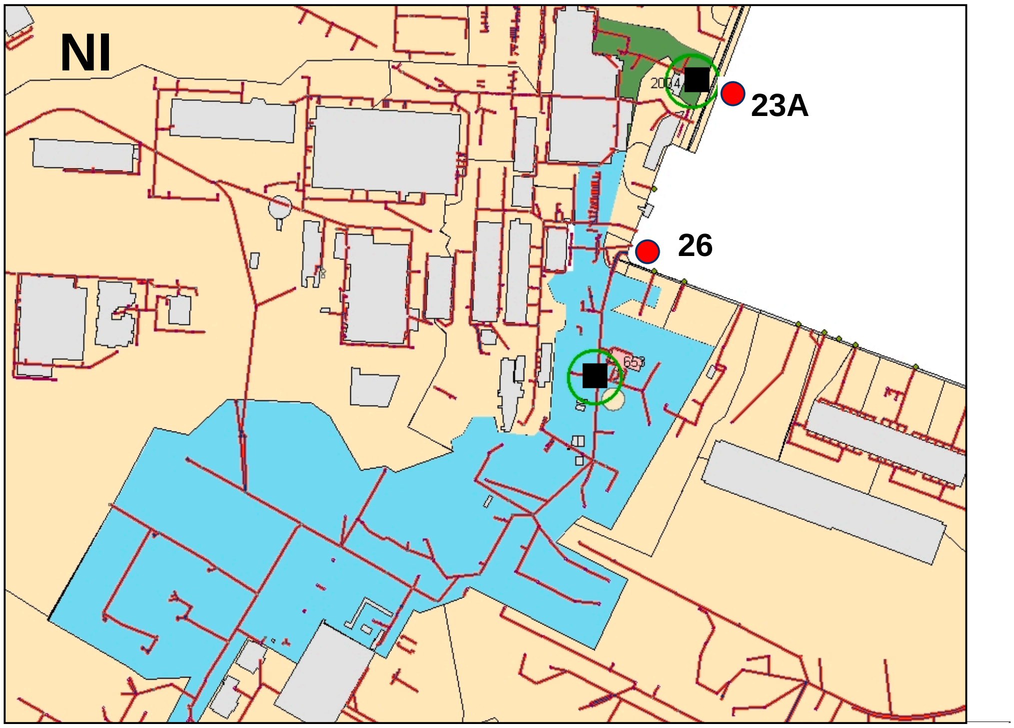


Figure 17. Detail of Naval Air Station North Island drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water sample locations are identified by the red circles and labeled with the associated outfall number. Position of offshore sampling locations is approximate because of the map scale.

Figure 18. Naval Air Station North Island storm water monitoring location for outfall 26. The site was located along the fence surrounding a steam plant.

6.3 SAMPLE COLLECTION METHODS

6.3.1 Design Storm Criteria

The goal of the project was to sample during typical rainfall conditions for the region. Seasonal rainfall for the immediate region averages about 10 inches, with 85% of it falling between November and March (http://www.wrh.noaa.gov/sgx/climate/san-san.htm) (NOAA, 2004). The historical data plotted as a cumulative frequency diagram (Figure 19) shows that a rainfall total of 0.25 inches or less represents nearly half of all rainfall events while up to a 0.5-inch rain total represents 68% of all storms. About 16% of all storms have rainfall totals greater than 1 inch.

The design storm used in this study was a rainfall total of at least 0.25 inch within a 24-hour time frame, with an antecedent dry period of 7 days. Given the inexact nature of weather predictions and the limited storm weather window in San Diego, the design storm was chosen primarily on the need to have sufficient time and runoff volume for sampling rather than on trying to obtain data during a specific loading condition. The permits specify only that grab samples be collected during scheduled facility operating hours during the first hour of discharge (flow measurement is not required) when preceded by at least 7 working days without storm water discharge. Unlike the NPDES permit requirement, sampling during this study was conducted on a 24-hour/7-day-per-week basis.

A decision to sample a storm was based on a better than 50% likelihood of rainfall (probability of measurable precipitation) and quantitative rainfall amount >0.25 inch, predicted by the San Diego office of the National Weather Service. The type of storm and its likelihood of meeting the predictions also played a role in the decision process. The purpose of these decision criteria was to help ensure that a full collection sequence could be completed once a decision to sample was made. The decision to end a storm (cease sampling) was made when there was no more storm flow and there was little likelihood for more significant rainfall, based on radar and satellite storm tracking.

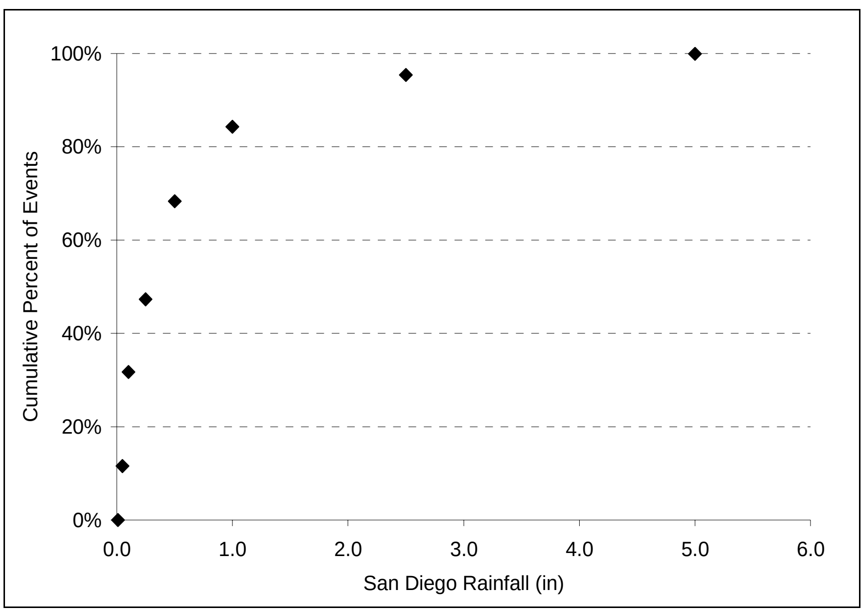


Figure 19. Cumulative frequency distribution plot of historical rainfall data for San Diego (Lindbergh Field). The plot shows rainfall totals for storm events occurring during the October–April rainy season. The plot represents percentages derived from over 15,000 records See the following website: http://www.wrh.noaa.gov/sgx/climate/san-san.htm

6.3.2 Onshore Storm Water Sampling

Onshore monitoring included the collection of first-flush and/or full-storm composite storm water samples from outfall locations using an automated sampler (American Sigma 900) or manual methods. The automated samplers also measured rainfall, storm water flow velocity and level in the discharge pipe, and conductivity data. These data were stored on the automated samplers as well as telemetered to SSC San Diego using radio frequency (RF) communications. Pictures of the automated systems have been shown in previous figures (e.g., Figure 15).

First-Flush. First-flush storm water samples were grabs collected during the first hour of storm flow by pumping water from the outfall using the automated sampling system pumps or similar but separate peristaltic pumps. At a few locations, a pre-cleaned plastic bucket was used to collect water as it exited the pipe before reaching the bay. In all cases, first-flush samples represented undiluted storm water discharge, similar to the requirement in the NPDES permit. The PR5 and PR6 pier samples collected at Naval Station San Diego were pumped from water that had pooled on top of a Teflon® sheet placed over part of the drain. The Naval Submarine Base San Diego outfall 26 samples were pumped from pre-cleaned funnels placed inside the drains that allowed water to continuously flow to the bay but maintained a volume of 0.5 L similar to the one used at the end of Amphibious Base Coronado outfall 18 (Figure 16). Sample water was usually pumped directly into the glass containers that were sent for toxicological or chemical analysis. In some instances, as a result of logistical constraints, an intermediate set of pre-cleaned glass bottles was filled and the sample transferred to bottles that were sent for analysis. All samples were stored at 4°C until processed for analysis, except for DOC samples, which were frozen.

Composite. Composite storm water samples were collected as a function of rainfall throughout a storm event using the automated sampling system. Though not included in the NPDES permit, composite sampling was initiated to characterize the total storm water discharge. Earlier work with the samplers indicated that sample collection triggered on rainfall was equivalent to flow-weighted sampling (Figure 20). Composite samples collected in this manner accurately represented the entire discharge. Between 250- and 535-mL aliquots were collected during each triggering event (rainfall = 0.01 inch). The volume and number of samples per bottle chosen for collection were preprogrammed based on the predicted rainfall total, the sample volume required for analysis, and number of aliquots considered representative of the predicted storm (CALTRANS, 2000). The volume of sample necessary to accomplish all toxicity and chemistry testing was 11 L. There were only a couple of instances when there was insufficient composite sample volume to fulfill all the analysis requirements. In those instances, the number of toxicity test species or number of dilutions were reduced. Samples were collected into pre-cleaned 4-L glass bottles. When all four bottles were filled, a second set was placed into the sampler and the sampling resumed. No sample collection occurred during the time it took to switch out bottles, download data, and restart the sampling program, a period of roughly 15 to 20 minutes. Composite samples collected on the piers and at Naval Submarine Base San Diego outfall 23CE were manually collected as a function of time. All samples were stored at 4°C until processed for analysis, except for DOC samples, which were frozen.

Sample Processing. Sample processing was done as soon as practical, but typically within 24 hours of collection. First-flush samples collected into intermediate bottles in the field were brought back to the lab and split into the final bottles used for analysis. The process typically involved splitting water from two 4-L bottles into multiple containers for metals, DOC, TSS, and organics. Each bottle was shaken and then poured to fill about half the volume of the receiving bottle based on visual inspection. The second bottle was then shaken and poured to fill the remaining volume needed. The sample remaining in the original bottles was used for the toxicity analyses.

Each of the samples used to produce the composite sample were checked for conductivity, temperature, oxygen, and pH by removing a small aliquot before compositing. The samples were also weighed when there were more than five full composite sample bottles to assist in the compositing process. If there were less than five full bottles, the entire contents of the samples in each bottle were added to a pre-cleaned 5-gal carboy. If more than five bottles were collected, a partial sample from each bottle based on weight was placed into the carboy. The bottles were stirred before and during transfers to minimize any losses of particulates. The full composite sample was then distributed from the carboy to individual chemistry bottles using a Teflon® hose siphon. The sample remaining in the 5-gal carboy was used for the toxicity analyses. Samples were stored at 4°C until analyzed, except for DOC samples, which were frozen.

6.3.3 Offshore Receiving Water Sampling

As described previously, offshore monitoring included collecting surface bay water samples directly outside of outfalls before, during, and after storm events. Some samples were also collected a distance away from the outfalls to evaluate toxicity and chemistry gradients. Sample locations were described earlier under site descriptions. Sample collection locations were usually determined visually but were recorded by the MESC navigation system. The discrete samples were collected from a boat-mounted pumping system or by sampling from shore using a peristaltic pump, or in a few instances, for logistical reasons, with a pre-cleaned bucket. Sampling by boat was performed using either a submersible stainless steel and Teflon® pump or a peristaltic pump. Both types of pumps used Teflon® hoses to deliver surface seawater to pre-cleaned sample bottles. The intake hoses were set at a depth of ~2 feet for collection. In all cases, water was pumped for at least 2 minutes before collecting the sample. Water was delivered directly to the sample bottles sent for analysis.

As a result of logistical constraints, receiving waters were occasionally sampled from shore. When this was done, only locations directly outside the outfalls were collected. In most cases, a peristaltic pump and Teflon® hose were used to obtain surface seawater. In a few instances, a pre-cleaned bucket was used. The pump system was outfitted with a small buoy and weight setup to ensure the sample was collected at a depth of about 2 feet. Bucket sampling provided a sample collected from the top 2 feet of the water column (cf. at a depth of 2 feet). Sample water was delivered to a set of intermediate pre-cleaned bottles and then placed on ice at 4°C until processed, except for DOC samples, which were frozen.

6.3.4 Plume Mapping

Offshore plume mapping was performed using the MESC real-time data acquisition and processing system designed and built by the U.S. Navy (Lieberman, Clavell, and Chadwick, 1989; Chadwick and Salazar, 1991; Katz and Chadwick, 1993). MESC was deployed onboard the 40-foot Navy research vessel (RV) ECOS or on a 20-foot survey craft, depending on availability. The primary MESC real-time measurement parameter for evaluating storm water plume magnitude and extent was salinity, though sample depth temperature, light transmission, and ultraviolet oil fluorescence were also evaluated. A Trimble Model 4000RLII differential global positioning system was used to acquire real-time position data. SeaBird Inc. Model 911 CTD was used to measure salinity, temperature, and sample depth. Oil fluorescence was measured using a Turner Designs Inc. Model 10AU fluorometer in flow-through mode. Light transmission was measured using a SeaTech 25-cm path-length transmissometer. Sensors were towed off the side of the vessel or run in flow-through mode by pumping water from the towed package to the onboard sensors.

The MESC was used to map out the above parameters as close in to the outfall pipe discharge location as possible, usually within a few feet of the discharge pipe, and expanded out to cover larger regions of the facility before, during, and after storm events. A few locations such as Submarine Base outfall 11B discharged under a pier and the closest sampling point was about 50 feet away. Outfalls NAB18 and NI26 discharged into shallow water that limited the ability to map closer than about 30 to 50 feet away, depending on tide height. Track lines varied with each survey to accommodate sample collections and wide-area plume mapping coverage. Most data were collected in the top 1 meter of the water column, though vertical profiles were also run periodically to evaluate plume depths at various locations in the survey area. When plume sizes were sufficiently large enough to track at depth, vertical tow-yos were run in which the sensors were raised and lowered through the top 10 meters of the water column as the boat was moving, and thus provided wide-area coverage of plume depth. The nominal along-track resolution when traveling at 5 knots was about 0.5 meter. The nominal depth resolution when performing tow-yos or vertical profiles was ~0.1 meter.

The objective for collecting MESC data was to develop maps of the areal extent of storm water plumes developed during events and to see how they dissipate with time. The salinity data were also used to quantify the magnitude of the freshwater input. While sampling plans included conducting multiple transects throughout storm events, waterside security measures and resources allowed for a more limited set of surveys. The set typically included a survey before the start of rainfall (typically <24 hours before), one or two surveys during storm water discharge, and one survey about 24 hours after rainfall had stopped. The data collected on each of these surveys were used to produce interpolated spatial maps that allowed evaluation of the area of impact through time. Interpolated maps of salinity were used to quantify the relative amount of freshwater derived from the storm discharge.

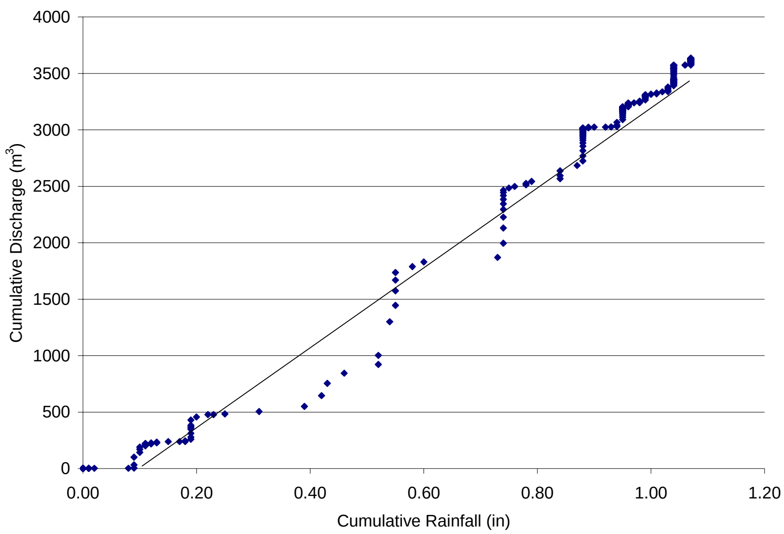


Figure 20. Relationship between rainfall and discharge volume during one storm at Naval Submarine Base San Diego outfall 11B. The good correlation validated the use of rainfall as a trigger for composite sampling for the four Navy facilities. The relationship is not expected to hold for regions with appreciable amounts of non-impervious surface.

6.3.5 Special Floating Bioassay Laboratory Study

A special floating bioassay laboratory study was conducted in October 2004 to monitor the receiving environment throughout an entire storm event and evaluate impacts under actual exposure conditions immediately outside the point of discharge. The storm event was a record rainfall total for October at 3.4 inches over a 2-day period. To perform this task, a flow-through bioassay system was placed aboard the RV ECOS along with the MESC real-time monitoring system. Monitoring was performed outside of Naval Station San Diego outfall 14 over a 4-day period from 26 to 30 October 2004. The ECOS with MESC system was tied up on the quay wall just outside the outfall so that its sensors and water intake system were directly in line with the outfall pipe discharge, about 5 meters away from the quay wall. The MESC sensors and water intake were placed at about 1-meter depth, though the full water column to about a depth of 7 meters was periodically evaluated. Surface salinity, temperature, sample depth, light transmission, pH, and oil fluorescence data were collected every 4 seconds. Two trace metal analyzers, using anodic stripping voltammetry techniques (Zirino, Lieberman, and Clavell, 1978) were used to measure dissolved copper and zinc about every 15 minutes. The MESC's trace-metal, clean Teflon® seawater pumping system was used to supply surface seawater to the bioassay flow-through system at a rate of about 10 L/min, and to collect discrete samples for chemical analysis before, during (four samples), and after (three samples) the storm event. First-flush and full-storm composite storm water samples were collected from the discharge during the storm event using the techniques already described above.

The bioassays were conducted with topsmelt, mysids, and mussel embryos. Two treatments were conducted, one under flow-through conditions and the other a "floating" control to assess any impacts associated with being in the field. Test organisms were held in clean, seawater-leached 400-mL polyethylene containers that were placed into a water bath (Figure 21). Matching lids with cutouts were used to prevent organism ejection during boat movement, yet allow access for water flow and feeding. Control (static) and flow-through chambers contained 250 mL of seawater at all times. The MESC flow-through system provided water to a PVC grid fitted with adjustable valves to regulate water flow to individual chambers. Overflow ports on flow-through chambers measured approximately 2 cm and were covered with a 300-µm PeCap mesh. The flow rate resulted in an average of 15 turnovers per hour. Seawater overflow from the exposure chambers filled the water bath to approximately 5 cm in height to help insulate against temperature shift. Control chambers were filled with clean, filtered, natural seawater from the research pier at Scripps Institution of Oceanography. One renewal of the control water was performed for 96-hour exposures, while 48-hour exposures were not renewed. Topsmelt and mysids swam freely in the chambers, while mussel embryos were contained in 5-cm-diameter polycarbonate drums with 20-µm Nitex® mesh on each side, as described in Phillips et al., 2004.

Six replicates of 10 mysids, 8 replicates of 5 topsmelt, and 6 replicates of 150 mussel embryos were used for each treatment. Mysid and topsmelt exposures were 96 hours while mussel exposures were 48 hours. Organisms were acclimated to expected testing temperatures in the exposure chambers over approximately 1 hour and carefully transported to the water bath system aboard the RV ECOS. All topsmelt and mysids were fed twice daily with freshly hatched *Artemia* nauplii. MESC sensors were used to monitor temperature, pH, and salinity for all flow-through chambers, and a HOBO® data logger was used to monitor temperature in static controls and the water bath. Dissolved oxygen was also monitored hourly in all chambers using a YSI oxygen meter.

Individual outfall and receiving water toxicity and chemistry results are described in the Naval Station San Diego results section. The real-time monitoring data results are included in the discussion. The full results of this special study are described in a Marine Technology Society Oceans 2005 proceedings paper (Katz and Rosen, 2005), Appendix H.

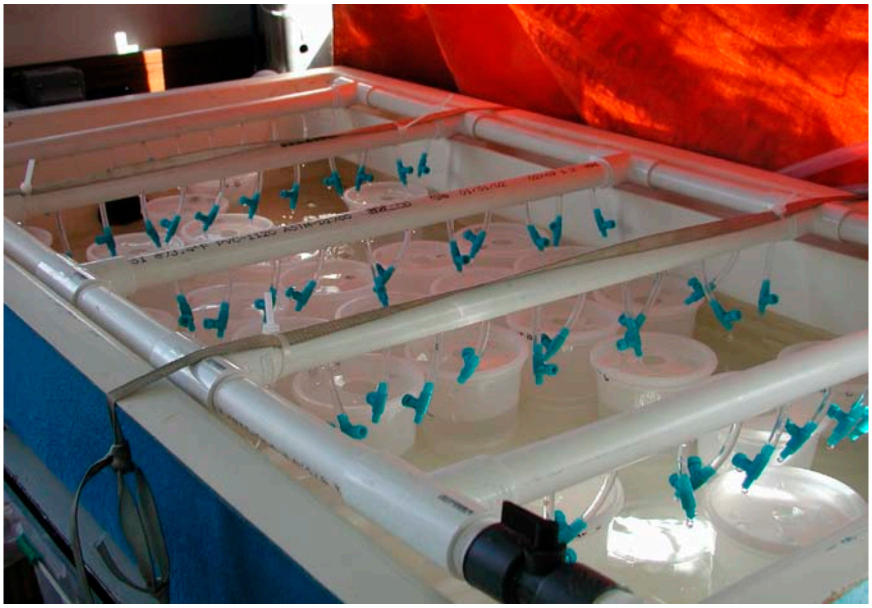


Figure 21. Flow-through bioassay setup aboard RV ECOS. Water was continuously dripped into each of the treatment beakers containing topsmelt, mysids, or mussel embryo larvae.

6.4 TOXICITY TESTING

6.4.1 Topsmelt (*Atherinops affinis*) and Mysid (*Americamysis bahia*) Survival

Test organisms. Both species were purchased from Aquatic Biosystems of Fort Collins, Colorado, and shipped overnight to SSC San Diego or Nautilus Environmental. Topsmelt were 7 to 9 days old, and mysids were 1 to 2 days old on the shipping date. Upon arrival, water quality (temperature, salinity, dissolved oxygen, pH) was measured. Organisms were then provided aeration, fed with freshly hatched brine shrimp nauplii (*Artemia*), and assessed for overall health. Partial water changes took place over the next 1 to 2 days to slowly acclimate the organisms to testing conditions. Dilution water used for water changes consisted of 0.45-µm filtered, natural seawater collected from Scripps Institution of Oceanography's pier. Salinity was adjusted by no more than 2 psu per 24-hour period. Mysids and topsmelt were held at 20 ±1°C during holding and all phases of testing.

Test Design. Because storm water effluent samples were generally freshwater, the salinity was increased to approximately 32 psu, which generally coincided with ambient bay water salinity and the requirements of the marine test species. For the topsmelt and mysid tests, the salinity was adjusted with addition of synthetic sea salts (Crystal Sea Marine Mix, a.k.a. Forty Fathoms, Bioassay Grade). Effluent samples were subsequently serially diluted with water collected before the storm (PRE water) and adjacent to the appropriate storm water outfall to produce three to five concentrations of effluent for dose-response determinations. Receiving water samples were tested without dilution and did not require any salinity adjustment.

Topsmelt tests were conducted in 400-mL glass beakers containing 200 mL of test material. Five topsmelt were distributed to each of four replicates for each treatment. Mysid tests were conducted in 300-mL glass beakers containing 200 mL of test material. Ten mysids were distributed to each of three replicates for each treatment. Test solutions were brought up to the testing temperature before introduction of test organisms. Test organisms were randomly selected from holding tanks and carefully added to test chambers using a 5-mL plastic pipette with the bottom 0.5 cm cut off to prevent injury to organisms. Test solutions were then mixed and gently added to the test chambers. Upon test initiation, test chambers were covered with a clear acrylic plate to prevent evaporation. All tests were 96-hour, static-renewal exposures, with a single renewal at 48 hours.

Controls. Pre-storm receiving water was used as the primary control water and as diluent for all the dilution series tests. In addition, filtered Scripps seawater and artificial salt mixtures were used as negative controls, and conducted alongside the pre-storm and storm water samples. Artificial salt controls consisted of deionized water and an appropriate amount of Crystal Sea Marine Mix to achieve a salinity of ~32 psu. The reference toxicant, copper sulfate, was used as a positive control. Reference toxicant tests were used to assess laboratory performance and batch sensitivity, and were performed alongside most storm water exposures. Up to six copper treatments (concentration range: 25 to 400 µg/L) were prepared from Scripps seawater and a measured copper sulfate stock solution.

Observations and Maintenance. Observations and removal of mortalities were made daily. Water quality parameters (salinity, DO, temperature, and pH) were recorded in one replicate per treatment daily. Dissolved oxygen in some mysid beakers occasionally dropped below 4 mg/L. In such instances, all beakers for that test were aerated. Test organisms were fed with freshly hatched *Artemia* nauplii twice daily, resulting in approximately 100 and 80 *Artemia* per organism per day or mysids and topsmelt, respectively.

6.4.2 Mussel (*Mytilus galloprovincialis*) Embryo-Larval Development

Test Organisms. Adult mussels were purchased from Carlsbad Aquafarm in Carlsbad, California. Animals were shipped overnight on ice or picked up by SSC San Diego staff and transported by car in an ice chest. Mussels were spawned on the day of arrival at the laboratory.

Test Design. For the mussel exposures, hypersaline brine (HSB), prepared by concentrating filtered, natural seawater collected from Scripps Pier was used to increase storm water sample salinity to ~32 psu. This dilution of the storm water effluent samples resulted in a maximum test concentration below 100%, generally around 60%. The brined solutions were then serially diluted with baseline water collected before a storm event (PRE) near the appropriate outfall to create a total of six test concentrations, including the control (e.g., 0, 6.25, 12.5, 25, 50, 60%). Depending on the test date, four or five replicates of each concentration were tested. Test chambers were seawater-leached 20-mL glass scintillation vials, which were filled with 10 mL of test solution. Tests were initiated by addition of approximately 20 embryos/mL test solution within 4 hours of fertilization.

Test Procedure. Approximately 30 to 50 mussels were induced to spawn by heat shock, which involved heating seawater 5 to 10ºC above ambient temperature. As mussels began to spawn, they were segregated into 200-mL beakers containing 15ºC, filtered seawater. After approximately 30 minutes of spawning, gametes were rinsed with seawater using a series of mesh screens. Upon verification of quality eggs (assessed by color, shape, and absence of germinal vesicles or signs of deterioration) and sperm (assessed by high degree of motility) under the microscope, three of the best quality egg stocks were individually fertilized with a sperm mixture collected from several males. After ~10 minutes, the mixtures were each poured through a 20-µm screen to remove sperm and rinsed with filtered seawater. Clean, fertilized eggs were allowed to develop in an environmental chamber for approximately 2 hours. The embryo suspension that appeared to have the highest proportion of dividing eggs was selected for density determination under a microscope. The appropriate volume needed to achieve a density of 15 to 20 embryos/mL was added via pipette to test chambers. Test vials were held in a temperature-controlled light chamber with a 16-hour light: 8-hour dark photo period. Water quality (dissolved oxygen, pH, temperature, salinity) was measured daily.

Controls. Filtered Scripps seawater and brine were used as negative controls and conducted alongside storm water samples. Brine controls consisted of deionized water and an appropriate amount of HSB to achieve a salinity of ~32 psu, and were used to assess any effects associated with the brine solution. The reference toxicant, copper sulfate, was used as a positive control. Reference toxicant tests were used to assess laboratory performance and batch sensitivity, and were performed alongside most storm water exposures. Up to six copper treatments (concentration range: 2.9 to 17.2 µg/L) were prepared from Scripps seawater and a measured copper sulfate stock solution.

Test Termination. Following 48 hours of exposure, tests were terminated by adding of 1 mL of concentrated formaldehyde to each vial. An inverted microscope was then used to quantify the proportion of normally developed, D-shaped (prodissoconch) larvae in the test vials. This task was achieved by evaluating a minimum of 100 larvae. The endpoint used for this test was the proportion of normal larvae to abnormal larvae (% normal development).

6.4.3 Statistical Evaluations

When evaluating the quality of toxicity results, bay water data were compared to the Scripps water control, while effluent data were compared to the relevant un-manipulated pre-storm bay water sample. Because bay water samples were not typically collected for the TIE studies, salt or brine controls were used in making statistical comparisons for those tests. Statistical analyses for storm water effluent, receiving water, and reference toxicant tests were performed using Toxcalc® Scientific Software, Version 5.0. The data were arcsin square root transformed before analysis. Shapiro–Wilk's Test was used to test for normality, while Bartlett's Test was used to confirm equality of variance. Depending on whether or not analysis of variance assumptions were met, Dunnet's Multiple Comparison Test, Steel's Many One Rank Test, or Bonferroni's t-Test was used to determine differences between the control and each test concentration, as described in step-wise procedures (e.g., flow charts) outlined in EPA (2002). These hypothesis tests provided the no observed effect concentration (NOEC) and the lowest observed effect concentration (LOEC). Where dose responses were observed, median effect concentrations such as the concentration causing 50% mortality (LC50) or a 50% effect (EC50) were calculated using the Maximum Likelihood-Probit or Trimmed Spearman–Karber point estimate methods, in that order of preference. Two sample t-tests ($\alpha = 0.05$) were also used to determine statistical differences between control means and individual treatments and receiving water samples, in accordance with EPA (2002). The PMSD (percent minimum significant difference), an indicator of within-test variability and test method sensitivity, and CVs (coefficient of variation) were also calculated using the Toxcalc® software.

6.4.4 Toxicity Data QA/QC

Toxicity testing was performed by SSC San Diego's in-house toxicity laboratory and by Nautilus Environmental. Both laboratories are certified by the State of California, and have internal quality assurance (QA) plans. Topsmelt (*Atherinops affinis*) and mysid (*Americamysis bahia*) tests followed guidance provided by the U.S. EPA's fifth edition of "Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms" (EPA, 2002). These test organisms were identified for use by inference in the NPDES permit. Mussel (*Mytilus galloprovincialis*) tests were guided by American Society for Testing and Materials (ASTM) protocols for conducting acute toxicity tests with marine bivalves (ASTM, 1999). Although the mussel test is not a requirement in the Navy's storm water permit, it was included as an indigenous species to San Diego Bay that would provide a sensitive endpoint for evaluating bay waters. Quality Assurance/Quality Control parameters for the toxicity tests were based on the contents of these documents. Results were assessed for sample holding time and holding temperature, testing methods, water quality conditions, negative control response, and positive control response (Table 4). Laboratory controls were performed concurrently with each assay, and nearly all assays were conducted with a concurrent reference toxicant test (minimum monthly requirement) as a means of confirming test organism quality and proper laboratory technique.

Test acceptability criteria (TAC) were ≥90% survival in controls for the topsmelt and mysid tests, and ≥70% normal development of resulting mussel larvae (Table 5). Any failure to meet the TAC resulted in invalidation of all sample data associated with that test. Data quality objectives (DQOs) were also evaluated on a case-by-case basis to determine if any excursions from the targeted range might be cause to invalidate the data. Excursions from the DQOs were flagged, and then assessed using a combination of decision criteria. For example, if the dissolved oxygen concentration briefly dipped below 4 mg/L at 48 hours, but mortality had occurred before the incident, the excursion was considered inconsequential.

There were a few deviations from the guidance documents, which were mostly a result of the attempt to match the laboratory study with conditions relevant to San Diego Bay. Test salinity was targeted at salinities typical of the bay (~32 psu). In addition, the testing temperature for mussels in one survey (SDB45) was adjusted to a higher, but also acceptable, temperature (18°C) to complement concurrent field exposures (e.g., floating laboratory bioassay). Due to supply issues with topsmelt, the first TIE study used inland silversides (*Menidia beryllina*), which were tested at 25°C, acceptable according to the guidance (EPA, 2002). A difference between the maximum and minimum temperature of more than 3°C within a test was weighed more heavily than temperature excursions slightly outside (e.g., <1°C) the targeted temperature range, which is also in accordance with the guidance (EPA, 2002).

Table 4. Toxicity testing QA/QC objectives.

Parameter	Topsmelt Survival	Mysid Survival	Mussel Larval Development
Sample holding time	< 36 hours	< 36 hours	< 36 hours
Sample holding temperature	4 ± 2 °C	4 ± 2 °C	4 ± 2 °C
Organism acclimation period	> 24 hours	> 24 hours	NA
Organism age at test initiation	9-15 days	2-5 days	1-4 hours
Negative control response	≥ 90% survival	≥ 90% survival	≥ 70% normal development
Copper reference toxicant test	LC50 within 2 SD of control chart mean	LC50 within 2 SD of control chart mean	EC50 within 2 SD of control chart mean
Water quality parameters:			
Temperature	20 ± 1°C; max/min deviation no > 3 °C	20 ± 1°C; max/min deviation no > 3 °C	15 ± 2°C
Salinity	32 psu ± 10%	32 psu ± 10%	32 psu ± 10%
Dissolved oxygen	>4.0 mg/L	>4.0 mg/L	>4.0 mg/L
pH	6.0-9.0	6.0-9.0	6.0-9.0

6.5 TOXICITY IDENTIFICATION EVALUATION (TIE)

Toxicity Identification Evaluations (TIE) were performed by Nautilus Environmental, LLC. One set of samples was collected by SSC San Diego from Naval Station San Diego outfalls 9, 11, and 14; naval Submarine Base San Diego outfalls 11B, 23CE, and 26; Naval Amphibious Base Coronado outfalls 9 and 18; and Naval Air Station North Island outfalls 23A and 26. These outfalls sampled corresponded to those outfalls focused on in the study. The selection of storm events sampled for TIEs was based only on logistical constraints.

The TIE consisted of baseline toxicity tests with topsmelt or inland silversides *(Menidia beryllina*), mysids, and mussel embryos. The baseline toxicity tests performed on samples collected at Naval Station San Diego and Naval Submarine Base San Diego were performed using inland silversides because topsmelt were unavailable from the supplier. The TIE evaluation using silversides in this step is not expected to be any different than having used topsmelt. Phase I manipulations included ethylenediaminetetraaceticacid (EDTA) additions to test for toxicity attributable to cationic metals and a solid phase extraction with a C18 column to test for toxicity attributable to non-polar organics. An aeration step was added for TIEs performed at samples collected from the Naval Amphibious Base Coronado and the Naval Air Station North Island to assess toxicity from volatile compounds. Phase II manipulations, dependent on the outcome of Phase I results included copper and zinc mixture studies to address samples exhibiting metals toxicity. They also included methanol extraction of the C18 column for samples exhibiting toxicity to non-polar organics. For the later TIE samples collected at Naval Amphibious Base Coronado and Naval Air Station North Island, an aeration foam add-back was also performed during this phase. Phase III TIE manipulations included copper and zinc toxicity studies, studies with mixtures of copper and zinc; comparison of sample metal concentrations with available literature values, statistical comparisons of predicted and actual TUs present in the samples, and comparisons of species sensitivity.

6.6 CHEMISTRY

Before the start of the study at Naval Station San Diego, a review of historical data were used to derive the contaminants of concern. Three sources of data were used to identify potential CoCs. These included data from The State of California's Bay Protection Toxic Cleanup Program (Fairey et al., 1996), a sediment quality report for the base (Chadwick et al., 1999), and historical storm water monitoring records. The list of CoCs used at the start of this study included copper, zinc, silver, mercury, lead, PAH, and PCB. As the study expanded to other bases, the list of CoCs grew to include chlorinated pesticides, as these were identified as CoCs for sediment TMDLs.

A full suite of total and dissolved metals were analyzed by Battelle Marine Sciences Laboratories (Sequim, WA). While the suite included the five metals identified as CoCs above, contractual requirements eventually resulted in the analysis of a suite of 14 metals described below. Some samples were analyzed for total and dissolved copper and zinc in-house by SSC San Diego. A suite of 48 PAH analytes, 31 PCB congeners, and 29 chlorinated pesticides were analyzed by Battelle Ocean Sciences (Duxbury, MA). DOC analyses were performed by Applied Marine Sciences (League City, TX). TSS analyses were performed in-house by SSC San Diego.

6.6.1 TSS

Total suspended solids analyses were performed at SSC San Diego. The analysis was performed using standard protocols developed at the University of New Hampshire, Jackson Estuarine Laboratory, by R. Langan in 1992. In summary, the samples were filtered using pre-dried/pre-weighed nitrate cellulose filters (GFC) with a 1.2-µm nominal pore retention. The suspended solids filters were dried in an oven (preset at 90 to 120ºC) for 24 hours and weighed again. The TSS concentration was determined by calculating the difference between the filter weights (before/after filtration), divided by the total volume filtered. An attempt to make a simplification in the filtration step during survey SDB2 resulted in data that could not be used. The nominal MDL was 0.1 mg/L.

6.6.2 DOC

DOC analyses were added to the suite of analytes in the study during the third storm event. Dissolved organic carbon analyses were performed by Applied Marine Sciences (League City, TX), using EPA method 415.1. Samples were filtered through a 0.45-μm filter, and acidified to pH 2 with hydrochloric acid before being converted to carbon dioxide by catalytic combustion or wet chemical oxidations. The carbon dioxide formed was measured directly by an infrared detector. The amount of carbon dioxide was proportional to the concentration of carbonaceous material in the sample. The nominal MDL was 0.01 mg/L.

6.6.3 Metals

Most samples were analyzed for 14 total and dissolved metals at Battelle Marine Sciences Laboratories (Sequim, WA), though some were analyzed for only total and dissolved copper and zinc at SSC San Diego. Once samples were returned to the laboratory, they were filtered through 0.45-μm glass fiber filters and acidified to pH ≤2 using ULTREX-grade nitric acid before further analysis. Storm water samples analyzed at Battelle were directly analyzed by inductively coupled plasma-mass spectrometry (ICP-MS) or by cold vapor atomic fluorescence spectrometry (CVAF) or cold vapor atomic absorption spectrometry (CVAA) for Hg according to Battelle SOP MSL-I-013, Total Mercury in Aqueous Samples by CVAF, which is derived from EPA Method 1631.

Seawater samples were preconcentrated using iron and palladium in accordance with the Battelle SOP MSL-I-025, Methods of Sample Preconcentration, which is derived from EPA Method 1640. The sample preconcentration was submitted for analysis by ICP-MS or Inductively Coupled Argon Plasma Optical Emission Spectrometer (ICP-OES) and graphite furnace atomic absorption spectrometry (GFAA). Seawater samples were analyzed by ICP-MS in accordance with Battelle SOP MSL-I-022, Determination of Elements in Aqueous and Digestate Samples by ICP-MS. This method is based on two EPA Methods: 200.8 and 1638. Analytes reported from the preconcentrated seawater samples include cadmium, chromium, copper, nickel, and lead.

Analytes reported from the direct analysis of the seawater samples include aluminum, iron, manganese, tin, and zinc. Silver was analyzed in the iron-palladium preconcentrate by GFAA following Battelle SOP MSL-I-029, Determination of Metals in Aqueous and Digestate Samples by GFAA, which is derived from EPA Method 200.9. Seawater samples were analyzed by hydride generation flow injection atomic spectroscopy (FIAS) for arsenic and selenium according to Battelle SOP MSL-I-030, Determination of Metals in Aqueous and Digestate Samples by HGAA-FIAS.

Total and dissolved copper and zinc samples were also analyzed at SSC San Diego using EPA methods 200.12, 200.9, and 289.2 for trace metals in seawater by GFAA (also see EPA, 1991b). Comparable QA/QC to Battelle's labs was conducted for these analyses. For these analyses, the data validation steps were conducted by the laboratory manager.

6.6.4 PAH

Water samples were extracted for 48 PAH analytes following general National Status and Trends (NS&T) methods (NOAA, 1993). The 16 priority pollutant PAHs measured are identified in Table 6. Approximately 2 liters of water was spiked with surrogates and extracted three times with dichloromethane using separatory funnel techniques. The combined extract was dried over anhydrous sodium sulfate, concentrated, processed through alumina cleanup column, concentrated, and further purified by GPC/HPLC. The post-HPLC extract was concentrated, fortified with Recovery Internal Standard (RIS) compounds, and split quantitatively for the required analyses. Extracts were analyzed using gas chromatography/mass spectrometry (GC/MS), following general NS&T methods. Sample data were quantified by the method of internal standards, using RIS compounds. The nominal MDL was 1 ng/L.

6.6.5 PCB

Water samples were extracted for 31 PCB congeners following general National Status and Trands(NS&T) methods (NOAA, 1993). The sum of these congeners multiplied by a factor of two is comparable to the total PCBs (TPCB) measured as the sum of Arochlors® (SFBRWQCB, 2004; NOAA, 1993) used for water quality standards. Approximately 2 liters of water was spiked with surrogates and extracted three times with dichloromethane using separatory funnel techniques. The combined extract was dried over anhydrous sodium sulfate, concentrated, processed through a alumina cleanup column, concentrated, and further purified by GPC/HPLC. The post-HPLC extract was concentrated, fortified with RIS, and split quantitatively for the required analyses. Extracts were analyzed using gas chromatography/mass spectrometry (GC/MS). The method is based on key components of the PCB congener analysis approach described in EPA Method 1668A. Sample data were quantified by the method of internal standards, using RIS compounds. The nominal MDL was 1 ng/L.

6.6.6 Pesticides

Samples were extracted for 29 chlorinated pesticides following general NS&T methods (NOAA, 1993). Approximately 2 liters of water was spiked with surrogates and extracted three times with dichloromethane using separatory funnel techniques. The combined extract was dried over anhydrous sodium sulfate, concentrated, processed through a alumina cleanup column, concentrated, and further purified by GPC/HPLC. The post-HPLC extract was concentrated, fortified with RIS and split quantitatively for the required analyses. Extracts intended for pesticide analysis were solvent exchanged into hexane and analyzed using a gas chromatography/electron capture detector (GC/ECD). Sample data were quantified by the method of internal standards, using the RIS compounds. The nominal MDL was 1 ng/L.

Table 5. List of total and dissolved metals analyzed with associated method detection limit.

Metal	ID	MDL (ug/L)
Aluminum	Al	2.31
Iron	Fe	2.51
Chromium	Cr	0.10
Manganese	Mn	0.03
Nickel	Ni	0.05
Copper	Cu	0.45
Zinc	Zn	0.12
Arsenic	As	0.12
Selenium	Se	1.47
Silver	Ag	0.02
Cadmium	Cd	0.04
Tin	Sn	0.50
Lead	Pb	0.01
Mercury	Hg	0.00015

Table 6. PAH analyte list with identifiers. Grayed-out analytes are included in the priority pollutant PAH list. The nominal MDL was 1 ng/L.

Analyte	ID	Analyte	ID
Naphthalene	C0N	Dibenzothiophene	C0D
C1-Naphthalenes	C1N	C1-Dibenzothiophenes	C1D
C2-Naphthalenes	C2N	C2-Dibenzothiophenes	C2D
C3-Naphthalenes	C3N	C3-Dibenzothiophenes	C3D
C4-Naphthalenes	C4N	C4-Dibenzothiophenes	C4D
2-Methylnaphthalene	2MN	Fluoranthene	FLANT
1-Methynaphthalene	1MN	Pyrene	PYR
Biphenyl	BIP	C1-Fluoranthenes/Pyrenes	C1F/P
2,6-dimethylnaphthalene	26N	C2-Fluoranthenes/Pyrenes	C2F/P
Acenaphthylene	ACEY	C3-Fluoranthenes/Pyrenes	C3F/P
Acenaphthene	ACE	Benzo(a)anthracene	BAA
2,3,5-trimethylnaphthalene	235N	Chrysene	C0C
Dibenzofuran	DBF	C1-Chrysenes	C1C
Fluorene	C0F	C2-Chrysenes	C2C
C1-Fluorenes	C1F	C3-Chrysenes	C3C
C2-Fluorenes	C2F	C4-Chrysenes	C4C
C3-Fluorenes	C3F	Benzo(b)fluoranthene	BBF
Anthracene	C0A	Benzo(j/k)fluoranthene	BKF
Phenanthrene	C0P	Benzo(e)pyrene	BEP
C1-Phenanthrenes/Anthracenes	C1P/A	Benzo(a)pyrene	BAP
C2-Phenanthrenes/Anthracenes	C2P/A	Perylene	PER
C3-Phenanthrenes/Anthracenes	C3P/A	Indeno(1,2,3-cd)pyrene	INDENO
C4-Phenanthrenes/Anthracenes	C4P/A	Dibenz(a,h)anthracene	DAA
1-Methylphenanthrene	1MP	Benzo(g,h,i)perylene	BGP

Table 7. List of PCB congeners and IDs. Nominal MDL was 1 ng/L.

PCB Congener	ID
PCB8 - 2,4'-Dichlorobiphenyl	Cl2(8)
PCB18 - 2,2',5-Trichlorobiphenyl	Cl3(18)
PCB28 - 2,4,4'-Trichlorobiphenyl	Cl3(28)
PCB44 - 2,2',3,5'-Tetrachlorobiphenyl	Cl4(44)
PCB49 - 2,2',4,5'-Tetrachlorobiphenyl	Cl4(49)
PCB52 - 2,2',5,5'-Tetrachlorobiphenyl	Cl4(52)
PCB66 - 2,3',4,4'-Tetrachlorobiphenyl	Cl4(66)
PCB77 - 3,3',4,4'-Tetrachlorobiphenyl	Cl4(77)
PCB87 - 2,2',3,4,5'-Pentachlorobiphenyl	Cl5(87)
PCB101 - 2,2',4,5,5'-Pentachlorobiphenyl	Cl5(101)
PCB105 - 2,3,3',4,4'-Pentachlorobiphenyl	Cl5(105)
PCB114 - 2,3,4,4',5-Pentachlorobiphenyl	Cl5(114)
PCB118 - 2,3',4,4',5-Pentachlorobiphenyl	Cl5(118)
PCB123 - 2',3,4,4',5-Pentachlorobiphenyl	Cl5(123)
PCB126 - 3,3',4,4',5-Pentachlorobiphenyl	Cl5(126)
PCB128 - 2,2',3,3',4,4'-Hexachlorobiphenyl	Cl6(128)
PCB138 - 2,2',3,4,4',5'-Hexachlorobiphenyl	Cl6(138)
PCB153 - 2,2',4,4',5,5'-Hexachlorobiphenyl	Cl6(153)
PCB156 - 2,3,3',4,4',5-Hexachlorobiphenyl	Cl6(156)
PCB157 - 2,3,3',4,4',5'-Hexachlorobiphenyl	Cl6(157)
PCB167 - 2,3',4,4',5,5'-Hexachlorobiphenyl	Cl6(167)
PCB169 - 3,3',4,4',5,5'-Hexachlorobiphenyl	Cl6(169)
PCB170 - 2,2',3,3',4,4',5-Heptachlorobiphenyl	Cl7(170)
PCB180 - 2,2',3,4,4',5,5'-Heptachlorobiphenyl	Cl7(180)
PCB183 - 2,2',3,4,4',5',6-Heptachlorobiphenyl	Cl7(183)
PCB184 - 2,2',3,4,4',6,6'-Heptachlorobiphenyl	Cl7(184)
PCB187 - 2,2',3,4',5,5',6-Heptachlorobiphenyl	Cl7(187)
PCB189 - 2,3,3’,4,4’,5,5’-Heptachlorobiphenyl	Cl7(189)
PCB195 - 2,2',3,3',4,4',5,6-Octachlorobiphenyl	Cl8(195)
PCB206 - 2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl	Cl9(206)
PCB209 - 2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl	Cl10(209)

Table 8. List of chlorinated pesticides. Nominal MDL was 1 ng/L.

Analyte	Analyte
2,4'-DDD	chlorpyrifos
2,4'-DDE	oxychlordane
2,4'-DDT	dieldrin
4,4'-DDD	endosulfan I
4,4'-DDE	endosulfan II
4,4'-DDT	endosulfan sulfate
aldrin	endrin
a-chlordane	endrin aldehyde
g-chlordane	endrin ketone
cis-nonachlor	heptachlor
trans-nonachlor	heptachlor epoxide
a-BHC	Hexachlorobenzene
b-BHC	methoxychlor
d-BHC	Mirex
Lindane	

6.6.7 Chemistry Data QA/QC

Chemical analyses were performed in-house and by Battelle's Ocean Sciences and Marine Sciences laboratories, in Duxbury, Massachusetts, and Sequim, Washington, respectively. All analyses were performed using standard NS&T low-detection methods with appropriate QA/QC controls including method blanks, blank-spikes, matrix spikes, duplicates, and standard reference. A key component of the chemistry analyses was to use low-detection methods to minimize the possibility of not detecting an analyte. Battelle Laboratories have consistently provided very low detection methods for chemical analyses made in freshwater and seawater matrices. The nominal method detection limit (MDL) for individual organic compounds was 1 ng/L, though it was determined early, that even with this very low MDL, PCB and chlorinated pesticides would not be detected in receiving water samples. Because of this situation, PCB and pesticides were measured in only a few bay water samples, while metals and PAH were measured in storm water and bay water samples. For the most part, the PCB and pesticides were only measured in composite storm water samples. Table 5 though Table 8 show the full list of chemical analytes. Table 9 shows the QA/QC objectives for the chemical analyses.

Battelle validates their data in three steps. First, by the analyst who generated the data, then by a Reporting group that finalizes the data tables, and then by a QC Chemist group that validates and reviews the full final data package. Their "checklist" is as follows:

- Review work plan:
- Review QC checklist:
- Review title page and original custody records:
- Ensure samples bracketed by calibration standards:
- Review all pertinent miscellaneous documentation:
- Validate QIS standard amounts:
- Check preparation records:

- Review IC check exceedances:
- Review instrument chemist documentation:
- Validate data tables:
- Ensure proper method was used to quantify:
- Review integrations:
- Review calibration exceedances:
- Review chemical reasonableness:
- Review calibration standard amounts:
- Control charts review:

The QC Chemist's group provided the most rigorous and thorough review of the data, including auditing 100% of sample preparation and analytical data packages against SOPs and project plans, validating and verifying analysis test codes, preparing and distributing audit reports, approving data packages on behalf of the Laboratory Manager, and maintaining control charts of key laboratory performance data. Additionally, 10% of the final data packages were audited by an independent QA unit. A project manager also performed a final review of the data before and after the final review and audit. Narrative QA/QC reports with each dataset are included in Appendix D.

Table 9. Sample quality assurance and quality control parameters for chemical sampling and analyses.

Parameter	Metals	TSS	DOC	Organics
Sample Processing Holding Time	2 days	7 days	7 days	7 days
Sample Analysis Holding Time	90 days	90 days	28 days	40 days
Sample Holding Temperature	4°C	4°C	4°C	4°C
Reference Method	CVAF; FIAS; GFAA; ICP/MS or ICP-OES*	UNH-JEL	EPA 415.1	General NS&T
Field Blank	>10 x MDL or <5 x blank	NA	NA	NA
Method Blank	<3 x MDL	NA	<20%	<5 x MDL
Surrogate Recovery	50-150%	NA	<25%	40-120%
Lab Control Standard (LCS) /Matrix Spike (MS)Recovery	50-150%	NA	<20%	40-120%
Standard Reference Material	≤20%	NA	≤20%	≤30%
Sample Replicate/Relative Precision (relative difference)	≤30%	<20%	<20%	≤30%
Method Detection Limits	0.01;0.05;0.2;0.5;1;10;50 μg/L+	0.1 mg/L	0.01 mg/L	0.09-1.93

Notes:
Sample Replicate/Relative Precision from matrix spike and matrix spike duplicate
Standard reference material for analytes >5x MDL
LCS/MS for target spike >5x native concentrations
* Method-Hg; As,Se; Ag; Ni,Cu,Cd,Pb,Mn,Zn,Sn,Cr,Fe,Al
+ MDL-Hg; Ni,Cu,Cd,Pb; Se; Mn,Zn,As, Ag,Sn; Cr; Fe; Al

6.7 DATA EVALUATION

Toxicity, chemistry, and plume mapping results were described for each base, with the combined results evaluated later in the discussion section. Though the evaluation included some comparisons amongst the bases, the study was not designed to, and did not, collect sufficient data to statistically compare outfalls or evaluate variability as a result of antecedent dry weather, rainfall total, or intensity. Most data were presented in summary tables and graphics. Individual data values and associated QA/QC were provided in the appendices.

6.7.1 Toxicity Data Benchmarks

Toxicity data were characterized for each base using basic statistical evaluations including minimum, mean, maximum, and relative standard deviation (standard deviation/mean expressed as percent; RSD). Both the topsmelt and mysid tests in first-flush storm water samples are used to meet the NPDES permit requirements. Therefore, these test results were evaluated using the 90% survival 50% of the time, as well as the 70% survival 10% of the time, criteria. Though not required in the permit, composite storm water samples were also evaluated for toxicity relative to these benchmarks to compare how samples representative of the whole discharge relate to first flush. Mussel test results, which are also not required in the permit, were appropriately evaluated by statistically comparing treatment results to the relevant controls.

Storm water toxicity data were also characterized using no observed effect concentration (NOEC) data derived from the dilution series tests. The NOEC represents the highest effect concentration in the dilution series that is not significantly different from the control response. The NOEC is determined very similarly to t-tests, except that multiple treatments (dilutions) are involved, as opposed to comparisons between only two samples (control and one treatment). The NOEC is thus an indicator of the receiving water concentration, once mixed with storm water, which does not result in a toxic effect. The dilution series tests were run with pre-storm bay water as the diluent to ensure that the results would account for any added background toxicity as well as any assimilative capacity of receiving waters to mitigate toxicity.

Individual toxicity test result quality was evaluated using the minimum significant difference (MSD), which is defined as “the smallest difference between the control and another test treatment that can be determined as statistically significant in a given test, and the PMSD, which is the MSD represented as a percentage of the control response” (EPA, 2000). As such, the PMSD provides a measure of test method variability and toxicity test quality.

Receiving water toxicity tests for all species were evaluated by statistically comparing results to the relevant control (Scripps natural seawater). Both absolute values for survival and normal development data were described as well as values relative to control.

The evaluation of toxicity in the discussion section considered combined results of the topsmelt and mysids tests (they are interchangeable from a permit perspective), comparison of results amongst bases, as well as an overall quantification of results combined from all tests from all bases. This assessment included a quantification of test result outcomes that are declared as “toxic” based on (1) meeting the permit requirement of either 90% or 70% survival, (2) a t-test that identifies a test result as statistically significant different from its associated control treatment, and (3) exceeding the 90^{th} percentile PMSD. This discussion is critical to understanding the impact of using the current permit requirement for declaring a toxic result compared to established, reproducible quantification of WET test results.

6.7.2 TIE Evaluation

TIE evaluations were developed by the contract toxicity laboratory, Nautilus Environmental, LLC. The evaluations described in the report are based on summaries of the full reports shown in appendices E and F.

6.7.3 Chemistry Data Benchmarks

Chemical concentration data were characterized for each base using basic statistical descriptions including minimum, mean, maximum, and relative standard deviation. In addition to quantifying the range in chemical concentrations, the chemistry data were compared to water quality benchmarks throughout the results and discussion sections. The permit has performance goals for first-flush sample concentrations for total copper and zinc. Therefore, their concentrations measured in first-flush samples were compared to their performance goals of 63.6 and 117 μg/L, respectively. Other CoCs were compared to aquatic life water quality standards (WQS), where available, to assess their magnitude relative to levels, below which, are considered protective of acute or chronic toxicity (EPA, 1991a). Chemicals measured in storm water were compared to EPA's aquatic life chronic maximum concentrations, which are the acute Water Quality Standards for the State of California (EPA, 2000a). The acute criterion is the appropriate benchmark for these short-lived discharges. Chemicals measured in receiving waters were compared to EPA's chronic continuous concentrations, which are the chronic Water Quality Standards for the State of California (EPA, 2000b). The chronic criterion is the appropriate benchmark for these samples that may represent longer-term conditions (before storm samples) as well as those occurring during short-term storm water exposures.

The dissolved phase of the metal was used when comparing metals concentrations to WQS standards. The comparison for dissolved mercury data was to the human health WQS of 0.05 μg/L because the acute WQS for mercury is currently "reserved" (EPA, 2000b). PAH, PCB, and most chlorinated pesticides measured in this study do not have published aquatic life acute or chronic WQS. Where available, PAH and PCB data were compared to minimum toxicity thresholds published in the literature. Seventy publications were reviewed for toxicity threshold data, with 28 containing unique citations specific to 13 PAH analytes, PCBs and pesticides (these references are specially cited in the Bibliography). Of these, the extensive review paper of Scannell, Duffy Perkins, and O'Hara (2005) was used to identify most of the minimum acute and chronic thresholds for individual PAH analytes to fish and invertebrates. Three additional papers (Kuhn and Lussier, 1987; Schimmel, Thursby, Heber, and Chammas, 1989; and Thursby, Berry, and Champlin, 1989) were used to identify a minimum acute or chronic threshold for another three PAH analytes. These PAH thresholds also include levels associated with toxic effects after ultraviolet light activation. Acute and chronic PCB thresholds were derived from EPA (1987) and EPA (2000b). These thresholds are for PCBs defined as the sum of Arochlors®. The sum of identified toxic thresholds for total PCBs was measured as the sum of Arochlors®. This measure of total PCB is approximately comparable to the sum of congeners*2 (NOAA Environmental Monitoring and Assessment Program [EMAP]; NOAA, 1989). Table 10 and Table 11 provide the chemical benchmark levels used for chemical concentration data comparisons made throughout the report.

6.7.4 Plume Mapping Evaluation

Plume mapping results were evaluated by visual inspection of spatial maps of salinity, turbidity, and ultraviolet-fluorescence generated before, during, and after storm event conditions. Quantitation of the maximum percentage of storm water present during or after a storm event was calculated by comparing the minimum salinity observed during a storm survey relative to the average salinity measured during the pre-storm survey:

Max Storm Water (%) = ((Ave Salinity Before – Minimum Salinity During)/Ave Salinity Before)*100

Table 10. Aquatic life water quality standards (EPA, 2000a) used as chemical benchmarks for metals and pesticide data comparisons. Storm water concentrations were compared to acute WQS, while receiving water data were compared to chronic WQS. Dissolved metal concentrations were compared to benchmarks. Total copper and total zinc in storm water samples were also compared to their permit performance goals of 63.7 and 117 μg/L, respectively.

Analyte	Acute WQS[1] (μg/L)	Chronic WQS[1] (μg/L)	NPDES Permit[2] (μg/L)
Arsenic	69	36	
Cadmium	42	9.3	
Chromium	1100	50	
Copper	4.8	3.1	63.6
Lead	210	8.1	
Mercury	0.05	0.05	
Nickel	74	8.2	
Selenium	290	71	
Silver	1.9		
Zinc	90	81	117
2,4'-DDD			
2,4'-DDE			
2,4'-DDT			
4,4'-DDD			
4,4'-DDE			
4,4'-DDT	130	1	
aldrin	1300		
a-chlordane	90*	4*	
g-chlordane			
a-BHC			
b-BHC			
d-BHC			
Lindane			
cis-nonachlor			
trans-nonachlor			
chlorpyrifos	11	5.6	
oxychlordane			
dieldrin	710	1.9	
endosulfan I	34	8.7	
endosulfan II	34	8.7	
endosulfan sulfate			
endrin	37	2.3	
endrin aldehyde			
endrin ketone			
heptachlor	53	3.6	
heptachlor epoxide	53	3.6	
Hexachlorobenzene			
methoxychlor			
Mirex			

[1] Dissolved metal
[2] Total Metal
* Used for sum of a- and g-chlordane

Table 11. Aquatic life water quality chemical benchmarks used for PAH and PCB. The values are based on minimum concentration thresholds derived from a review of the literature. Storm water concentrations were compared to acute thresholds while receiving waters were compared to chronic thresholds. The literature source citation is shown in the last column.

Analyte	Minimum Acute Literature Threshold (ng/L)	Minimum Chronic Literature Threshold (ng/L)	Minimum Threshold Citation
Naphthalene	510000	-	Scannell et. al., 2005
2-Methylnaphthalene	600000	-	Scannell et. al., 2005
1-Methylnaphthalene	1900000	-	Scannell et. al., 2005
2,6-dimethylnaphthalene	80000	-	Scannell et. al., 2005
2,3,5-trimethylnaphthalene	320000	-	Scannell et. al., 2005
Acenaphthene	460	63990	Schimmel et al., 1989-acute Thursby et al., 1989-chronic
Fluorene	320000	-	Scannel et. al., 2005
Phenanthrene	370000	8129	Scannell et. al., 2005-acute Kuhn and Lussier, 1987-chronic
Anthracene	3600	82000	Scannell et. al., 2005
1-Methylphenanthrene	300000	-	Scannell et. al., 2005
Fluoranthene	1090	810	Scannell et. al., 2005
Pyrene	230	910	Scannell et. al., 2005
Chrysene	1000000	-	Scannell et. al., 2005
Benzo(a)pyrene	1000000	-	Scannell et. al., 2005
Dibenz(a,h)anthracene	1000000	-	Scannell et. al., 2005
TPCB*	10000	30	EPA, 1987-acute EPA, 2000-chronic

* TPCB is the sum of arochlors ≅ 2*sum of congeners

7. RESULTS

7.1 DATA QUALITY

7.1.1 Toxicity Data

Twelve storms were sampled for toxicity evaluation. Only in one instance (mussels during storm event SDB1) did failure of meeting the test acceptability criteria result in invalidating the test. Therefore, no samples from that dataset were used in this study. Samples were processed for testing immediately upon arrival in the laboratory, or the morning after collection, thus the 36-hour holding time was always met. In all cases, all species met the relevant acclimation period. With some minor exceptions, most other data quality objectives were met throughout the study, and a summary for each test species is provided. Except where noted, deviations were deemed inconsequential to the results of the study based on the decision-making criteria outlined previously.

Topsmelt. Laboratory (Scripps natural seawater) and salt controls always exceeded the 90% minimum survival criterion for test acceptability (range = 95 to 100%). All concentrations causing 50% lethality (LC50) for copper reference tests fell within two standard deviations of each laboratory's mean. Nautilus reference toxicant EC50s fell within SSC San Diego's control chart limits for SSC San Diego, suggesting similar performance between the two laboratories. The pH was always within the objectives. Only one dissolved oxygen concentration (0.1% of measurements) momentarily fell below 4 mg/L, which was immediately corrected with gentle aeration. The maximum and minimum temperature never varied by more than 3ºC. Temperature did fall slightly outside the targeted temperature range 23% of the time, but this exceedance was by less than 1ºC for all but one sample. The DQO for salinity was met for all samples, with average minimum and maximum salinities of 31.6 and 34.3 psu, respectively.

Mysids. Laboratory (Scripps natural seawater) and salt controls always exceeded the 90% minimum survival criterion for test acceptability (range = 93 to 100%). All concentrations causing 50% lethality (LC50) for copper reference tests fell within two standard deviations of each laboratory's mean. Nautilus reference toxicant EC50s fell within SSC San Diego's control chart limits for SSC San Diego, suggesting similar performance between the two laboratories. The pH always fell within the DQO. A total of 13 measurements (1.4% of total) indicated a dissolved oxygen concentration of less than 4.0 mg/L. Most D.O. excursions were associated with SDB2 and TIE2 samples early in the exposure, and corrective action (aeration) was taken immediately, resulting in acceptable levels for the remainder of the tests. Temperature never varied by more than 3ºC, as required. Temperature did fall outside the targeted temperature range 13% of the time, but the exceedance was by less than 1ºC for 98% of those samples. Average salinity minimum and maximums were 31.8 and 34.5 psu, respectively, with less than 1% of values falling outside the range designated by the DQOs.

Mussels. Laboratory (Scripps natural seawater) and brine controls always exceeded the 70% minimum percentage normal development criterion for test acceptability (range = 80 to 98%). This does not include data from SDB1, which was not included in the final analysis of this study due to low control performance. All concentrations causing a 50% effect (EC50) for copper reference tests fell within two standard deviations of each laboratory's mean. Nautilus reference toxicant EC50s generally fell within SSC San Diego's control chart limits for SSC San Diego, suggesting similar performance between the two laboratories. The Cu reference test EC50 associated with TIE2, however, was 23% higher than SSC San Diego's control chart range. The pH always fell within the DQO. Three measurements (1.1% of total) indicated that dissolved oxygen concentration was low. However, analysis of the data indicated these values did not impact the results of the tests. Temperature never fell outside the targeted range. Salinity was below the DQO (by less than 1 psu) for 2.8%

of the measurements, which coincided with a lower targeted salinity for these particular tests (SDB5 and SDB6), where 30 psu was sought instead of 32 psu. The lower salinity is considered acceptable for this endpoint (EPA, 1995).

7.1.2 Chemistry Data

For the most part, the chemistry data quality met the data QA/QC objectives set forth at the beginning of this study. All samples were maintained at holding temperatures before analysis and all samples were processed in the required holding times. The TSS data for the SDB2 storm were compromised in processing and could not be used for further evaluation. DOC analyses met all QA/QC requirements. The metals data met all QA/QC objectives for matrix spikes and recoveries, blanks, replicates, method detection limits, and standard reference materials. Nearly all metal concentrations were measured above MDLs. Silver, selenium, and tin were occasionally not detected above their respective MDLs. Non-detect results were reported as the MDL value and were qualified in the appendices.

The PAH data met QA/QC objectives with the following exceptions. Initial analysis of sample NAV-OF14-SD45-FF (Battelle ID S5983) for SDB45 yielded low surrogate recoveries. The archived non-fractionated extract for this sample was reprocessed and reanalyzed outside of the 40-day holding time. These data were qualified with a “T” in the data tables. Analysis of sample OF-NAB9-SDB6-FF (Battelle ID S7118) for storm SDB6 yielded percent recoveries for surrogate compounds naphthalene-d8 and chrysene-d12 outside of the laboratory control limits specified by the method (40 to 120% recovery). The chromatography and calculations were reviewed and no discrepancies were found. The exceedances were qualified with an “N” in the data tables and no further corrective action was taken. For SDB7, percent recovery for surrogate compound naphthalene-d8 in sample OF-NI26-SDB7-FF was outside of the laboratory control limits. Chromatography and calculations were reviewed with no discrepancies found. The sample preparation records indicate an emulsion formed during the extraction of this sample and the extract had difficulty passing through the alumina cleanup column. The exceedance was qualified with an “N” and no further corrective action was taken. Concentrations of analytes making up the list of priority pollutant PAHs were above their respective MDLs in storm water samples 93% of the time while the same analytes in seawater sample were above MDLs 43% of the time. Non-detect results were reported as the MDL value. Summations were computed using one-half MDL values. MDLs ranged up to a maximum of 1.6 ng/L.

PCB data met all QA/QC requirements with the following exceptions. Storm SDB1 PCB extracts were reanalyzed after the 40-day holding time due to cross contamination of the procedural blank caused by the previous run of a standard. The associated QA/QC of the second analysis appeared good and was reported. The PCB analysis on samples collected during storm SDB2 was not dual-column confirmed, thus these data used only a single-column analysis. No corrective action was taken, and these data were flagged with a “NC” qualifier in the data tables. The value for C17(180) was above normal calibration limits and the value was estimated and qualified with an “E”. The matrix spike and matrix spike duplicate run with samples collected during the SD45 storm event yielded analyte recoveries between 121 and 129%, outside the laboratory control limit of 40 to 120%. Chromatography and calculations were reviewed and no discrepancies were found. The exceedances were qualified with an “N” in the data tables. Samples for the SDB45 storm were prepared for analysis as a single analytical batch and were extracted within 7 days of sample collection. However, extracts were not analyzed within the 40-day holding time. These data were qualified with a “T” in the data tables.

Chlorinated pesticides data met all QA/QC requirements. Over 90% of all analytes were below their MDL in storm water and bay water samples. Summations were computed using ½ MDL values. MDLs ranged up to a maximum of 2.2 ng/L.

7.1.3 Plume Mapping Data

The plume mapping objective of spatially mapping salinity variations as a result of freshwater plumes emanating from all four bases was met on all occasions. However, base security limitations (e.g., floating barriers) precluded continuously monitoring plume development that could be used to capture tidal variations. The salinity data collected were adequate to quantify the magnitude of the freshwater input as well. Vertical profile data used to evaluate plume depths were sufficient to look at large-scale conditions, but insufficient to evaluate any fine structure that might develop near the sea surface. All measurement parameters were not available on all surveys, but the key parameter, salinity, was successfully measured on all occasions.

7.2 NAVAL STATION SAN DIEGO

7.2.1 Storm Water Toxicity

Nineteen storm water outfall samples were tested, not necessarily for all species, for toxicity at Naval Station San Diego, including samples collected during the special floating bioassay laboratory study. Figure 22 shows the 100% storm water effluent toxicity data. A statistical summary of the results are provided in Table 12, with all data provided in Appendices B and C. The composite sample collected at outfall 9 during storm SDB1 was only run at the 50% effluent concentration and was therefore not plotted in the figure. Included in topsmelt data are results from three first-flush tests conducted with the inland silverside (*Menidia beryllina*) due to the inability to acquire topsmelt for that sampling event (TIE1). Based on the LC50 for zinc, silversides are expected to be more sensitive to metals than topsmelt (Cardin, 1985). However, the data were combined because both fish species are applicable under the permit.

In general, topsmelt and mysids responded similarly to outfall samples, both averaging 75% survival in the undiluted storm water effluent. First-flush samples, however, were more toxic than composites, averaging about 60% survival compared to 93% in composite samples. Some of this toxicity reduction was probably a result of tide water partially (≤30%) mixing into the outfall composite sample. For topsmelt, 60% of first-flush samples would have failed the 90% survival requirement, compared with a 14% failure rate for composites. Similarly, mysids failed 70% of the time when tested in first-flush samples, and failed only 13% of the time with the composites. Topsmelt and mysids in first-flush samples would have failed the 70% survival requirement 40% and 50% of the time, respectively. All the composite samples would have passed the 70% requirement.

For Naval Station San Diego samples, 67% of NOECs for combined topsmelt and mysid in first-flush and composite samples were 100% storm water effluent. Three of the 36 dilution series results for first-flush samples had a NOEC of 10%, one first-flush sample from Pier 5 had a NOEC less than 10%, and one composite sample had a NOEC of 50%. These data suggest that with the exception of one sample, a receiving water mixture with less than a 10% storm water fraction would result in no observable toxicity.

Mussel larvae were more sensitive than the permitted species in outfall samples, with an overall average of 27% normal development in undiluted storm water effluent (maximum effluent concentrations ranged between 70% and 81% because of brine addition). Because this bioassay is not included in the permit, the 90% requirement does not apply. Relative standard deviations of the toxicity data indicated four to six times more variability in first-flush samples compared to composites. This variability commonly occurs as toxicity increases, but also may be due to the variability associated with collecting grab samples versus composite samples. In addition, mussel data were considerably more variable than topsmelt and mysid data for all sample types. NOECs for mussels ranged from 10 to 65% (the maximum effluent concentration tested), though one sample had a NOEC of <6.25%. These data suggest that with the exception of one sample, a receiving water mixture with less than a 10% storm water fraction would result in no observable toxicity.

This study was not designed to, and did not, collect sufficient data to statistically contrast and compare outfalls. Data were insufficient to evaluate variability as a result of antecedent dry weather, storm rain totals, or storm intensity. However, a qualitative review of the data showed that the highest toxicity was observed for samples collected at outfall 11 and pier 5 during SDB2. The next most toxic samples were from pier 6 during SDB2 and from outfall 14 collected during the first flush of the year sampling (SDB4). However, outfalls 11 and 14 showed considerable variability during multiple samplings indicating that there are factors beyond the general activities occurring within a drainage area that control the outcome.

As described earlier method variability in toxicity testing is an important consideration for evaluating results.

Table 13 shows the PMSD for Naval Station San Diego industrial storm water dilution series toxicity tests, including baseline TIE results. PMSD values ranged from 8 to 32% for topsmelt and averaged 16%. PMSD for mysid tests ranged from 3 to 15 and averaged 8%. The mussel embryo-larval development tests ranged from 3 to 25% and averaged 9%. The mysid results all fell well within EPA guidelines for test acceptability (EPA, 2000). The topsmelt and mussel data also met the PMSD test acceptability criteria for comparable endpoints (inland silverside survival and mussel survival and normal development). These differences are described later in the discussion section.

7.2.2 Receiving Water Toxicity

Twenty-eight receiving water samples were tested, not necessarily for all species, for toxicity at Naval Station San Diego. No toxicity was observed for topsmelt or mysids in bay water samples. Survival was very high (≥ 90%) for topsmelt and mysids exposed to bay waters. All topsmelt and mysid receiving water data were statistically indistinguishable from lab controls ($p<0.05$). Mussel larval development in bay water samples averaged 89% overall, and with one exception, was not statistically different from controls. The exception was for a sample collected outside outfall 14 during a first-flush of the year event (SDB4) after a record 6-month antecedent dry period. Toxicity results in the floating laboratory study showed a similar lack of observable effects to all species as those conducted previously using standard laboratory bioassays.

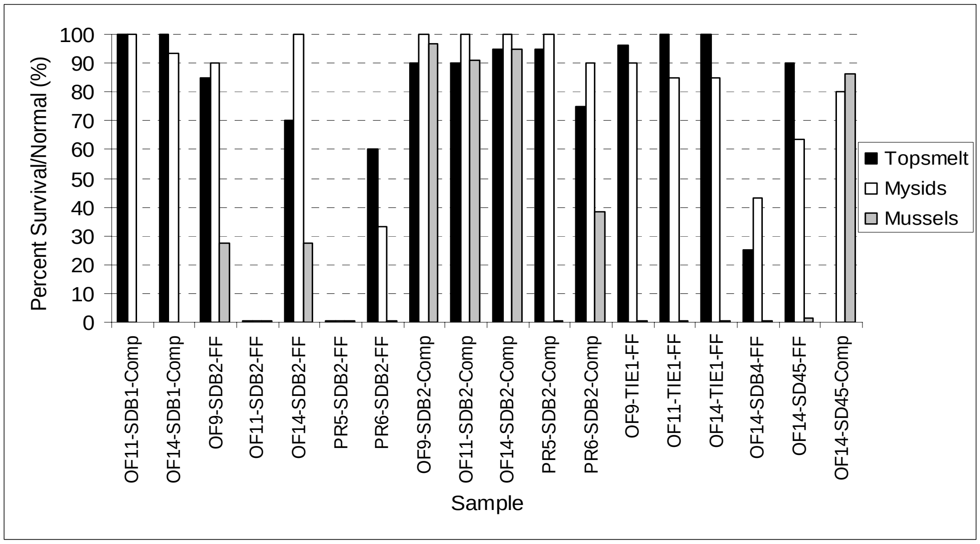


Figure 22. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Station San Diego.

Table 12. Statistical summary of toxicity data in Naval Station San Diego first-flush (FF) or composite (Comp) undiluted storm water or in receiving water (Bay) samples. Results are expressed as percent survival for topsmelt and mysids and as percent normal embryo-larval development for mussels. "# <90% and % Failing" refers to the number and percentage of samples that did not meet the 90% survival criterion in the permit.

NAV	Topsmelt Survival (%)			Mysid Survival (%)			Mussel Normal Development (%)		
	FF	Comp	Bay	FF	Comp	Bay	FF	Comp	Bay
n	10	8*	28	10	9*	28	10	6	16
Min	0	75	90	0	80	97	0	0	8
Mean	63	92	96	59	95	100	5	68	89
Max	100	100	100	100	100	100	28	97	97
RSD	64	9	4	64	8	1	217	58	25
# <90%	6	1	NA	7	1	NA	NA	NA	NA
% FAILING	60%	14%	NA	70%	13%	NA	NA	NA	NA

NA Not applicable
* One sample was run only at maximum 50% effluent

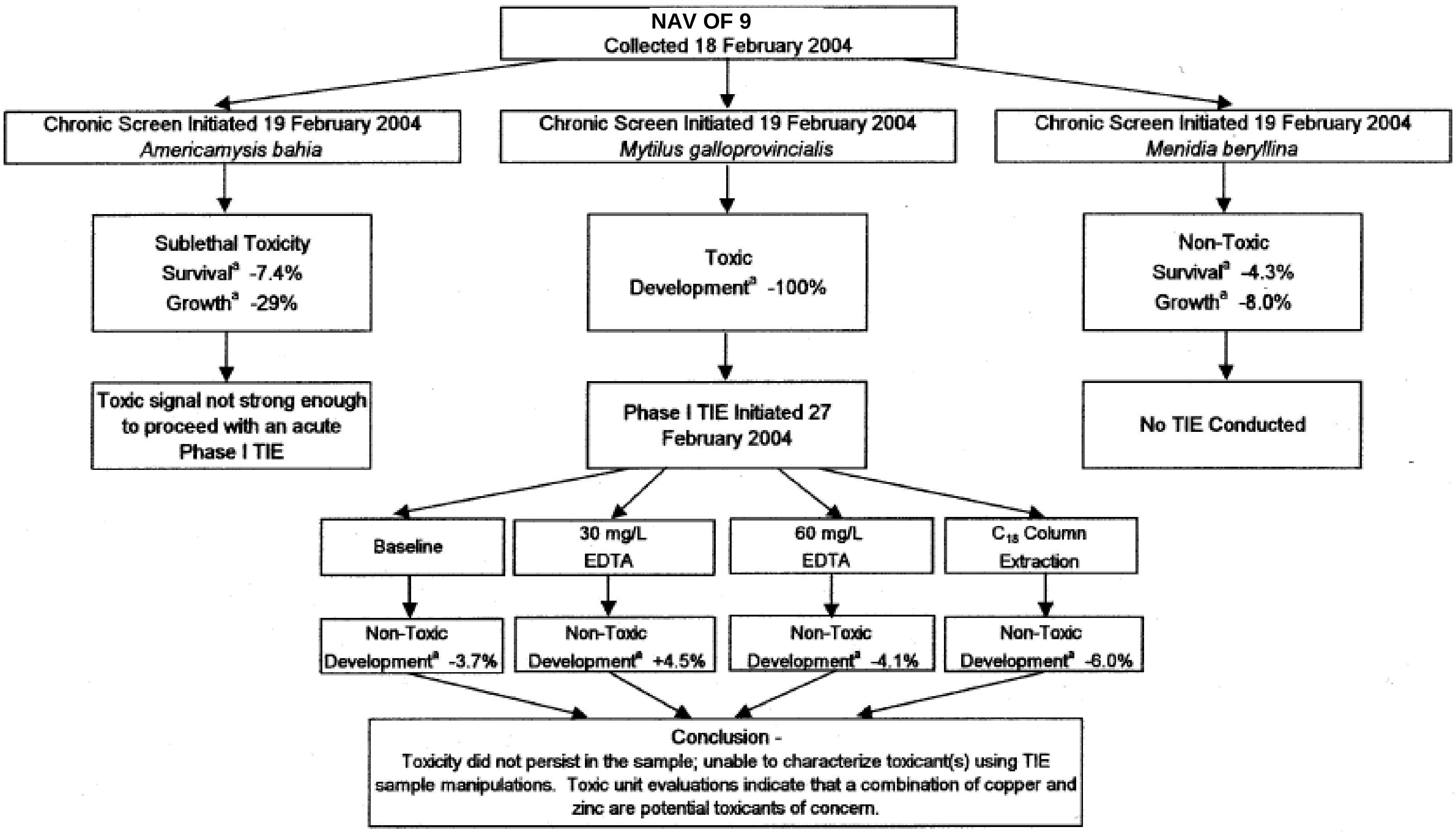
Table 13. Percent Minimum Significant Difference (PMSD) for Naval Station San Diego toxicity tests.

PMSD	Topsmelt	Mysids	Mussels
n	18	16	12
Min (%)	8	3	3
Mean (%)	16	8	9
Max (%)	32	15	25

7.2.3 TIE

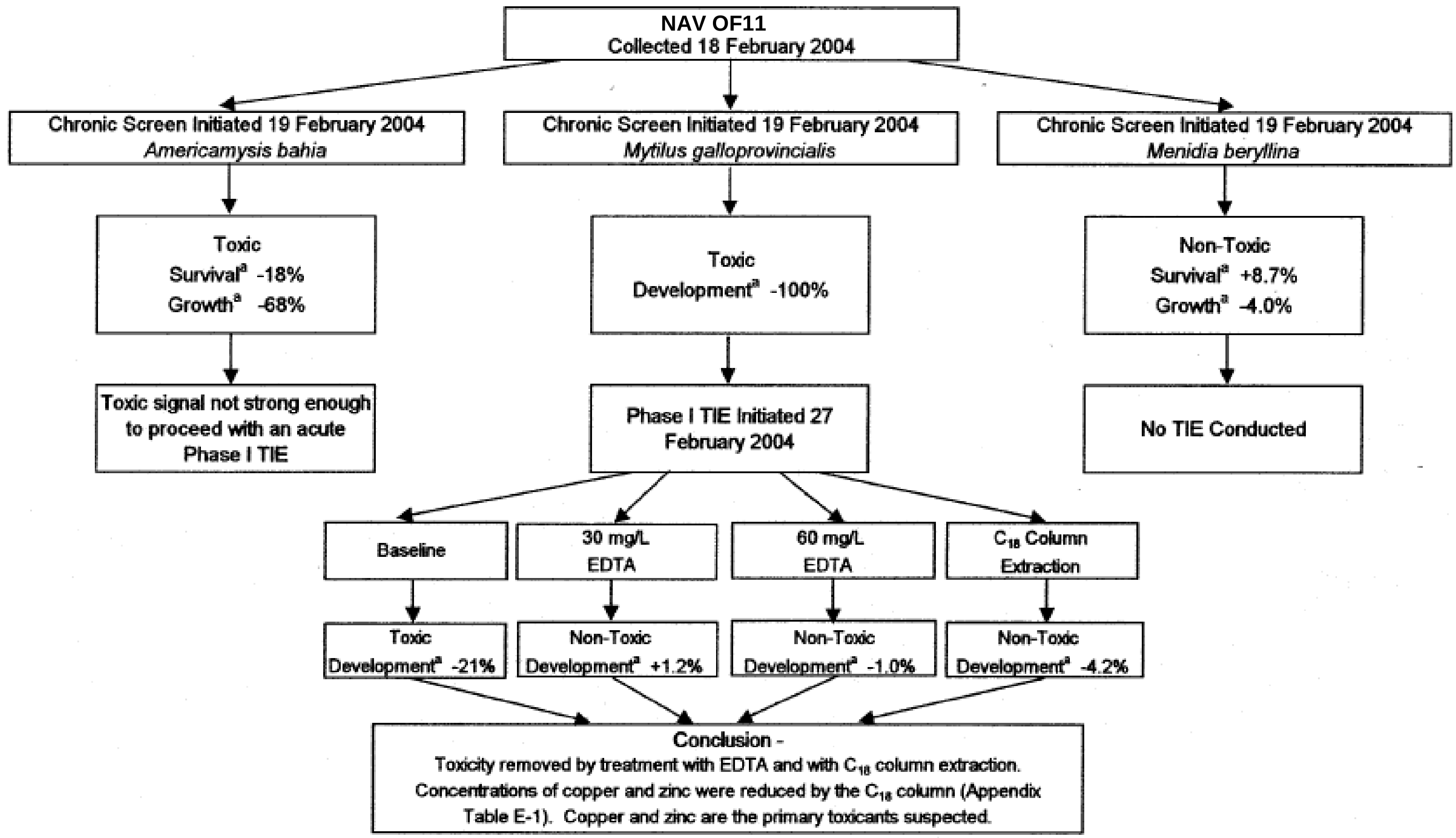
A Toxicity Identification Evaluation was performed on first-flush storm water samples collected from each of the three outfalls at Naval Station San Diego during the storm event on 18 February 2004. First-flush samples were collected at the start of a very low rainfall event in which only 0.19 inches of rainfall fell. The report for this effort is included as Appendix E. Inland silversides *(Menidia beryllina*) were used in lieu of topsmelt in these tests because topsmelt were unavailable from the supplier. It is expected that the results for inland silversides would have been the same for topsmelt. Figure 23 through Figure 25 show the manipulations performed for each outfall sample.

Toxicity screening results showed that there was insufficient toxicity to inland silversides or to mysids to perform a TIE for any of the outfall samples. It is expected that the results would have been similar using topsmelt. TIEs were therefore conducted only using the mussel embryo-larval development tests. The TIE results identified copper and zinc as the primary causes of toxicity in all three outfall samples at Naval Station San Diego. For outfall 9 and outfall 11, copper and zinc were present at concentrations that were sufficient to be the causative agents in those samples. The sample at outfall 14 had insufficient amounts of copper or zinc to individually cause toxicity, but taken together, the two chemicals were in sufficient quantity to cause toxicity. The Phase III TIE established that copper and zinc were additive in their toxicity.



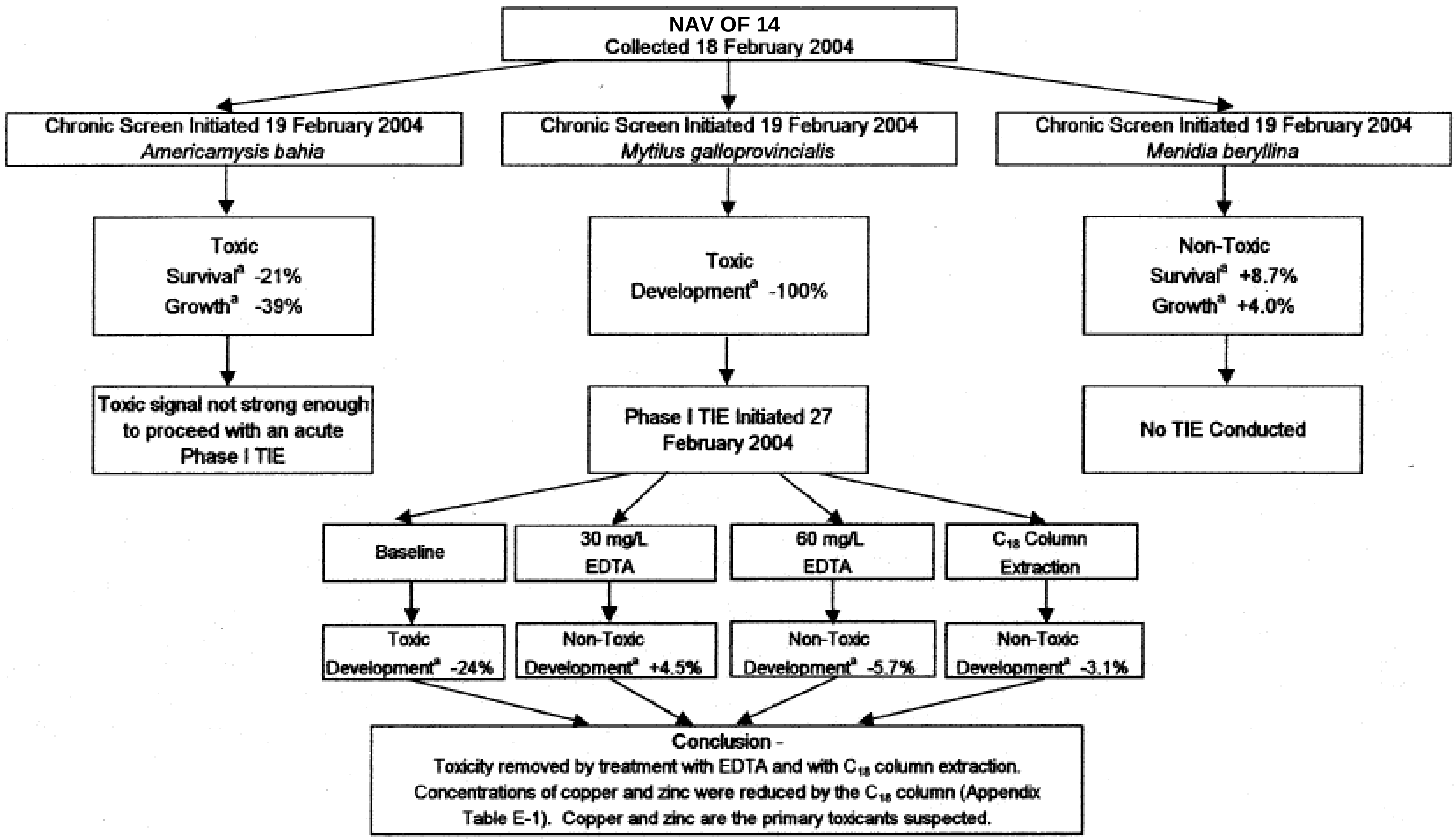
[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

Figure 23. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Station San Diego outfall 9.



[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

Figure 24. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Station San Diego outfall 11.



[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

Figure 25. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Station San Diego outfall 14.

7.2.4 Chemistry

TSS/DOC. A total of 28 and 10 samples were analyzed for TSS and DOC, respectively, at Naval Station San Diego. Table 14 shows a statistical summary of the TSS and DOC data. Appendix D shows all individual sample data. TSS in storm water ranged from ~60 to over 800 mg/L and averaged about 233 mg/L. On average, first-flush samples had higher TSS concentrations than composite samples, though the loss of TSS data during the second storm sampling limits this comparison. The first-flush samples also showed a considerably higher variability than the composite samples, as described by the relative standard deviation (RSD). The maximum TSS level was measured in the first-flush samples collected during the first-flush of the year storm event (SDB4) in October 2004. Bay samples were about an order of magnitude lower in TSS than the outfall samples and ranged from ~1 to 21 mg/L, with an average of 2.6 mg/L. The average value for bay samples collected before the storm increased about a factor of three during the storm and then decreased back to pre-storm conditions in the “after” samples showing the ephemeral nature of the storm derived particles in the water column. The “during” samples were considerably more variable than the other bay samples showing the variable nature of plumes.

The DOC data came exclusively from samples collected during a single storm event (SDB45) in October 2004 because DOC analyses were not added to the suite of analysis until the third storm event (SDB3). DOC in the composite sample was about a factor of two higher than in the first-flush sample, and about a factor of 10 higher than the average bay water sample. Elevated DOC in storm water runoff is expected from solubilization of terrigenous organic matter (SFERMP, 1994). The higher DOC in composite samples might indicate that there is a lag time in the discharge of organic compounds in storm water. Bay water “during” samples averaged about 30% higher than the pre-storm and post-storm samples, indicating storm water as a source of DOC to the bay.

Table 14. Statistical summary of TSS and DOC data at Naval Station San Diego. Sample types include first-flush (FF) and composite (Comp) outfall samples as well as receiving water (Bay) samples collected before, during, and after storm events.

TSS (mg/L)	Outfalls		Bay		
	FF	Comp	Before	During	After
n	2	4	6	9	7
Min	61	79	0.8	0.7	0.5
Mean	450	125	1.3	4.4	1.3
Max	839	170	1.8	21	2.9
RSD	122%	30%	24%	144%	77%
DOC (mg/L)					
n	1	1	1	4	3
Min				0.61	0.62
Mean	6.0	12	0.91	1.23	0.91
Max				1.73	1.3
RSD	NA	NA	NA	44%	42%

Metals. Forty-seven samples were analyzed for total and dissolved metals at Naval Station San Diego, which included 16 outfall samples and 31 receiving water samples. Of the total, 11 were analyzed for only copper and zinc. Appendix D shows all individual sample data.

Table 15 shows a statistical summary of the outfall metals data for Naval Station San Diego. The table data are summarized by first-flush and composite samples and by total and dissolved metals. The data show considerable variability of the individual metals spanning a range of ~25% to 180% for both the dissolved and total metal. Variability was typically about the same or lower in composite samples than in first-flush samples.

Nearly all total copper (71%) and all total zinc concentrations in first-flush storm water samples were above their respective performance goals in the NPDES permit of 63.6 and 117 μg/L. Only dissolved copper and zinc were elevated in outfall samples above their respective acute saltwater water quality standards of 4.8 and 90 μg/L, respectively, with the remaining dissolved metals all well below WQS (EPA, 2000a). This also includes dissolved mercury data that were compared to the human health WQS of 0.05 μg/L because the acute WQS for mercury is currently “reserved” (EPA, 2000a). Dissolved copper and zinc exceeded their acute WQS by a maximum factor of 36 and 27, respectively in first-flush samples. The comparable ratio in composite samples was reduced to 12 and 9, respectively.

Maximum total copper and zinc concentrations measured in the outfalls were 240 and 3600 μg/L, respectively. These levels were measured in the first-flush of the year sample (SDB4) at outfall 14 (Figure 26). This result matches the observation for TSS and DOC (note: no other chemicals were measured in SDB4 samples). The lowest copper and zinc levels were in the composite sample collected at outfall 14 during the second storm event SDB2. Except for one sample, total copper and zinc concentrations were higher in first-flush samples than their paired composite samples (Figure 26). Dissolved copper and zinc concentrations were always higher in first-flush samples though this was not the case for all metals. Tidal mixing (<38%) inside the outfall pipe was at least a partial explanation for the reduction in some of the composite sample concentrations.

Copper and zinc ranged from about 30 to over 90% and averaged ~60% as the dissolved phase metal in first-flush and composite samples. First-flush samples showed a slightly higher amount of the dissolved phase metal than observed in composite samples, indicating a potential lag of particles in the storm discharge.

Table 16 shows a statistical summary of the bay seawater sample data. Appendix D shows all individual sample data. The variability in these data was generally lower than observed in storm water samples with the exception of zinc. As was observed for storm water, bay water concentrations of copper (14 μg/L) and zinc (182 μg/L) were highest in samples collected during the first-flush of the year storm event (SBD4). This sample was one of only two receiving water samples in the study to exhibit mussel larvae toxicity. These concentrations represent about a factor of three for copper and 10 for zinc above typical levels. They also represent a reduction from first-flush levels by a factor of about 20. The concentrations of copper and zinc in this sample also exceeded chronic WQS (no other metals were analyzed in this sample). All other bay water metals were measured at concentrations well below their respective chronic WQS. Additionally, copper exceeded its chronic WQS of 3.1 μg/L (EPA, 2000b) in nearly all samples as a result of chronic sources, presumably from hull coating leachate or other bay sources. This was supported by copper concentrations that were not always higher in “during” samples than were measured in pre- or post-storm samples. Dissolved zinc concentrations measured during storm events were higher than those measured in pre-storm samples, except in one instance. The predominant phase of copper and zinc in seawater was as the dissolved metal, averaging about 70% for copper and 97% for zinc. Thus, these metals in bay waters tended toward the dissolved phase of the metal compared to the outfall discharge.

Table 15. Statistical summary of first-flush (FF) and composite (Comp) outfall (OF) metals data at Naval Station San Diego. Values for the total and dissolved metal are shown. NPDES performance goals and acute WQS are also shown. Grayed-out cells are values equal to the MDL.

OF FF Total (μg/L)	Ag	Cu	Pb	Hg	Zn	Al	As	Cd	Cr	Fe	Mn	Ni	Se	Sn
n	6	7	6	6	7	6	6	6	6	6	6	6	6	6
Min	0.052	45.3	4.06	0.0056	314	179	1.18	0.99	3.33	426	22.4	7.2	0.149	0.21
Mean	0.148	107.5	22.5	0.0348	945	1332	2.01	2.14	6.72	1943	78.7	11.6	0.59	0.82
Max	0.229	244	43.8	0.0629	3631	2640	3.20	5.49	13.7	3940	131	17.2	1.30	1.44
RSD	47%	70%	56%	68%	126%	71%	42%	81%	55%	68%	45%	36%	86%	50%
NPDES Performance Goal		63.6			117.0									
OF FF Dissolved (μg/L)														
n	6	7	6	6	7	6	6	6	6	6	6	6	6	6
Min	0.006	18.9	0.37	0.0027	175	11	0.37	0.39	0.80	19	14.4	3.7	0.087	0.09
Mean	0.021	62.3	2.5	0.0059	614	22	1.09	1.47	1.65	46	36.7	7.3	0.48	0.21
Max	0.029	177	11.8	0.0133	2453	40	2.04	4.97	3.6	161	82	17.2	1.33	0.50
RSD	43%	92%	182%	65%	133%	51%	55%	119%	65%	121%	63%	67%	107%	77%
OF Comp Total (μg/L)														
n	9	9	9	9	9	6	6	6	6	6	6	6	6	6
Min	0.063	28.9	6.50	0.0151	200	722	1.33	0.659	4.70	1149	31.5	4.48	0.035	0.536
Mean	0.132	72.8	15.9	0.0660	393	1244	1.72	1.06	7.88	1986	49.7	6.85	0.167	0.903
Max	0.247	136	23.5	0.2662	969	2618	2.39	2.27	12.9	4481	72	11.2	0.53	1.13
RSD	52%	55%	38%	118%	63%	56%	25%	58%	35%	63%	31%	37%	109%	24%
OF Comp Dissolved (μg/L)														
n	9	9	9	9	9	6	6	6	6	6	6	6	6	6
Min	0.004	7.2	0.16	0.0018	68	8	0.81	0.244	1.12	18	5.9	1.66	0.035	0.060
Mean	0.012	28.8	0.4	0.0052	252	22	1.14	0.40	3.01	45	14.3	2.42	0.167	0.213
Max	0.025	60	0.6	0.0123	776	40	1.72	0.67	10.0	71	25	4.1	0.36	0.50
RSD	49%	77%	38%	79%	98%	53%	30%	42%	115%	54%	44%	38%	82%	75%
WQS Acute (μg/L)	1.9	4.8	210		90		69	42	1100			74	290	

Table 16. Statistical summary of total and dissolved bay seawater metals data at Naval Station San Diego. Values for the total and dissolved metal are shown. Chronic WQS are also shown. Grayed-out cells are values equal to the MDL.

Bay Total (μg/L)	Ag	Cu	Pb	Hg	Zn	Al	As	Cd	Cr	Fe	Mn	Ni	Se	Sn
n	21	31	21	21	31	2	2	2	2	2	2	2	2	2
Min	0.015	3.50	0.140	0.001	8.42	74.9	1.15	0.105	1.75	129	10.7	1.93	0.044	0.201
Mean	0.025	5.87	0.275	0.002	20.2	91.0	1.16	0.107	1.86	141	11.6	2.00	0.049	0.227
Max	0.058	20.5	0.629	0.004	238	107	1.17	0.109	1.96	152	12.5	2.06	0.054	0.253
RSD	37%	48%	55%	31%	202%	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bay Dissolved (μg/L)														
n	21	31	21	21	31	2	2	2	2	2	2	2	2	2
Min	0.010	3.00	0.054	0.001	7.70	2.32	1.11	0.100	0.219	88.5	9.01	1.17	0.035	0.228
Mean	0.021	4.17	0.085	0.002	18.0	8.01	1.12	0.103	0.231	107	9.51	1.19	0.050	0.232
Max	0.033	14.1	0.137	0.005	182	13.7	1.13	0.106	0.242	125	10.0	1.21	0.064	0.235
RSD	32%	45%	20%	67%	171%	NA	NA	NA	NA	NA	NA	NA	NA	NA
WQS Chronic (μg/L)		3.1	8.1		81		36	9.3	50			8.2	71	

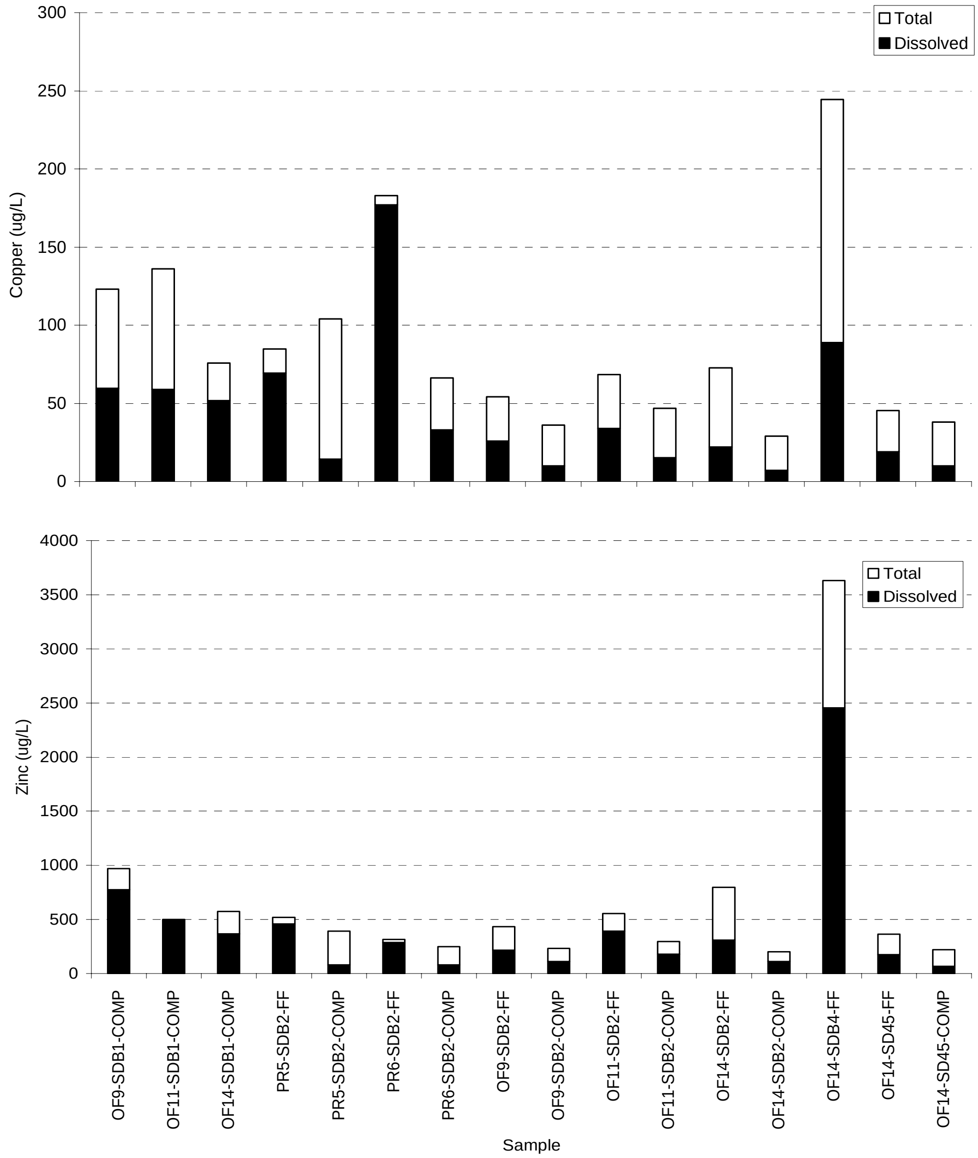


Figure 26. Total and dissolved copper and zinc concentrations measured in Naval Station San Diego first-flush (FF) and composite (Comp) outfall samples.

PAH. Thirty-six samples were analyzed for PAH at Naval Station San Diego. This total includes 15 outfall samples and 21 receiving water samples. Table 17 shows a statistical summary of storm water and bay water samples that is based on the summation of the 16 priority pollutant PAH data. Appendix D shows all individual sample data. The sum of priority pollutant PAH concentrations in outfall samples ranged from ~60 to 2,160. Only about 3% of these PAHs were below a MDL, which ranged from 0.33 to1.6 ng/L, depending on the specific analyte. Analytes not detected were given a value equal to one-half the MDL in the summation. The highest level was found in the first-flush sample collected from outfall 11 during the second storm event SDB2. First-flush samples were not always higher than their corresponding composite sample, even though their average concentration (738 ng/L) was about 35% higher (471 ng/L).

Average summed priority pollutant PAH concentrations in bay water samples were relatively low, ranging from 20 to 246 ng/L and averaged 52 ng/L. These levels were about an order of magnitude lower than measured in composite outfall samples. About 45% of these PAH analytes in bay water samples were below a MDL. Analytes not detected were given a value equal to one-half the MDL in the summation.

Acute or chronic WQS for PAHs do not exist. A review of the literature identified minimum acute and chronic thresholds for individual PAH analytes to fish and invertebrates (Table 11). The minimum acute level for pyrene in one first-flush sample collected from outfall 11 during the second storm event SDB2 was exceeded by 70%. All the receiving water samples contained PAH concentrations below the minimum chronic threshold value shown in Table 11.

Figure 27 shows the average relative composition of the PAH in first-flush and composite samples. Figure 28 shows a comparable plot for bay water samples. These distributions were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type: first-flush, composite, or bay sample. The PAH distribution in first-flush and composite samples were very similar. The main differences were the relatively lower naphthalenes and higher methylated fluorenes in the first-flush samples. Both sample types had compositions that were consistent with a predominantly low-level petrogenic (fuel) and minor pyrogenic (combustion) source. The composite samples had a relatively higher petrogenic component. Receiving water PAH compositions were very similar in samples collected before, during, and after storm events. These samples had a distinctly different composition than that of storm water with a distribution more characteristic of weathered petrogenic and pyrogenic source.

Table 17. Statistical summary of priority pollutant PAH data at Naval Station San Diego. The summation used one-half the MDL for analytes not detected in the sample. Sample types include first-flush (FF) and composite (COMP) outfall samples as well as receiving water (Bay) samples collected before (PRE), during (DUR), and after (AFT) storm events.

Sum Priority Pollutant PAH (ng/L)	Outfalls		Bay		
	FF	COMP	PRE	DUR	AFT
n	6	9	5	8	8
Min	62	93	20	28	28
Average	738	471	31	50	66
Max	2156	977	45	77	246
RSD	102%	62%	36%	38%	115%

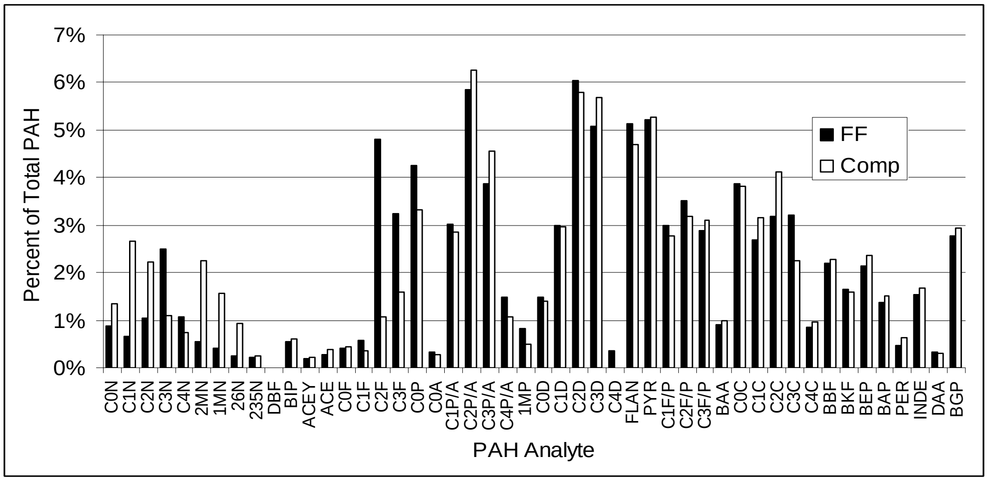


Figure 27. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Station San Diego. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

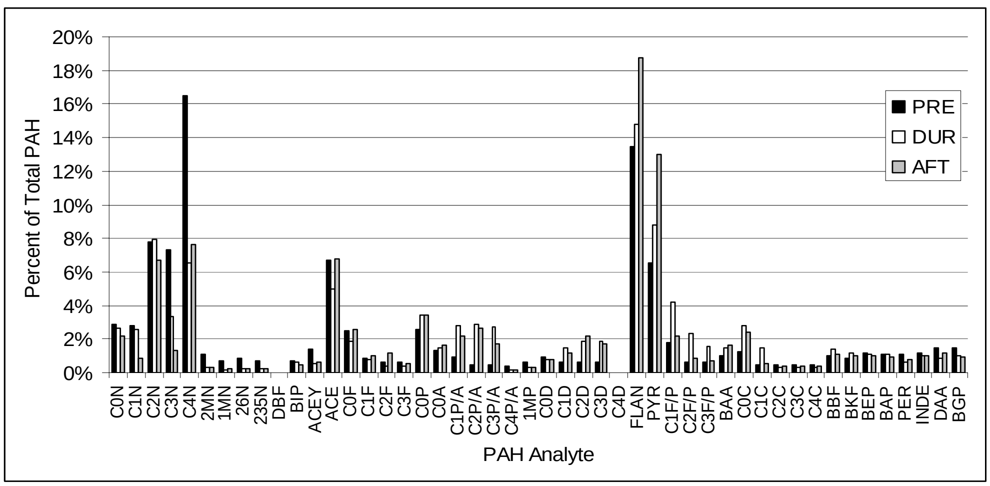


Figure 28. Average PAH composition in receiving waters before (PRE), during (DUR), and after (AFT) storm events at Naval Station San Diego. Table 6 shows analyte IDs.

PCB. Fifteen outfall samples were analyzed for PCB congeners at Naval Station San Diego. Table 18 shows a statistical summary of storm water of PCB data. No seawater PCB analyses were conducted because historical analyses showed levels typically all below detection even with MDLs of 1 ng/L. Appendix D shows all individual sample data. The sum of PCBs was calculated by summing all of the individual congeners in a sample. Congeners not detected were give a value equal to one-half the MDL, which ranged from 0.1 to 1.8 ng/L, depending on the congener. The sum of PCBs averaged 50 ng/L in first-flush samples and 19 ng/L in composite samples. Though the sum of PCBs in first-flush samples was three times higher than levels found in composite samples, the difference was not statistically significant at the 95% confidence level because the results were highly variable. The variations can be seen in Figure 29. All samples contained total PCB concentrations well below the minimum acute threshold value of 10,000 ng/L described earlier under chemical benchmarks (EPA, 1987).

Table 18. Statistical summary of PCB data at Naval Station San Diego. "Sum PCB" is the summation of all congeners measured in the sample. The summation used one-half the MDL for congeners not detected in the sample. Sample types include first-flush (FF) and composite (COMP) outfall samples. The minimum acute threshold described earlier is also shown.

Sum PCB (ng/L)	Outfalls	
	FF	COMP
n	6	9
Min	6.9	4.0
Average	50	19
Max	154	35
RSD	111%	62%
Acute Threshold		10000

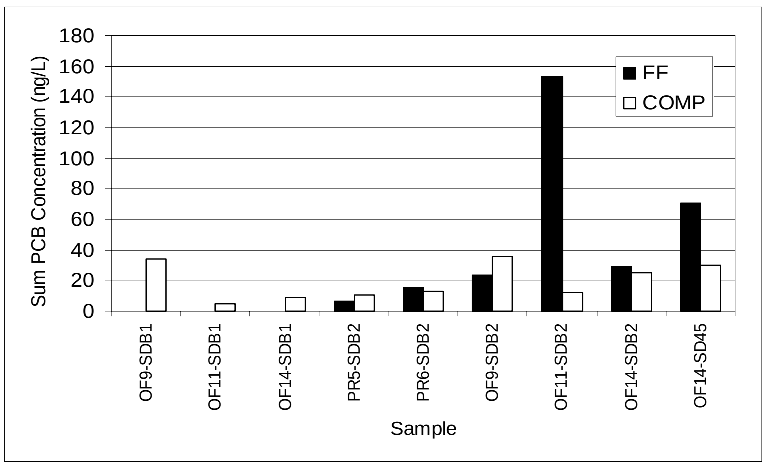


Figure 29. Summed PCB concentrations for first-flush (FF) and composite (COMP) outfall samples at Naval Station San Diego. The summation used one-half the MDL for congeners not detected in the sample.

Pesticides. Table 19 shows chlorinated pesticides data analyzed in two storm water samples collected at Naval Station San Diego. Pesticide analyses were added later in the study and no seawater pesticide analyses were conducted because of detection limit considerations. The two samples analyzed were collected as part of the SD45 storm event (Floating Bioassay Laboratory Study). A total of only nine analytes were detected in the two samples above a MDL, which ranged between 0.2 and 1.9 ng/L, depending on the analyte. The lack of detectable data precludes a meaningful evaluation of differences between first-flush and composite samples. However, 4',4' DDE, 4'4' DDT, a-chlordane, and trans-nonachlor were higher in first-flush samples than their paired composite sample. All the pesticides measured in storm water samples were below acute WQS.

Table 19. Chlorinated pesticide data measured in one first-flush (FF) and one composite (COMP) outfall sample at Naval Station San Diego outfall 14. Grayed-out cells are values equal to the MDL. Acute WQS are also shown.

Pesticide	Outfalls		Acute WQS (ng/L)
	OF14-SD45-FF (ng/L)	OF14-SD45-COMP (ng/L)	
2,4'-DDD	0.99	0.62	
2,4'-DDE	0.84	0.52	
2,4'-DDT	0.59	0.37	
4,4'-DDD	1.16	1.49	
4,4'-DDE	1.62	1.1	
4,4'-DDT	4.12	0.45	130
aldrin	0.48	0.3	1300
a-chlordane	2.16	1.67	
g-chlordane	0.49	0.31	90
a-BHC	0.42	0.26	
b-BHC	0.58	0.36	
d-BHC	0.47	0.3	
Lindane	0.6	1.49	
cis-nonachlor	0.79	0.49	
trans-nonachlor	2.03	1.44	
oxychlordane	0.48	0.3	
dieldrin	0.93	0.58	710
endosulfan I	0.33	0.21	34
endosulfan II	0.84	0.53	34
endosulfan sulfate	0.79	0.49	
endrin	0.92	0.57	37
endrin aldehyde	1.03	0.65	
endrin ketone	1.08	0.68	
heptachlor	0.72	0.45	53
heptachlor epoxide	1.92	1.2	53
Hexachlorobenzene	1.01	0.63	
methoxychlor	1.19	0.74	
Mirex	0.75	0.47	

7.2.5 Plume Mapping

Plume mapping was performed at Naval Station San Diego in November 2002 (SDB1) and February 2003 (SDB2). Figure 4 shows the timetable of the surveys and rainfall. Figure 30 shows example spatial maps of surface salinity from surveys made before, during, and after storm event SDB2. Appendix G shows spatial plots for all parameters measured for all surveys. Rainfall for this storm totaled about an inch. The salinity plots show that the storm water plumes during the storm were limited to an area immediately along the shoreline. Evidence of the plume extent was observed with most other parameters, particularly light transmission, which is a measure of the particle loading. Vertical cross-sections of salinity collected during the storm event showed that the plumes were limited to a maximum depth of 2 meters (Figure 31). The plume depth decreased with distance away from the shoreline until there was no evidence of it ~300 meters from the quay wall. Most parameters, particularly the “after” storm survey, showed a very slight reduction in salinity out to the ends of the piers. This reduction in salinity was a result of an unexpected short but intense rain squall that occurred during the survey. The effects of this squall rainfall can clearly be seen in the “after” plot, where a freshwater plume was observed discharging from Chollas Creek bordering the north side of the base.

The maximum fraction of storm water in the receiving water as measured by the reduction in salinity was 4%. This value was calculated as described earlier by comparing the minimum salinity measured during a storm event to the average salinity measured on the pre-storm survey. The maximum value was measured right along the quay wall.

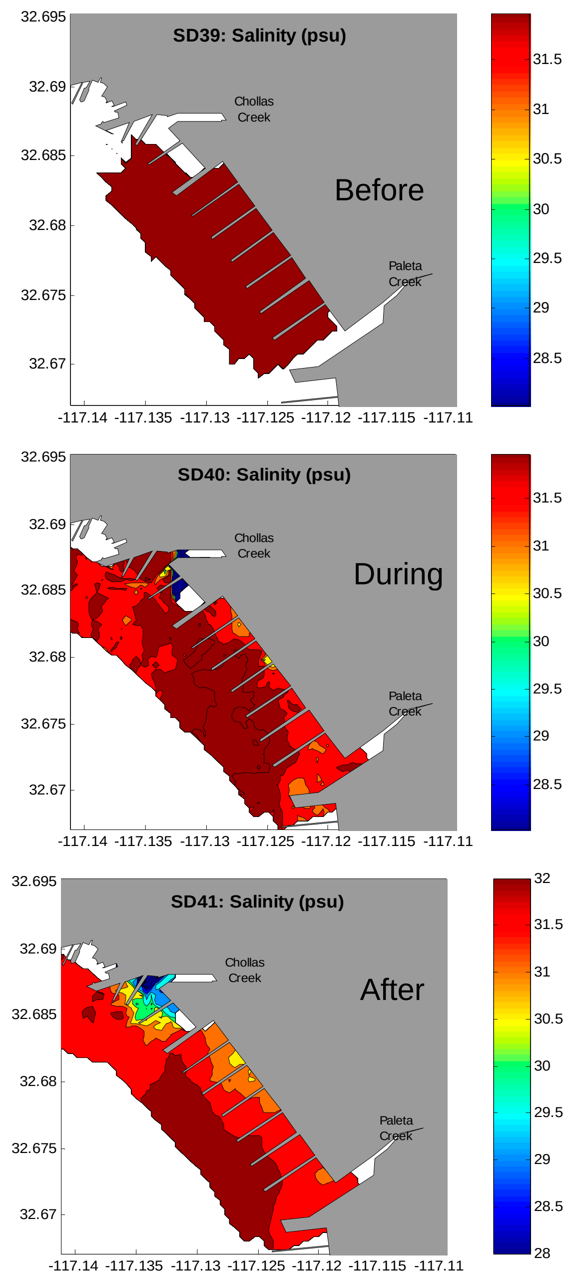


Figure 30. Surface salinity mapping before, during, and 24 hours after a storm event (SDB2) at Naval Station San Diego.

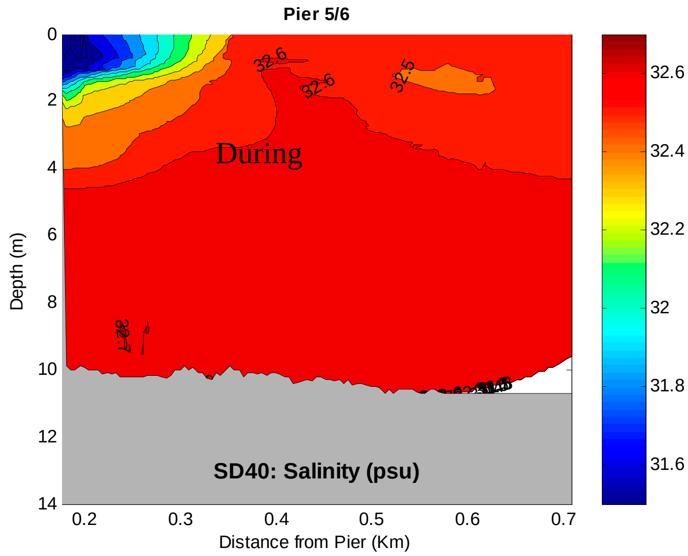


Figure 31. Vertical cross section of salinity between piers 5 and 6 (outside of outfall 9) during storm event SDB2 at Naval Station San Diego.

7.3 NAVAL SUBMARINE BASE SAN DIEGO

7.3.1 Storm Water Toxicity

Thirteen storm water outfall samples were tested, not necessarily for all species, for toxicity at Naval Submarine Base San Diego. Figure 32 shows the 100% storm water effluent toxicity data. A statistical summary of the results are provided in Table 20, with all data provided in Appendices B and C. Similar to Naval Station San Diego results, the three TIE tests conducted with the inland silverside (*Menidia beryllina*) were counted in the topsmelt results. In general, topsmelt and mysids responded similarly to outfall samples, averaging 91 and 80% survival in the undiluted effluent. First-flush and composite samples did not differ in toxicity, averaging 85% survival for both sample types, with low RSDs observed for both species. Though survival was relatively high, 40% of first-flush samples and 33% of composite samples would have failed the 90% survival requirement when tested with topsmelt. When mysids were used, failure rates were substantially higher, with 70 and 100% of samples resulting in <90% survival for first-flush and composite samples, respectively. Topsmelt in first-flush samples would not have failed the 70% survival requirement, though mysids would have failed 20% of the time. All the composite samples would have passed the 70% requirement.

For Naval Submarine Base San Diego samples, 96% of NOECs (combined for topsmelt and mysids) were 100% storm water effluent. Three of the 26 dilution series test results run on first-flush samples had a NOEC of 50% and two of the composite samples had a NOEC of 50%. These data suggest that a receiving water mixture with less than a 50% storm water fraction would result in no observable toxicity.

Mussel larvae were more sensitive than the permitted species in outfall samples, with an overall average of <2% normal development in undiluted storm water effluent (maximum effluent concentrations ranged between 58 and 65% because of brine addition). Because this bioassay is not included in the permit, the 90% requirement does not apply. The mysid and mussel toxicity data were more variable in first-flush samples than in composite samples. A qualitative review of the data showed that the highest toxicity was observed in the first-flush sample collected from outfall 11B during the first flush of the year sampling (SDB4). Though the study was not designed to compare outfalls, a qualitative review of paired data showed that toxicity in samples from the Naval Submarine Base San Diego outfalls were similar, though there was a slight increase observed for outfall 23CE during the TIE1 sampling. NOECs for mussels ranged from 10 to 33%, though one sample had a NOEC of <6.25%. With the exception of this one sample, a receiving water mixture with less than a 10% storm water fraction would result in no observable toxicity.

As described earlier, method variability in toxicity testing is an important consideration for evaluating results. Table 21 shows the PMSD for Naval Submarine Base San Diego industrial storm water dilution series toxicity tests, including baseline TIE results. PMSD values ranged from 6 to 24% for topsmelt and averaged 13%. PMSD for mysid tests ranged from 4 to 13 and averaged 9%. The mussel embryo-larval development tests ranged from 8 to 19% and averaged 13%. The mysid results all fell well within EPA guidelines for test acceptability (EPA, 2000). The topsmelt and mussel data also met the PMSD test acceptability criteria for comparable, endpoints (inland silverside survival and mussel survival and normal development). These differences are described later in the discussion section.

7.3.2 Receiving Water Toxicity

Twenty-four receiving water samples were tested, not necessarily for all species, for toxicity at Naval Submarine Base San Diego. No toxicity was observed in bay water samples. Survival was very high for topsmelt and mysids exposed to bay waters, with a combined average survival of 98%. All topsmelt and mysid bay water data were statistically indistinguishable from lab controls ($p<0.05$). Mussel larval development in all samples averaged 87% and was not statistically different from controls.

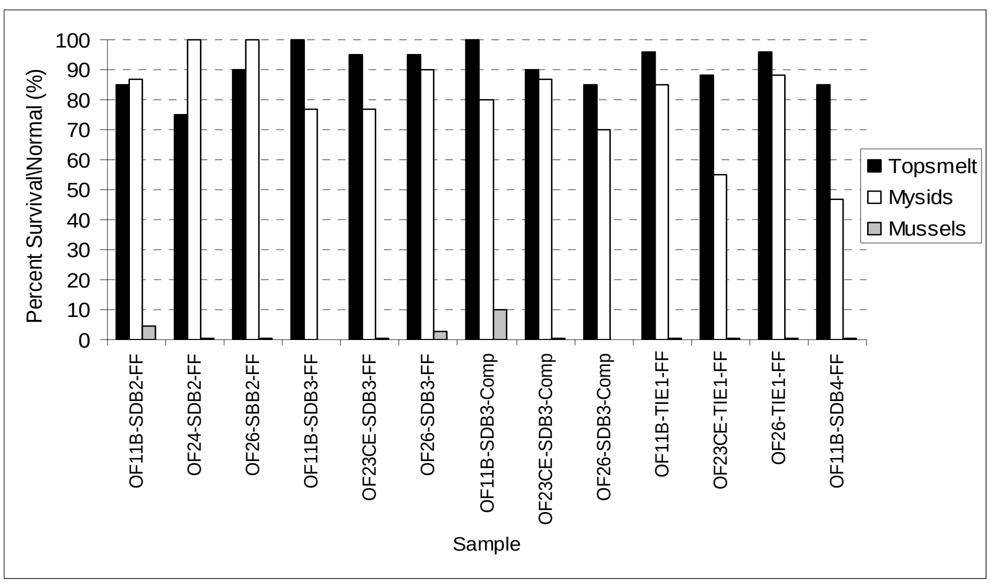


Figure 32. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Submarine Base San Diego.

Table 20. Statistical summary of toxicity data in Naval Submarine Base San Diego first-flush (FF) or composite (Comp) undiluted storm water or in receiving water (Bay) samples. Results are expressed as percent survival for topsmelt and mysids and as percent normal embryo-larval development for mussels. "# <90% and % Failing" refers to the number and percentage of samples that did not meet the 90% survival criterion in the permit.

SUB	Topsmelt Survival (%)			Mysid Survival (%)			Mussel Normal Development (%)		
	FF	Comp	Bay	FF	Comp	Bay	FF	Comp	Bay
n	10	3	21	10	3	20	9	2	24
Min	75	85	90	47	70	93	0	0	86
Mean	91	92	97	80	79	99	1	5	92
Max	100	100	100	100	87	100	4	10	97
RSD	8	8	4	22	11	2	199	NA	4
# <90%	4	1	NA	7	3	NA	NA	NA	NA
% FAILING	40%	33%	NA	70%	100%	NA	NA	NA	NA

NA Not applicable

Table 21. Percent Minimum Significant Difference (PMSD) for Naval Submarine Base San Diego toxicity tests.

PMSD	Topsmelt	Mysids	Mussels
n	13	12	11
Min (%)	6	4	8
Mean (%)	13	9	13
Max (%)	24	13	19

7.3.3 TIE

A Toxicity Identification Evaluation was performed on first-flush samples collected from each of the three outfalls at Naval Submarine Base San Diego during the storm event on 18 February 2004. First-flush samples were collected at the start of a very low rainfall event in which only 0.19 inches of rainfall fell. Appendix E includes the report for this effort. Inland silversides *(Menidia beryllina*) were used in lieu of topsmelt in these tests because topsmelt were unavailable from the supplier. It is expected that the results for inland silversides would have been the same for topsmelt. Figure 33 through Figure 35 show the manipulations performed for each outfall sample.

Toxicity screening results showed that there was insufficient toxicity to inland silversides or to mysids to perform a TIE at outfall 11B or outfall 26. Therefore, TIEs were conducted only using the mussel embryo-larval development tests at these two outfalls. The sample from outfall 23CE was sufficiently toxic to mysids, so the TIE for this sample was conducted with mussel embryos and mysids.

The TIE showed copper as the toxic agent in all three outfall samples. Zinc was identified as an additional causative agent in two of the outfalls, 23CE and 26. In the case of 23CE, zinc was the toxic agent for mussels and mysids. An additional compound identified by the toxicity laboratory that may have caused additive toxicity at outfall 11B was a non-polar organic compound called nonylphenol (see addendum report of Appendix E). Nonylphenol is a surfactant (or wetting agent) that is a degradation product from a broader class of surfactant compounds known as nonylphenol ethoxylates common in paints, resins and protective coatings, pest control products, and various cleaning products. The toxicity laboratory identified this as a likely additive causative agent based on their historical data. However, after the evaluation was completed, EPA published an acute saltwater aquatic life criterion for nonylphenol as 7.0 μg/L (EPA, 2006). The concentration of 0.18 μg/L nonylphenol estimated in the samples was below this toxic threshold and suggests it may not have been a causative agent for toxicity measured in the sample.

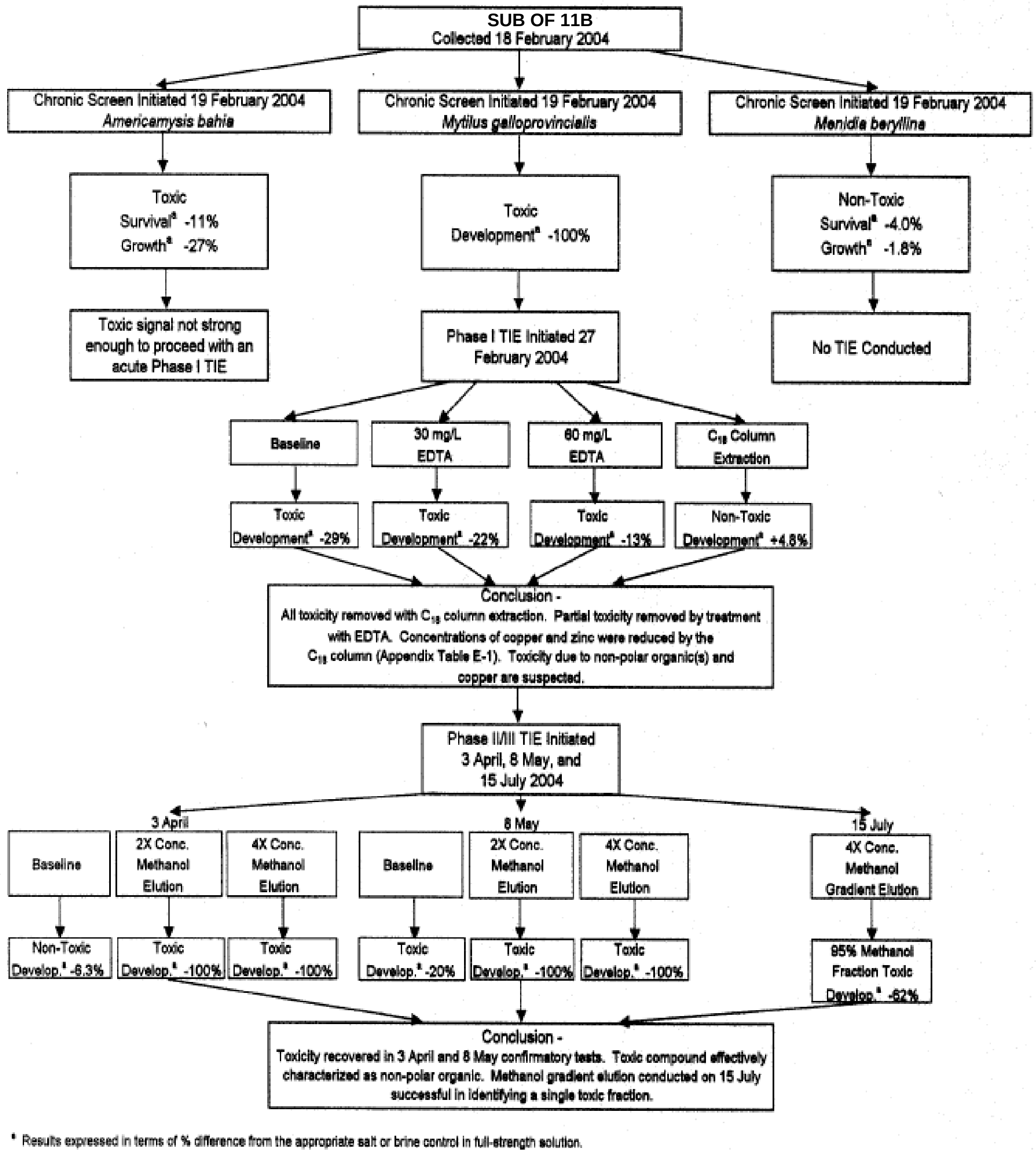
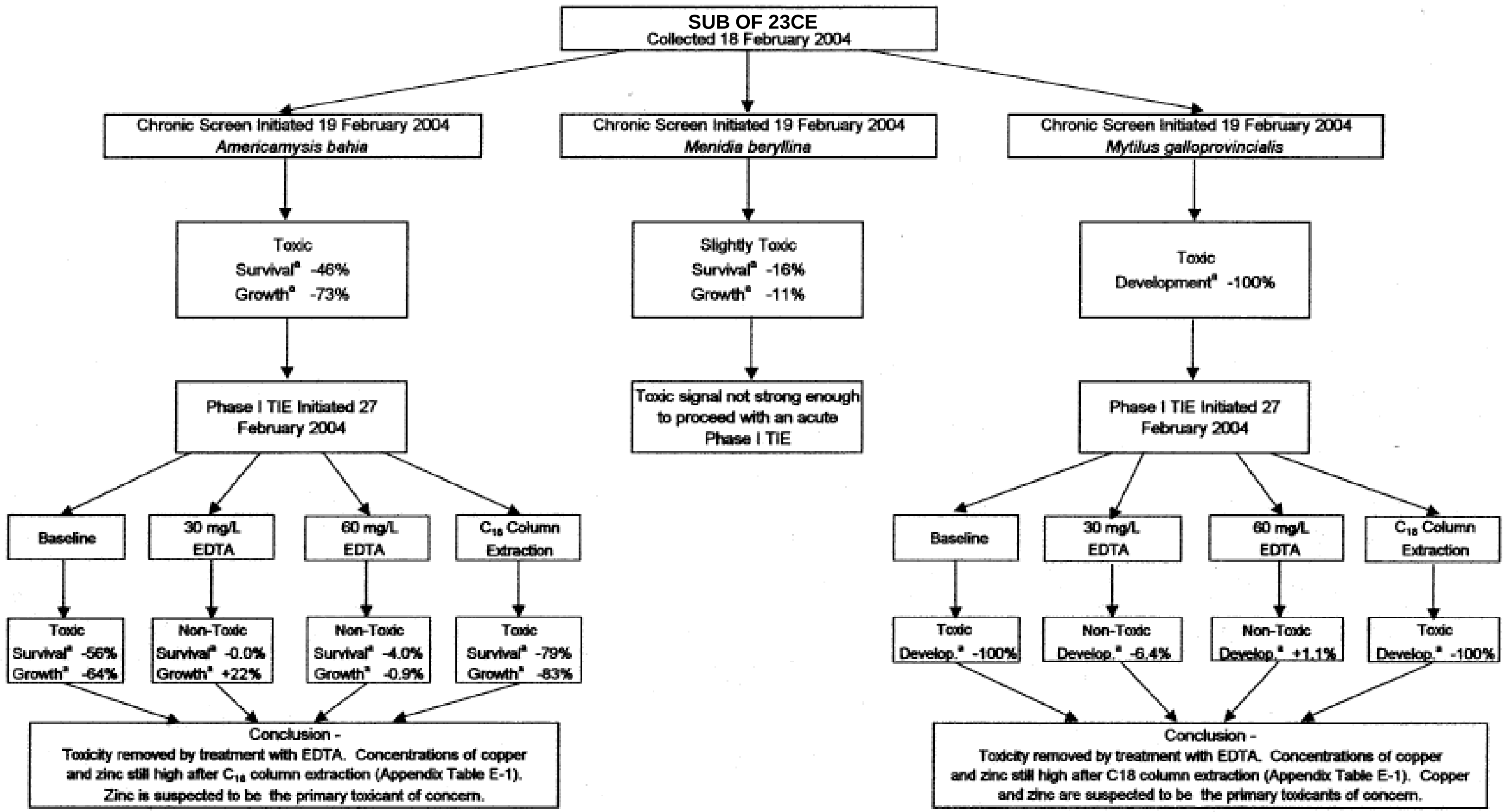
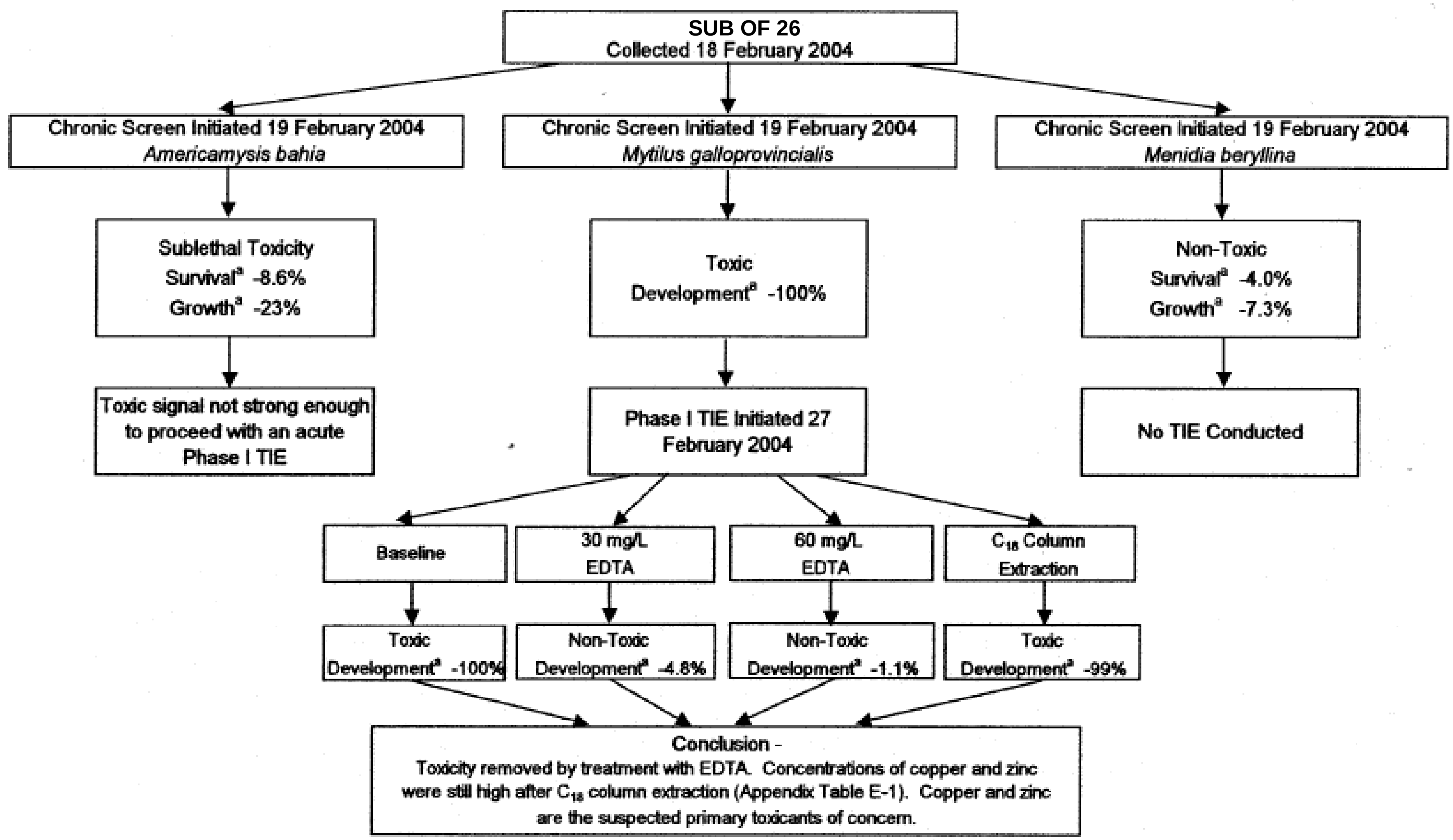


Figure 33. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Submarine Base San Diego outfall 11B.



[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

Figure 34. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Submarine Base San Diego outfall 23CE.



[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

Figure 35. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Submarine Base San Diego outfall 26.

7.3.4 Chemistry

TSS/DOC. A total of 20 and 18 samples were analyzed for TSS and DOC, respectively, at Naval Submarine Base San Diego. Table 22 shows a statistical summary of the TSS and DOC data for Naval Submarine Base San Diego. Appendix D shows all individual sample data. TSS in storm water ranged from ~21 to over 150 mg/L and averaged about 60 mg/L. These levels were about a factor of five lower than those observed at Naval Station San Diego. On average, first-flush samples had higher TSS concentrations than composite samples. The first-flush samples also showed a considerably higher variability than the composite samples as described by the relative standard deviation (RSD). The maximum TSS level was measured in the first-flush samples collected during the first-flush of the year storm event (SDB4) in October 2004. This level was also observed for Naval Station San Diego measurements. Bay samples were about an order of magnitude lower in TSS than the outfall samples, ranged from ~2 to 9 mg/L, and averaged 2.2 mg/L. The average value for bay samples collected before the storm increased about 30% during the storm and then decreased back to pre-storm conditions in the “after” samples. The “during” samples were considerably more variable than the other bay samples.

The DOC data came exclusively from samples collected during a single storm event (SDB3) February 2004, as this measurement was added later in the study. DOC levels in outfall samples were about the same as measured at Naval Station San Diego. Composite samples were about a factor of two higher in DOC than first-flush samples. This was also the case for samples collected at Naval Station San Diego and suggests a lag time in the discharge of organic compounds during storm events. Receiving water samples ranged between 0.5 and 0.8 mg/L DOC before, during, and after the storm event and were about a factor of 10 to 20 lower in DOC than outfall samples.

Table 22. Statistical summary of TSS and DOC at Naval Submarine Base San DIego. Sample types include first-flush (FF) and composite (Comp) outfall samples as well as receiving water (Bay) samples collected before, during, and after storm events.

TSS (mg/L)	Outfalls		Bay		
	FF	Comp	Before	During	After
n	4	3	4	5	4
Min	37	21.2	2.2	2.1	2.4
Mean	68	57	2.8	3.7	3.0
Max	153	97	3.4	8.6	3.7
RSD	82%	66%	20%	74%	23%
DOC (mg/L)					
n	3	3	4	4	4
Min	4.5	11.3	0.5	0.5	0.5
Mean	8.3	12.2	0.7	0.6	0.6
Max	11	13	0.8	0.7	0.8
RSD	42%	7%	19%	16%	21%

Metals. Twenty-eight samples were analyzed for total and dissolved metals at Naval Submarine Base San Diego, which included 11 outfall samples and 17 receiving water samples. Of those, 18 were analyzed for only copper and zinc. Table 23 shows a statistical summary of the outfall metals data. The appendices show all individual sample data. The table data are summarized by first-flush and composite samples and by total and dissolved metals. The data show variability of the individual metals spanning a range of ~4% to 135% for the dissolved and total metal. Copper and zinc concentrations were about double the average storm water value in samples collected during the first-flush of the year (SDB4) storm event. This result matches the observation for TSS and DOC (no other chemicals measured in SDB4 samples).

Nearly all total copper (71%) and all total zinc concentrations in first-flush storm water samples were above their respective performance goals in the NPDES permit of 63.6 and 117 µg/L. Only dissolved copper and zinc were elevated in outfall samples above their respective acute saltwater water quality standards of 4.8 and 90 µg/L, respectively, with the remaining dissolved metals all well below WQS (EPA, 2000b). The comparison made for mercury was to the human health WQS of 0.05 µg/L, as discussed previously. Dissolved copper and zinc exceeded their acute WQS by a maximum factor of 19 and 14, respectively, in first-flush samples. The comparable ratio in composite samples was 29 and 6, respectively.

Maximum total copper and zinc concentrations measured in the outfalls were 149 and 1290 µg/L, respectively. The highest total zinc concentration was measured in the first-flush of the year sample (SDB4) at outfall 11B (Figure 36). However, the highest total copper concentration was measured in the composite sample collected from outfall 26 on Sierra Pier. Composite samples were always higher in copper than their corresponding first-flush samples (Figure 36). However, there was no consistent pattern for zinc for dissolved or total metal.

Copper and zinc ranged from about 41 to 59% and averaged ~48% as the dissolved phase metal in first-flush and composite samples. First-flush samples showed a slightly higher amount of dissolved phase copper than observed in composite samples, indicating a potential lag of particles in the storm discharge. The phase of zinc between sample types was not as consistent.

Table 24 shows a statistical summary of the bay seawater sample data. Appendix D shows all individual sample data. The variability in these data was generally higher than observed in storm water samples, a result not seen at Naval Station San Diego. Most of this variation appeared to be more related to stage of the tide than to storm condition. As was observed for storm water, bay water dissolved concentrations of copper and zinc were highest in the SDB4 sample collected at outfall 11B during the first-flush of the year. Concentrations were 5.5 and 53 µg/L, respectively, and represent an increase above typical concentrations by a factor of 3 and 7, respectively. This was the only bay water sample in which a metal concentration exceeded a chronic WQS. In this instance, dissolved copper was a factor of 1.8 above the WQS.

Table 23. Statistical summary of first-flush (FF) and composite (Comp) outfall metals data at Naval Submarine Base San Diego. Values for the total and dissolved metal are shown. NPDES performance goals and acute WQS are also shown. Grayed-out cells are values equal to the MDL.

OF FF Total (μg/L)	**Ag**	**Cu**	**Pb**	**Hg**	**Zn**	**Al**	**As**	**Cd**	**Cr**	**Fe**	**Mn**	**Ni**	**Se**	**Sn**
n	3	7	3	3	7	3	3	3	3	3	3	3	3	3
min	0.056	20.4	9.9	0.0067	130	453	1.23	0.56	3.44	750	22.60	6.58	0.24	0.44
mean	0.101	95.0	22.6	0.0129	554	1317	1.31	0.97	5.09	2424	120	11.9	0.27	0.55
max	0.152	149	43.5	0.0253	1291	3040	1.46	1.26	6.23	5770	306	16.6	0.30	0.69
RSD	48%	54%	81%	83%	77%	113%	10%	38%	29%	120%	135%	42%	12%	22%
NPDES Performance Goal		63.6			117.0									
OF FF Dissolved (μg/L)														
n	3	7	3	3	7	3	3	3	3	3	3	3	3	3
min	0.010	15.1	0.184	0.0034	59.3	18.60	0.45	0.17	0.51	15.3	11.0	3.30	0.10	0.04
mean	0.014	45.2	0.376	0.0056	358	25.6	0.91	0.43	1.09	34.2	22.7	7.53	0.21	0.08
max	0.017	92.6	0.575	0.0098	1255	32.9	1.14	0.65	1.59	53.6	44.8	11.8	0.28	0.14
RSD	24%	68%	52%	65%	126%	28%	44%	57%	50%	56%	84%	56%	46%	63%
OF COMP Total (μg/L)														
n	3	4	3	3	4	3	3	3	3	3	3	3	3	3
min	0.040	24.9	7.8	0.0166	123	529	1.09	0.24	4.79	1980	48.7	6.76	0.26	0.50
mean	0.059	118	13.4	0.0257	458	1423	2.60	1.28	5.89	2497	72.3	7.92	0.48	0.64
max	0.072	216	20.1	0.0432	792	2190	4.62	2.60	6.71	3210	89.7	9.31	0.63	0.87
RSD	28%	86%	47%	59%	60%	59%	70%	94%	17%	26%	29%	16%	41%	32%
OF COMP Dissolved (μg/L)														
n	3	4	3	3	4	3	3	3	3	3	3	3	3	3
min	0.009	15.2	0.400	0.0074	37.4	9.05	0.72	0.09	0.89	30.9	11.1	3.14	0.20	0.50
mean	0.015	74.5	0.554	0.0165	286	14.9	2.18	0.46	1.21	32.0	23.6	4.03	0.36	0.50
max	0.026	142	0.742	0.0265	505	18.2	4.31	0.86	1.80	33.5	35.9	5.76	0.65	0.50
RSD	66%	90%	31%	58%	68%	34%	86%	83%	42%	4%	53%	37%	69%	0%
WQS Acute (μg/L)	1.9	4.8	210		90		69	42	1100			74	290	

Table 24. Statistical summary of total and dissolved bay seawater metals data for Naval Submarine Base San Diego. Values for the total and dissolved metal are shown. Chronic WQS are also shown.

Bay Total (μg/L)	**Ag**	**Cu**	**Pb**	**Hg**	**Zn**
n	4	17	4	4	17
min	0.013	0.55	0.11	0.001	1.19
mean	0.015	2.02	0.24	0.003	8.6
max	0.018	10.5	0.56	0.010	71
RSD	19%	113%	92%	128%	193%
Bay Dissolved (μg/L)					
n	4	17	4	4	17
min	0.022	0.34	0.054	0.001	1.17
mean	0.026	1.30	0.064	0.006	7.4
max	0.030	5.5	0.083	0.013	53
RSD	13%	91%	20%	97%	165%
WQS Chronic (μg/L)		3.1	8.1		81

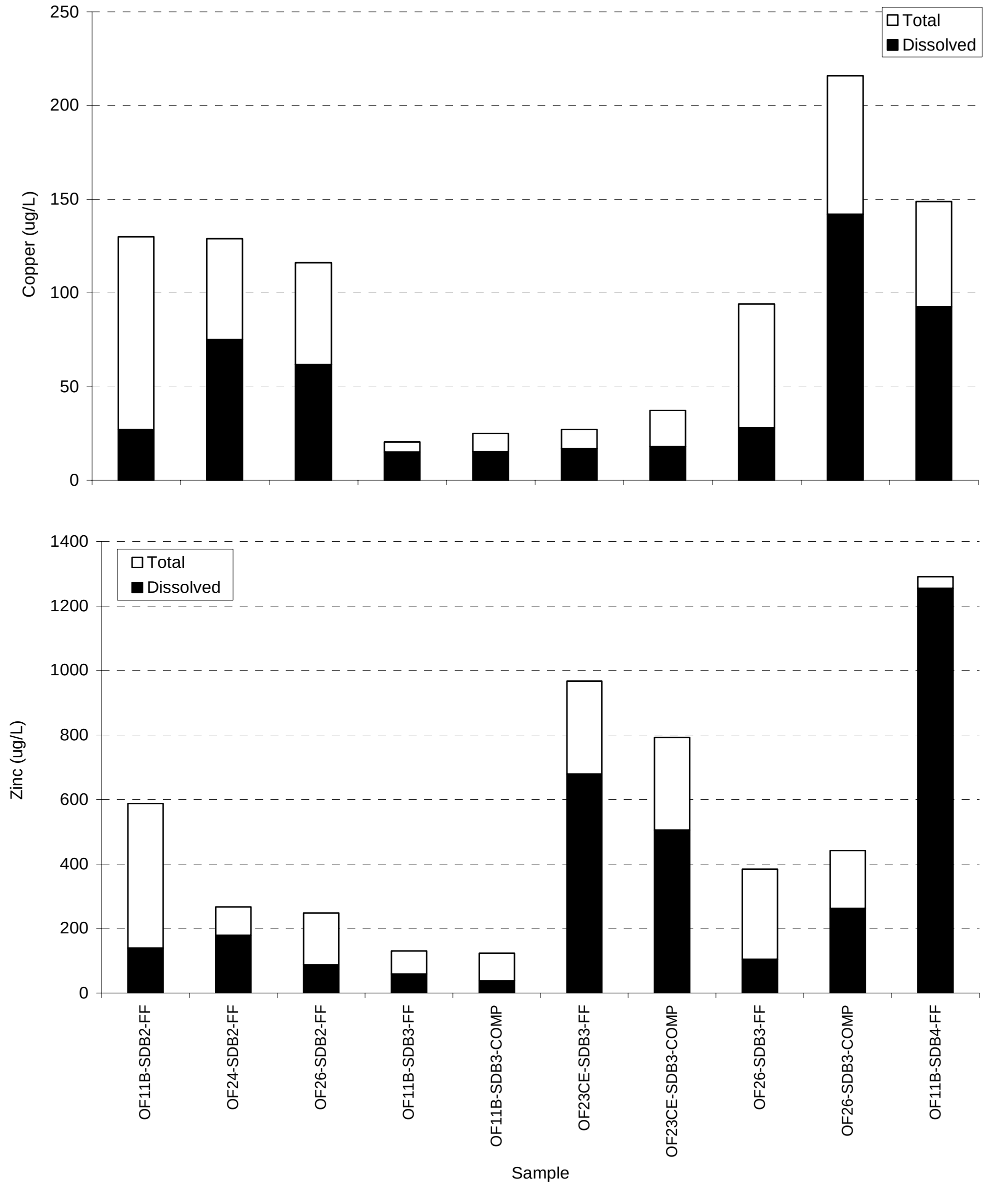


Figure 36. Total and dissolved copper and zinc concentrations measured in Naval Submarine Base San Diego first-flush (FF) and composite (Comp) outfall samples.

PAH. Twenty-five samples were analyzed for PAH at Naval Submarine Base San Diego. Of this total, nine samples were collected from outfalls and 16 were collected in receiving waters. Table 25 shows a statistical summary of storm water and bay water samples that is based on the summation of the 16 priority pollutant PAH data. Appendix D shows all individual sample data. The sum of priority pollutant PAH concentrations in outfall samples ranged from 94 to 325 ng/L and averaged about 220 ng/L. This average was less than half that observed in samples collected at Naval Station San Diego. All priority pollutant PAH analytes were detected above the MDL that ranged from 0.28 to 1.5 ng/L, depending on the specific analyte. The highest level was found in the first-flush sample collected from outfall 23CE during the SDB3 storm event. First-flush samples were not always higher than their corresponding composite sample.

Average summed priority pollutant PAH concentrations in receiving water samples were relatively low, ranging from 9 to194 ng/L and averaged 31 ng/L. These levels were about a factor of five lower than levels measured in composite outfall samples. About 11% of these PAH analytes in receiving water samples were below the MDL. Analytes not detected were given a value equal to one-half the MDL in the summation.

All the storm water samples contained PAH concentrations below the minimum acute thresholds identified in Table 11. All the receiving water samples had PAH at levels below the minimum chronic threshold values in the same table.

Figure 37 shows the average relative composition of the PAH in first-flush composite samples. Figure 38 shows a comparable plot for bay water samples. These distributions were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type; first-flush, composite, or bay sample. The PAH distribution in first-flush and composite samples were very similar, with only very minor variations. Both sample types had compositions that were consistent with a predominantly low-level weathered petrogenic source and a minor pyrogenic (combustion) source. Receiving water PAH compositions were very similar in samples collected before, during, and after storm events. They had a distinctly different composition than that of storm water, having a distribution more characteristic of weathered pyrogenic source.

Table 25. Statistical summary of priority pollutant PAH data at Naval Submarine Base San Diego. The summation used one-half the MDL for analytes not detected in the sample. Sample types include first-flush (FF) and composite (Comp) outfall samples as well as receiving water (Bay) samples collected before (PRE), during (DUR), and after (AFT) storm events.

Sum Priority Pollutant PAH (ng/L)	Outfalls		Bay		
	FF	COMP	PRE	DUR	AFT
n	6	3	5	7	4
Min	94	137	8.8	9.0	14
Average	213	219	28	41	18
Max	325	314	58	194	21
RSD	42%	41%	70%	165%	16%

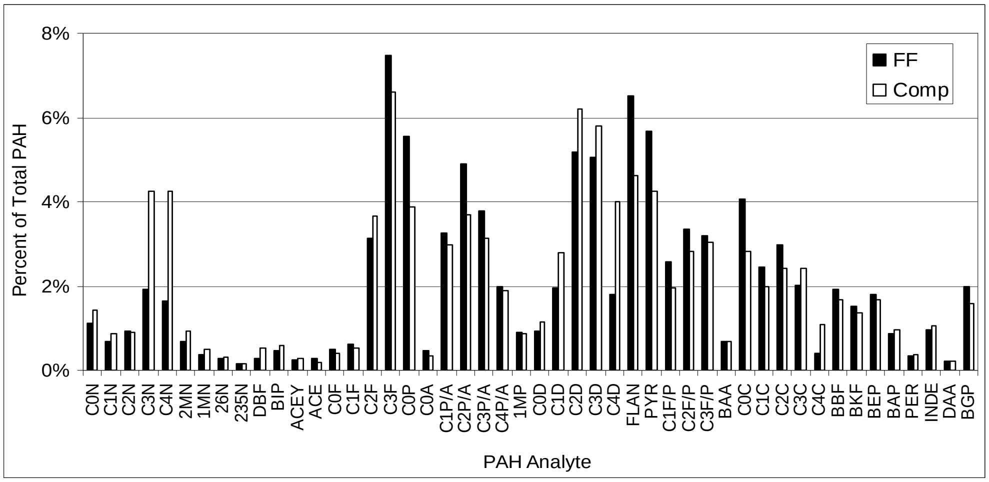


Figure 37. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Submarine Base San Diego. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

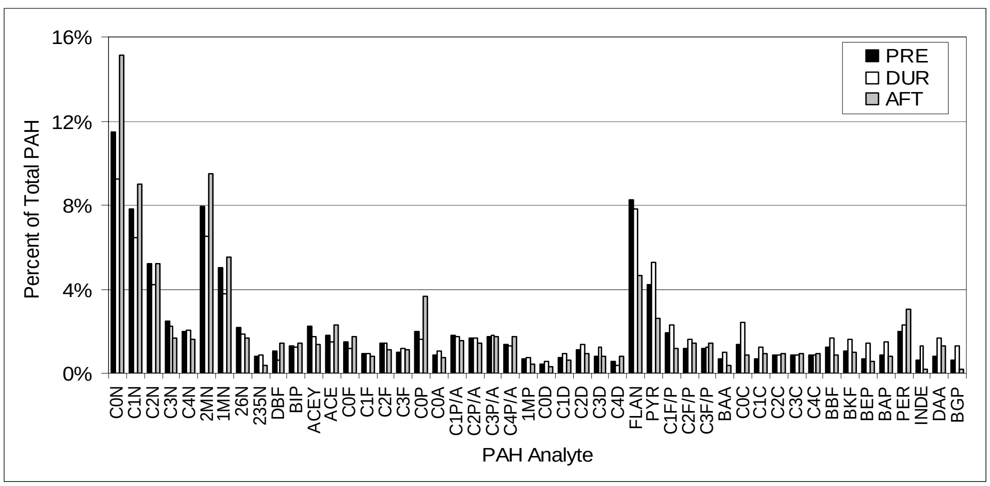


Figure 38. Average PAH composition in receiving waters before (PRE), during (DUR), and after (AFT) storm events at Naval Submarine Base San Diego. Table 6 shows analyte IDs.

PCB. Six outfall samples were analyzed for PCB congeners at Naval Submarine Base San Diego. Table 26 shows a statistical summary of storm water PCB data. No seawater PCB analyses were conducted. Appendix D shows all individual sample data. The sum of PCBs was calculated by summing all the individual congeners in a sample. Those congeners not detected were give a value equal to one-half the MDL, which ranged from 0.1 to 1.8 ng/L, depending on the congener. The sum of PCBs averaged 8.3 ng/L in first-flush storm water samples and 3.3 ng/L in composite samples, though the samples were not collected from the same outfalls during the same storms. Nearly 90% of these totals were a result of non-detect data. PCB levels measured in outfalls all fell below the minimum acute toxicity thresholds (EPA, 1987).

Table 26. Statistical summary of PCB at Naval Submarine Base San Diego. "Sum PCB" is the summation of all congeners measured in the sample. The summation used one-half the MDL for congeners not detected in the sample. Sample types include first-flush (FF) and composite (COMP) outfall samples. The acute toxicity benchmark is also shown.

Sum PCB (ng/L)	Outfalls	
	FF	COMP
n	3	3
min	4.1	2.4
mean	8.3	3.3
max	12	5.0
RSD	49%	45%
Acute Threshold		10,000

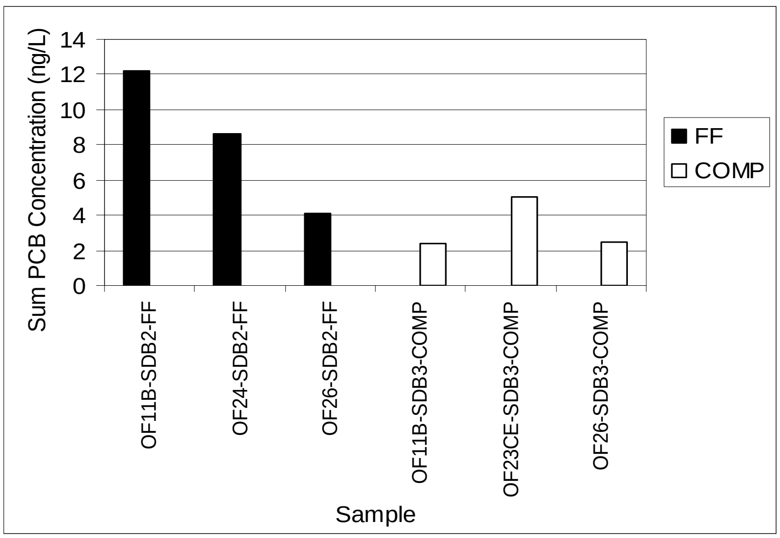


Figure 39. Summed PCB concentrations for first-flush (FF) and composite (COMP) outfall samples at Naval Submarine Base San Diego.

Pesticides. Three outfall composite samples were analyzed for chlorinated pesticides at Naval Submarine Base San Diego. All pesticides measured in these samples were below detection limits ranging from 0.21 to 2.2 ng/L. These concentrations were well below acute WQS shown in Table 10.

7.3.5 Plume Mapping

Plume mapping was performed once at Naval Submarine Base San Diego in February 2004 (SDB3). Figure 4 shows the timetable of the surveys and rainfall. Figure 40 shows spatial maps of surface salinity from surveys made before, during, and after the storm event. Appendix G shows spatial plots for all parameters measured during these surveys. Rainfall for this storm totaled about a half-inch. The salinity plots show that the storm water plumes were limited to an area immediately along the shoreline. Evidence of the plume extent was observed with most other mapping parameters. Water quality conditions around the base measured 24 hours after the storm event had returned to pre-storm conditions. The lack of any measurable plume feature at that time was a result of the limited spatial extent of the plume to begin with as well as the more effective tidal mixing near the mouth of the bay. The maximum fraction of storm water in the receiving water as measured by the reduction in salinity was 5%. This maximum value was measured right along the shoreline.

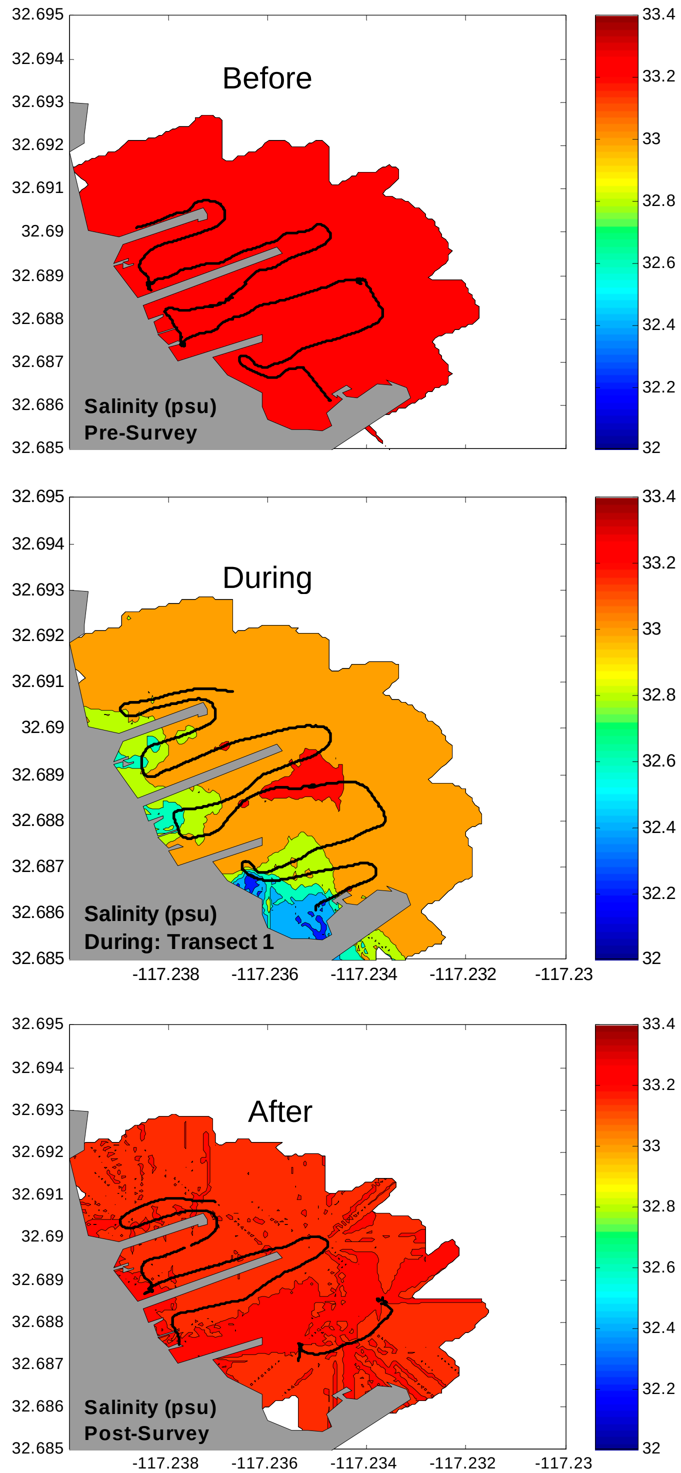


Figure 40. Surface salinity mapping before, during, and after a storm event (SDB3) at Naval Submarine Base San Diego.

7.4 NAVAL AMPHIBIOUS BASE CORONADO

7.4.1 Storm Water Toxicity

Ten storm water outfall samples were tested, not necessarily for all species, for toxicity at Naval Amphibious Base Coronado. Figure 41 shows the 100% storm water effluent toxicity data. A statistical summary of the results are provided in Table 27, with all data provided in Appendices B and C.

Overall, topsmelt were less sensitive than mysids, with average survival rates of 66 and 46% in the undiluted first-flush effluent, respectively. Although the average survival in composite samples was higher than in first-flush samples, a review of the paired results (Figure 41) shows no clear difference. For topsmelt, 43% of the first-flush samples would have failed the 90% survival requirement, while 33% of composites would have failed. Mysids failed the requirement in 80% of the first-flush samples, but passed in the single composite sample tested.

For Naval Amphibious Base Coronado samples, 56% of NOECs (combined for topsmelt and mysids) were 100% storm water effluent. Two of the 16 dilution series results had a NOEC of 12.5% and one of the composite samples had a NOEC of 50%. These data suggest that a receiving water mixture with less than a 12% storm water fraction would result in no observable toxicity.

Mussel larvae were much more sensitive than the topsmelt or mysids in outfall samples, with no observations of any normal larvae in the highest concentration of storm water effluent tested for any sample. Because this bioassay is not included in the permit, the 90% requirement does not apply. Topsmelt and mysids in first-flush samples would have failed the 70% survival requirement 33 and 60% of the time, respectively. All but one of the composite samples would have passed the 70% requirement for both species. Mussel larvae were much more sensitive than the permitted species in outfall samples, with no observations of any normal larvae in the highest concentration of storm water effluent tested for any sample. Though the study was not designed to compare outfalls, a qualitative review of paired data showed that toxicity in samples from the two outfalls was highly variable, with no clear pattern of relative magnitude of effects in one outfall versus the other. Three mussel-test NOECs were 12.4% effluent. Another two tests had NOECs of <12.4% and one had a NOEC of <6.25%. These data suggest that with the exception of two samples, a receiving water mixture with less than a 6% storm water fraction would result in no observable toxicity.

As described earlier, method variability in toxicity testing is an important consideration for evaluating results. Table 28 shows the PMSD for Naval Amphibious Base Coronado industrial storm water dilution series toxicity tests, including baseline TIE results. PMSD values ranged from 9 to 18% for topsmelt and averaged 14%. PMSD for mysid tests ranged from 6 to 29% and averaged 16%. The mussel embryo tests ranged from 3 to 7% and averaged 4%. The mysid results all fell well within EPA guidelines for test acceptability (EPA, 2000). The topsmelt and mussel data also met the PMSD test acceptability criteria for comparable, endpoints (inland silverside survival and mussel survival and normal development). These differences are described later in the discussion section.

7.4.2 Receiving Water Toxicity

Twelve receiving water samples were tested, not necessarily for all species, for toxicity at Naval Amphibious Base Coronado. No toxicity was observed for topsmelt or mysids in bay water samples. Survival was very high for topsmelt and mysids exposed to bay waters, with a combined average survival of 98%. All topsmelt and mysid bay water data were statistically indistinguishable from lab controls ($p<0.05$). Mussel larval development in receiving water samples averaged 87% overall and, with one exception, was also not statistically different from controls. The exception was for a sample collected outside outfall 18 during a first-flush of the year event (SDB4) after a record 6-month antecedent dry period.

Table 27. Statistical summary of toxicity data in Naval Amphibious Base Coronado first-flush (FF) or composite (Comp) undiluted storm water or in receiving water (Bay) samples. Results are expressed as percent survival for topsmelt and mysids and as percent normal embryo-larval development for mussels. "# <90% and % Failing" refers to the number and percentage of samples that did not meet the 90% survival criterion in the permit.

NAB	Topsmelt Survival (%)			Mysid Survival (%)			Mussel Normal Development (%)		
	FF	Comp	Bay	FF	Comp	Bay	FF	Comp	Bay
n	7	3	12	5	1	8	5	1	12
Min	0	60	90	0	90	97	0	0	4
Mean	66	83	98	46	90	99	0	0	87
Max	100	100	100	90	90	100	0	0	98
RSD	69	25	3	93	NA	2	0	NA	30
# <90%	3	1	NA	4	0	NA	NA	NA	NA
% FAILING	43%	33%	NA	80%	0%	NA	NA	NA	NA

NA Not applicable

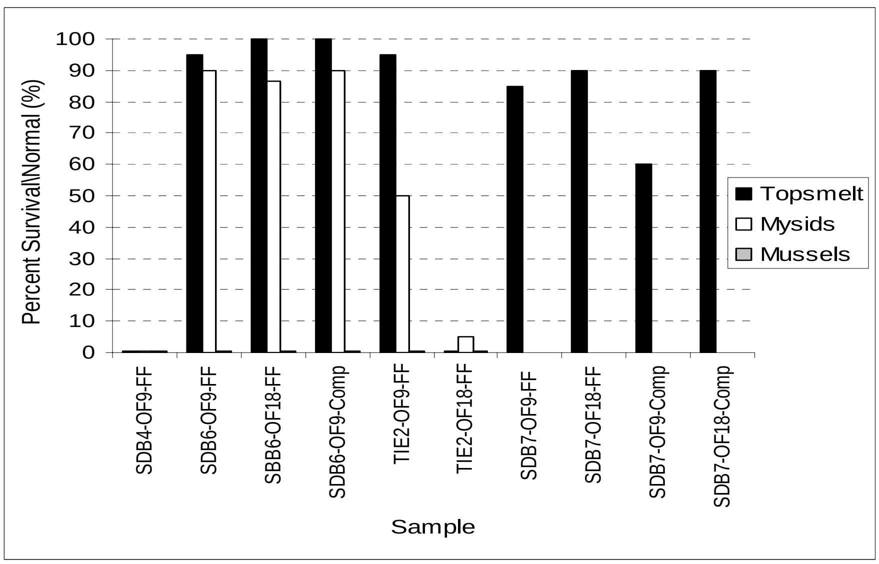


Figure 41. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Amphibious Base Coronado.

Table 28. Percent Minimum Significant Difference (PMSD) for Naval Amphibious Base Coronado toxicity tests.

PMSD	Topsmelt	Mysids	Mussels
n	7	6	6
Min (%)	9	6	3
Mean (%)	14	16	4
Max (%)	18	29	7

7.4.3 TIE

A Toxicity Identification Evaluation was performed on first-flush samples collected from each of the two outfalls at Naval Amphibious Base Coronado during the storm event on 19 March 2005. First-flush samples were collected during a very minimal rainfall event in which only 0.07 inches of rainfall fell. The TIE was performed by Nautilus Environmental LLC, San Diego. Appendix F includes the report for this effort. The TIE consisted of baseline acute toxicity tests with topsmelt, mysids, and mussel embryos.

Toxicity screening results showed that there was sufficient toxicity (>20% relative to control) to perform a TIE with mysids and mussel embryos at outfall 9 and with all three test species at outfall 18. Figure 42 and Figure 43 show the manipulations performed for each outfall sample.

The cause of toxicity to mysids and to mussel embryo-larval development at outfall 9 was copper and zinc. While copper was the primary toxicant to the mussels, it was not clear which toxicant was the primary cause of toxicity to mysids. The cause of toxicity to mussel embryos at outfall 18 was copper and zinc in combination with surfactants. Surfactants were also the primary cause of toxicity to mysids and possibly the cause of toxicity to topsmelt in this sample. The surfactants were not uniquely identified but were attributed to a class of compounds called methylene blue activated substances (MBAS). Though the toxicity data for these compounds is limited, Nautilus Environmental LLC has previously identified these compounds as having toxicity at concentrations above 1 mg/L. The sample collected from outfall 18 had a MBAS concentration of 1.9 mg/L.

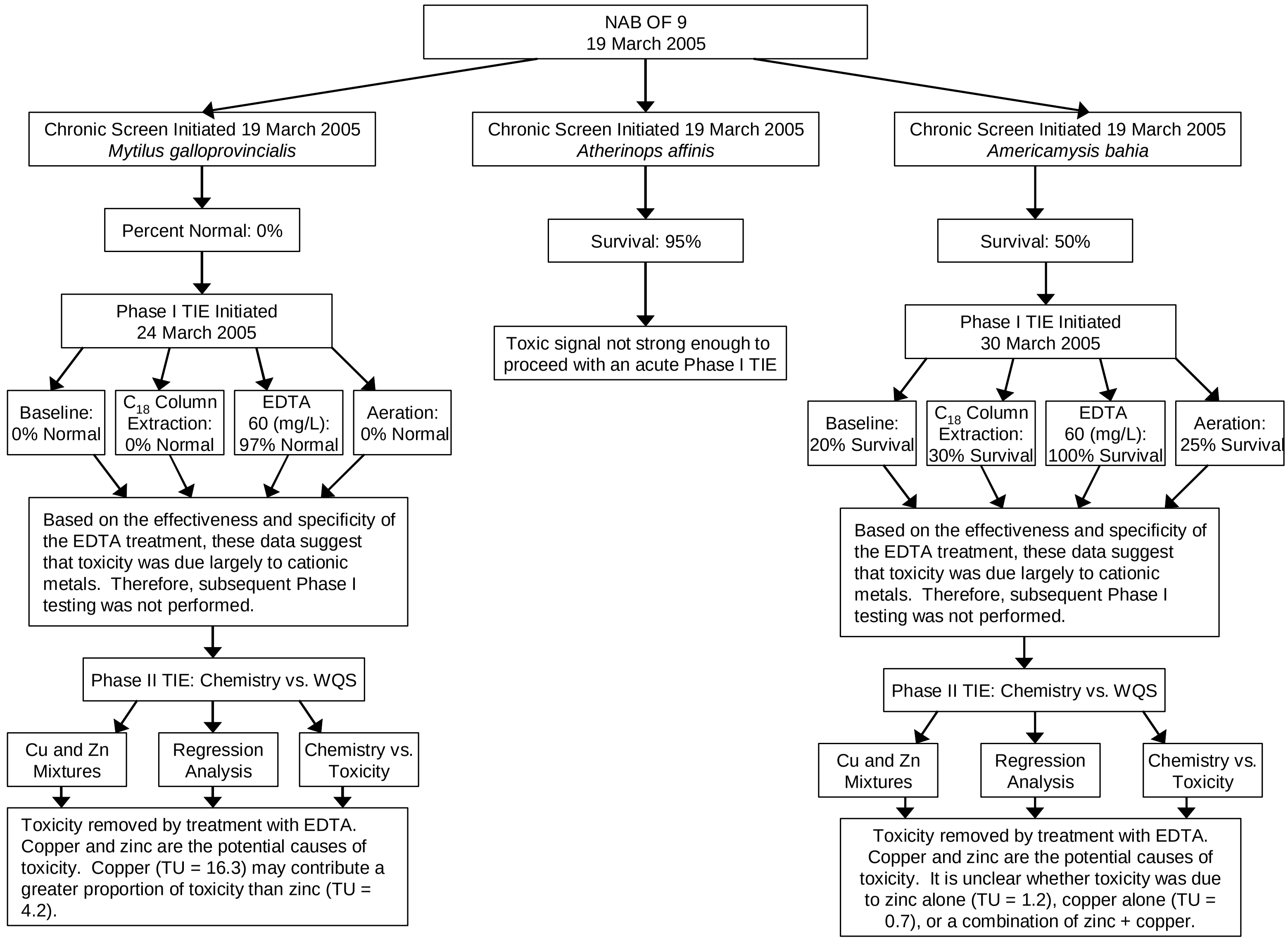


Figure 42. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Amphibious Base San Diego outfall 9.

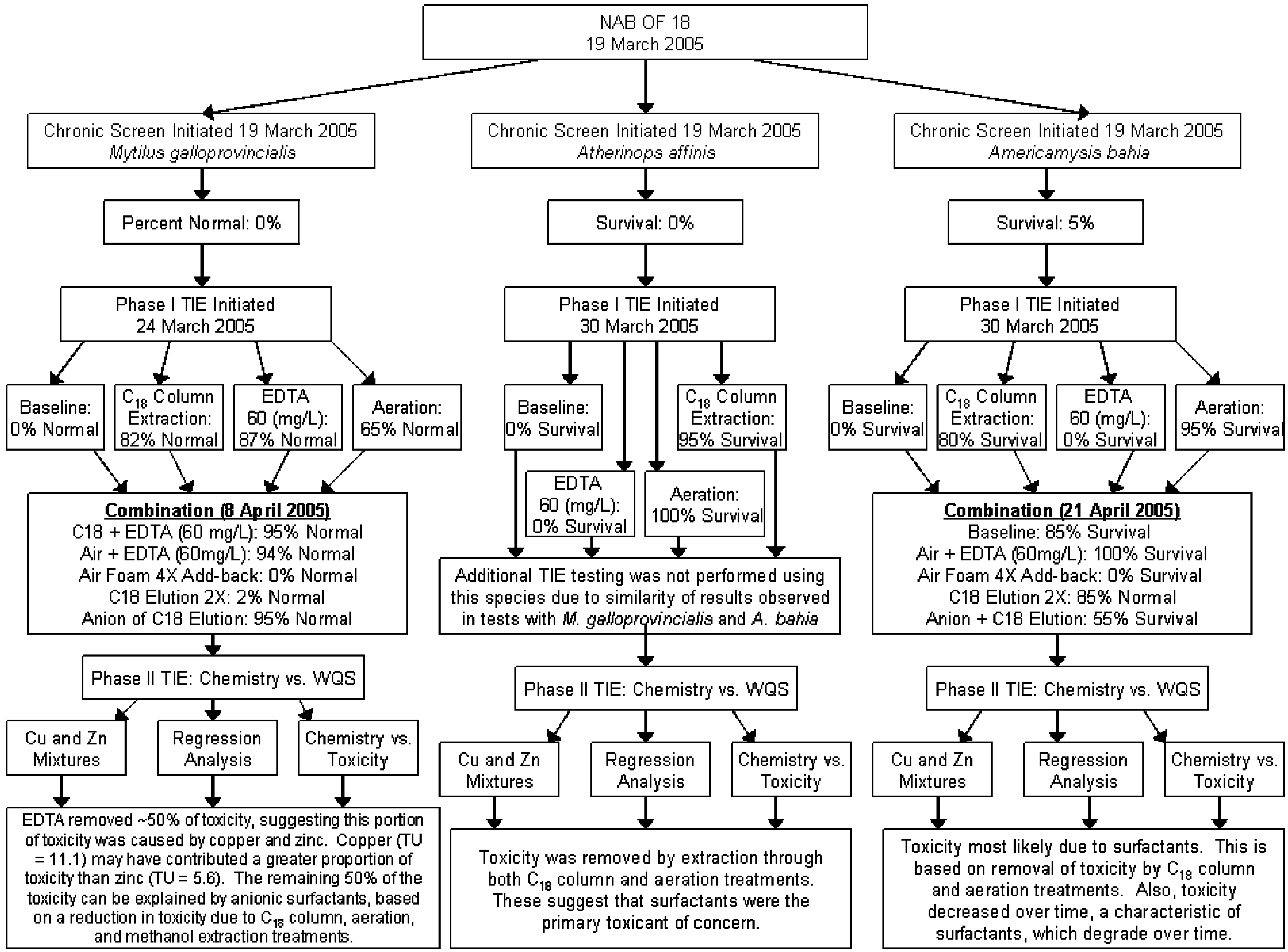


Figure 43. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Amphibious Base outfall 18.

7.4.4 Chemistry

TSS/DOC. A total of 18 and 16 samples were analyzed for TSS and DOC, respectively, at Naval Amphibious Base Coronado. No after-storm samples were collected or analyzed. Table 29 shows a statistical summary of the TSS and DOC data. Appendix D shows all individual sample data. TSS in storm water ranged from ~6 to over 230 mg/L and averaged about 60 mg/L. On average, composite samples had higher TSS concentrations than first-flush samples, which is opposite to observations at Naval Station San Diego and Naval Submarine Base San Diego. However, the difference was not statistically significant at the 95% confidence level. First-flush samples showed similar variability to the composite samples as described by the relative standard deviation (RSD). The maximum TSS level was measured in a composite sample collected at outfall 18 during the SDB7 storm in April 2005. This level was unlike other outfall measurements that showed maximum TSS in first-flush samples collected during the first-flush of the year storm event (SDB4).

Bay sample TSS concentrations ranged from ~2 to 15 mg/L. On average TSS concentrations were about a factor of two higher than off Naval Station San Diego across the bay. Water depths along portions of the base are quite shallow and wind driven resuspension was observed during all storm event sampling. No after-storm bay samples were collected at Naval Amphibious Base Coronado. Average bay TSS values were about a factor of 10 less than the average in outfall samples. The maximum bay water TSS level was measured in the sample collected during the SDB7 storm event. TSS levels increased about a factor of two in samples collected during storms compared to samples collected before storms. This difference was statistically significant at the 95% confidence level.

DOC levels in outfall samples were about the same as found at the other bases, ~10 mg/L. Like the other bases, composite samples were almost always higher than their corresponding first-flush sample suggesting a lag time in the discharge of organic compounds during storm events. DOC concentrations in bay water samples were about a factor of 5 lower than found in outfall samples. These levels were about double the concentrations measured off Naval Station San Diego and Submarine Base San Diego.

Table 29. Statistical summary of TSS and DOC data at Naval Amphibious Base Coronado. Sample types include first-flush (FF) and composite (Comp) outfall samples as well as receiving water (Bay) samples collected before and during storm events.

TSS (mg/L)	Outfalls		Bay	
	FF	Comp	Before	During
n	5	4	4	5
Min	6	10.0	2.2	6.1
Mean	40	81	4	11
Max	130	234	6	15
RSD	133%	128%	106%	33%
DOC (mg/L)				
n	4	4	4	4
Min	7.8	5.4	1.6	1.7
Mean	9.1	11.7	1.7	2
Max	11.4	15.2	1.8	2
RSD	18%	39%	7%	19%

Metals. A total of 18 samples were analyzed for total and dissolved metals at Naval Amphibious Base Coronado, which included nine storm water and nine receiving water samples. All first-flush and bay water samples were analyzed for only copper and zinc. Table 30 shows a statistical summary of the outfall metals data. Appendix D shows all individual sample data. The data are summarized by first-flush and composite samples and by total and dissolved metals. The data show considerable variability of the individual metals spanning a range of ~25% to 190% for the dissolved and total metal. Copper and zinc variability were considerably lower in composite samples than in first-flush samples as was seen at Naval Station San Diego.

Half of the total copper and all total zinc concentrations in first-flush storm water samples were above their respective performance goals in the NPDES permit of 63.6 and 117 μg/L. Only dissolved copper and zinc were elevated in outfall samples above their respective acute saltwater water quality standards (WQS) of 4.8 and 90 μg/L, respectively, with the remaining dissolved metals all well below WQS (EPA, 2000a). The comparison made for mercury was to the human health WQS of 0.05 μg/L as discussed previously. Dissolved copper and zinc exceeded their acute WQS by a maximum factor of 35 and 79, respectively, in first-flush samples. The comparable ratio in composite samples was reduced to eight for both metals.

Maximum total copper and zinc concentrations measured in the outfalls were 668 and 8051 μg/L, respectively. These levels were measured in the first-flush of the year sample (SDB4) at outfall 9 (Figure 26) and represent the highest levels measured during the study. These maxima were a factor of four greater than the average and were in part, the reason for the relatively high variability as measured by the RSD. Dissolved copper and zinc concentrations were usually the similar or higher in composite samples than in first-flush samples (Figure 44).

Copper and zinc ranged from about 43 to 72% and averaged ~60% as the dissolved phase metal in first-flush and composite samples. First-flush samples showed a higher amount of the dissolved phase metal than observed in composite samples, indicating a potential lag of particles in the storm discharge.

Table 31 shows a statistical summary of the bay seawater copper and zinc data. All individual sample data. As was observed for storm water, receiving water concentrations of copper (17 μg/L) and zinc (176 μg/L) were highest in samples collected during the first-flush of the year storm event (SBD4). These concentrations represent about a factor of five for copper and eight for zinc above typical levels. The concentrations of copper and zinc in this sample also exceeded chronic WQS by factors of five and two, respectively. Additionally, copper exceeded its chronic WQS of 3.1 μg/L in two other samples collected during storm events. Dissolved zinc concentrations measured during storm events were higher than those measured in pre-storm samples. The predominant phase of copper and zinc in seawater was as the dissolved metal, averaging about 61% for copper and 75% for zinc. Thus, these metals in bay waters tended toward the dissolved phase of the metal compared to the outfall discharge.

Dissolved copper exceeded its chronic WQS in three seawater samples collected during storm events. Dissolved zinc exceeded its WQS in a single sample collected during the SDB4 storm event. This sample was one of only two receiving water samples in the study to exhibit mussel larvae toxicity. The maximum elevation above a WQS was about a factor of six for copper and a factor of two for zinc. The average bay sample was ~65% as the dissolved metal.

Table 30. Statistical summary of first-flush (FF) and composite (Comp) storm water metals data at Naval Amphibious Base Coronado. Values for the total and dissolved metal are shown. NPDES performance goals and acute WQS are also shown. Grayed-out cells are values equal to the MDL.

OF FF Total (µg/L)	Ag	Cu	Pb	Hg	Zn	Al	As	Cd	Cr	Fe	Mn	Ni	Se	Sn
n		5			5									
min		33.3			137									
mean		170			1925									
max		668			8051									
RSD		163%			178%									
NPDES Performance Goal		63.6			117.0									
OF FF Dissolved (µg/L)														
n		5			5									
min		17.6			134									
mean		59.4			1617									
max		172			7134									
RSD		107%			191%									
OF COMP Total (µg/L)														
n	4	4	4	4	4	4	4	4	4	4	4	4	4	4
min	0.040	44.4	3.21	0.0071	214	192	2.28	0.55	2.11	832	26.1	2.45	1.47	0.50
mean	0.074	80.0	11.3	0.0121	830	1625	8.28	1.46	5.48	3406	113	7.10	17.4	0.67
max	0.125	108	23.0	0.0201	1832	4717	23.4	2.91	11.1	6550	197	11.60	52.4	0.90
RSD	56%	41%	79%	49%	85%	129%	123%	73%	77%	88%	69%	62%	139%	27%
OF COMP Dissolved (µg/L)														
n	4	4	4	4	4	4	4	4	4	4	4	4	4	4
min	0.040	26.2	0.13	0.0019	101	13.2	1.20	0.32	0.57	14.3	8.6	1.27	1.47	0.50
mean	0.040	33.8	0.35	0.0034	329	22.1	6.99	0.57	1.02	55.1	49.6	4.41	16.5	0.50
max	0.040	40.0	0.85	0.0046	709	46.4	20.2	1.04	1.60	145	95.9	8.68	48.8	0.50
RSD	0%	19%	96%	34%	84%	73%	128%	56%	45%	110%	75%	70%	136%	0%
WQS Acute (µg/L)	1.9	4.8	210		90		69	42	1100			74	290	

Table 31. Statistical summary of total and dissolved bay seawater metals data at Naval Amphibious Base Coronado. Chronic WQS are also shown.

Bay Total (µg/L)	Cu	Zn
n	9	9
min	3.05	8.51
mean	7.65	55.4
max	22.9	256
RSD	89%	143%
Bay Dissolved (µg/L)		
n	9	9
min	2.01	6.19
mean	4.79	38.3
max	17.4	176
RSD	106%	141%
WQS Chronic (µg/L)	3.1	81

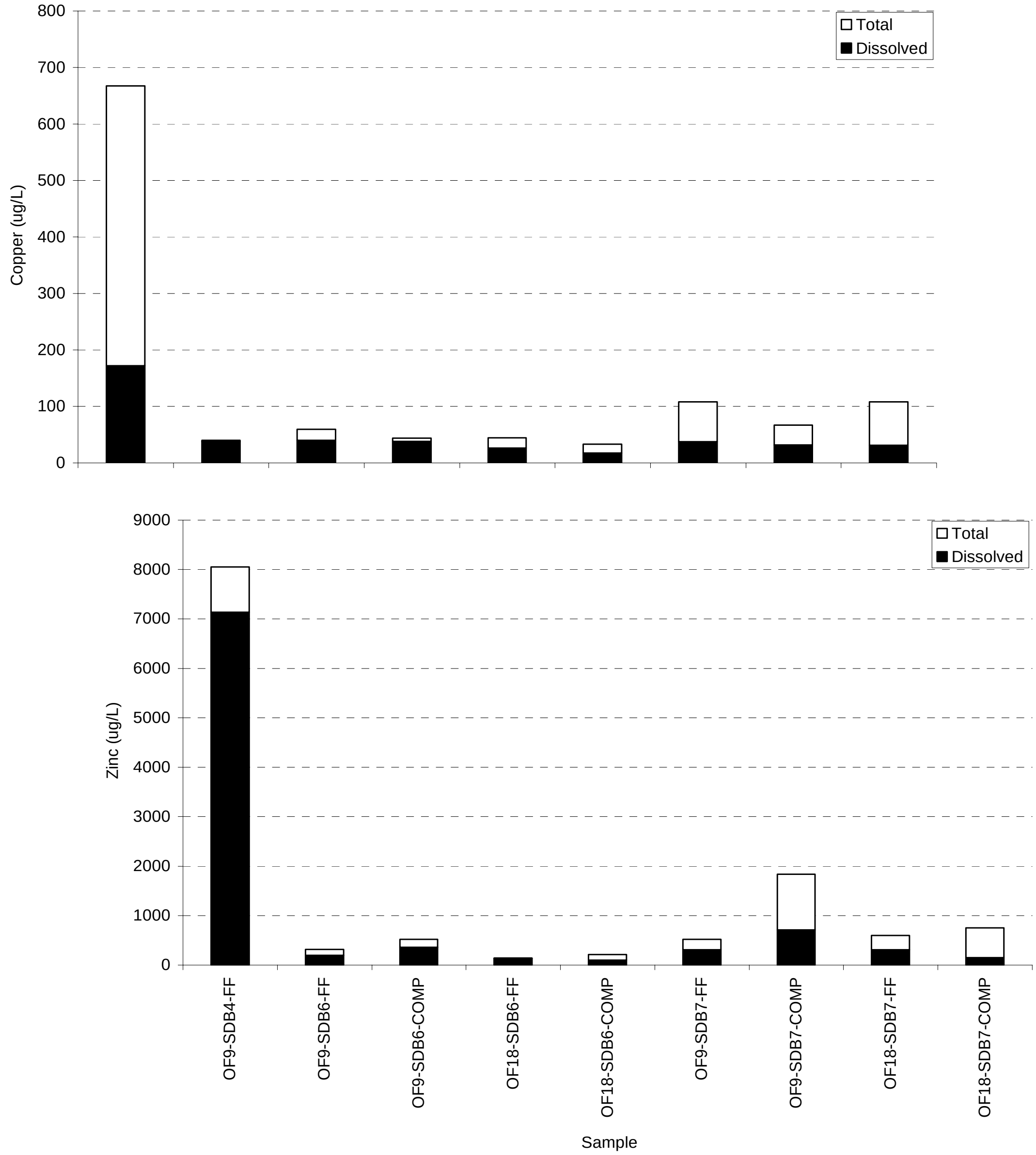


Figure 44. Total and dissolved copper and zinc concentrations measured in Naval Amphibious Base Coronado first-flush (FF) and composite (Comp) storm water outfall samples. Values for the total and the dissolved phase of the metal are shown.

PAH. A total of 16 samples were analyzed for PAH at Naval Amphibious Base Coronado. This total includes eight storm water outfall and eight receiving water samples. Table 32 shows a statistical summary of the storm water and seawater priority pollutant PAH data. Appendix D shows all individual sample data. The sum of priority pollutant PAH concentrations in storm water samples ranged from ~30 to 735 ng/L. About 19% of these PAHs were below a MDL, which ranged from 0.4 to 1.5 ng/L, depending on the specific analyte. Analytes not detected were given a value equal to one-half the MDL in the summation. The highest level was found in the composite sample collected from outfall 18 during storm event SDB7. This sample was also elevated in TSS and DOC. PAH levels in first-flush samples were always lower than in corresponding composite samples. The difference was about a factor of two.

Average summed priority pollutant PAH concentrations in receiving water samples relatively low, ranging from 12 to 94 ng/L and averaged 45 ng/L. About 25% of the PAH analytes in bay water samples were below a MDL. While the average receiving water PAH concentration was a factor of five lower than the average composite value, the bay water sample collected outside outfall 18 during the SDB7 storm event was actually higher than its corresponding outfall samples (FF and COMP). This suggests another source of PAH to the bay that was not sampled.

All the storm water samples contained PAH concentrations below the minimum acute thresholds identified in Table 11. All the receiving water samples had PAH at levels below the minimum chronic threshold values in the same table.

Figure 45 shows the average relative composition of the PAH in first-flush and composite samples. Figure 46 shows a comparable plot for bay water samples. These distributions were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type: first-flush, composite, or bay sample. The PAH distribution in first-flush and composite samples were very similar. Both sample types had compositions that were consistent with a predominantly low-level petrogenic and minor pyrogenic source. Receiving water PAH compositions were very similar in samples collected before and during storm events. They had a distinctly different composition than that of storm water, having a distribution more characteristic of a highly weathered low concentration pyrogenic source.

Table 32. Statistical summary of priority pollutant PAH data at Naval Amphibious Base Coronado. The summation used one-half the MDL for analytes not detected in the sample. Sample types include first-flush (FF) and composite (Comp) storm water outfall samples as well as receiving water (Bay) samples collected before (PRE) and during (DUR) storm events.

Sum Priority Pollutant PAH (ng/L)	Outfalls		Bay	
	FF	COMP	PRE	DUR
n	4	4	4	4
Min	31	53	12	43
Average	124	327	22	68
Max	232	735	32	94
RSD	80%	99%	45%	32%

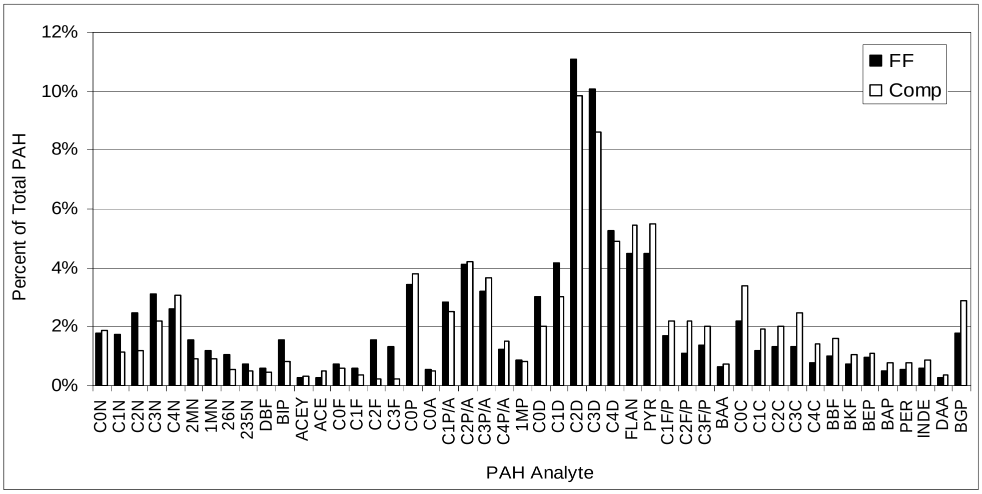


Figure 45. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Amphibious Base Coronado. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

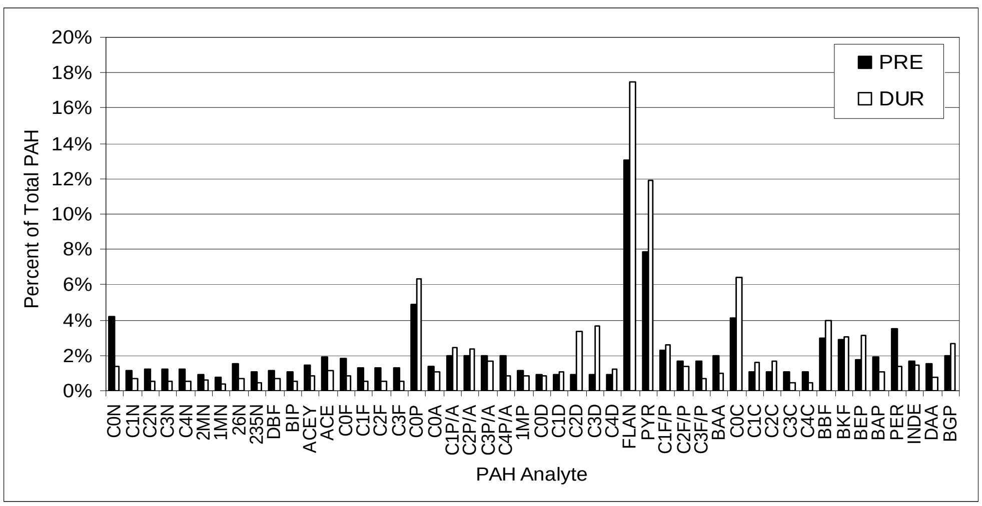


Figure 46. Average PAH composition in bay waters before (PRE) and during (DUR) storm events at Naval Amphibious Base Coronado. Table 6 shows analyte IDs.

PCB. Ten samples were analyzed for PCB at Naval Amphibious Base Coronado. The total includes six storm water outfall and four receiving water samples. Table 33 shows a statistical summary of PCB data. Appendix D shows all individual sample data. PCB concentrations in all but one storm water and bay water sample were non-detect, with the MDL ranging from 0.1 to 0.7 ng/L, depending on the congener. The composite sample collected at outfall 18 during storm SDB7 had a summed PCB concentration of 37 ng/L. This sample was also elevated in TSS, DOC, and PAH. PCB levels measured in storm water all fell well below the minimum acute toxicity threshold (EPA, 1987). PCB levels measured in receiving waters were all below chronic WQSC (EPA, 2000b).

Table 33. Statistical summary of PCB data at Naval Amphibious Base Coronado. “Sum PCB” is the summation of all congeners measured in the sample. The summation used one-half the MDL for congeners not detected in the sample. Sample types include first-flush (FF), composite (COMP) storm water outfall samples and bay samples collected before (PRE) and during (DUR) a storm event. Toxicity threshold benchmarks are also shown.

Sum PCB (ng/L)	Outfalls		Bay	
	FF	COMP	PRE	DUR
n	2	4	2	2
min	2.8	2.8	2.8	2.8
mean	2.8	13	2.8	2.8
max	2.8	37	2.8	2.8
RSD		126%		
Threshold	Acute 10,000		Chronic 30	

Pesticides. Ten samples were analyzed for chlorinated pesticides at Naval Amphibious Base Coronado. including six storm water outfall and four receiving water samples. Chlorinated pesticide concentrations in storm water samples were nearly all (93%) non-detect, with the MDL ranging from 0.2 to 1.6 ng/L, depending on the analyte (Table 34). All receiving water samples were non-detect. Appendix D shows all individual sample data. All storm water pesticide concentrations fell well below acute WQS, while all pesticide levels measured in receiving waters were below chronic WQS shown in Table 10.

Table 34. Chlorinated pesticide data collected at Naval Amphibious Base Coronado. Grayed-out cells contain values that were *above* the MDL, with all other data at the MDL. Sample types include first-flush (FF) and composite (Comp) storm water outfall samples. Acute WQS are also shown. The WQS shown for g-chlordane is actually for the sum of chlordane isomers.

Analyte (ng/L)	NAB-SDB6-OF9-FF	NAB-SDB6-OF18-FF	NAB-SDB6-OF9-COMP	NAB-SDB6-OF18-COMP	NAB-SDB7-OF9-COMP	NAB-SDB7-OF18-COMP	Acute WQS
2,4'-DDD	0.62	0.63	0.63	1.63	0.61	0.61	
2,4'-DDE	0.41	0.53	0.76	1.37	0.25	0.52	
2,4'-DDT	0.37	0.37	0.37	0.97	0.37	0.37	
4,4'-DDD	0.73	0.73	0.73	1.9	0.72	0.72	
4,4'-DDE	0.52	0.53	0.53	1.37	0.52	0.9	
4,4'-DDT	0.45	0.45	0.45	1.18	1.39	0.44	130
aldrin	0.3	0.3	0.3	0.79	1.65	0.3	1300
a-chlordane	0.29	0.29	0.29	0.76	0.34	0.28	90*
g-chlordane	0.31	0.31	0.31	0.81	0.3	0.3	
a-BHC	0.26	0.26	0.26	0.69	0.26	0.26	
b-BHC	0.36	0.36	0.36	0.95	0.36	0.36	
d-BHC	0.3	0.3	0.3	0.78	0.99	0.67	
Lindane	0.38	0.38	0.38	0.99	0.37	0.37	
cis-nonachlor	0.49	0.5	0.5	1.29	0.49	0.49	
trans-nonachlor	0.31	0.31	0.31	0.81	1.14	0.31	
Chlorpyrifos	0.39	0.39	0.39	1.02	0.39	0.39	11
oxychlordane	0.3	0.3	0.3	0.78	0.3	0.3	
dieldrin	0.58	0.59	0.59	1.53	0.58	0.58	710
endosulfan I	0.21	0.21	0.21	0.55	0.21	0.21	34
endosulfan II	0.53	0.53	0.53	1.38	0.52	0.52	34
endosulfan sulfate	0.5	0.5	0.5	1.3	0.49	0.49	
endrin	0.57	0.58	0.58	1.5	0.57	0.57	37
endrin aldehyde	0.65	0.65	0.65	1.7	0.64	0.64	
endrin ketone	0.68	0.68	0.68	1.78	0.67	0.67	
heptachlor	0.45	5.65	4.57	1.17	0.44	0.44	53
heptachlor epoxide	1.2	1.21	1.21	3.15	1.19	1.19	53
Hexachlorobenzene	0.63	0.64	0.64	1.65	0.62	0.62	
methoxychlor	0.75	0.75	0.75	1.76	0.74	5.28	
Mirex	0.47	0.48	0.48	1.24	0.47	0.47	

7.4.5 Plume Mapping

Plume mapping was performed at Naval Amphibious Base Coronado on three occasions, during the SDB4, SDB6, and SDB7 storm events. Three surveys were conducted after the SDB4 storm event, which began with 0.1-inch rainfall on 17 October 2004. First-flush samples were collected at that time. The first plume mapping survey did not begin until the 18 October, when it became clear that the bulk of the storm was on its way. The “Pre”-SDB4 mapping survey was conducted as it began to rain on 18 October. The “During” surveys were conducted during the next 2 days, when up to 1.7 inches of rain fell over the time period. No “After” surveys were conducted because of logistical constraints.

Figure 47 shows spatial maps of surface salinity from surveys made before and during the SDB4 storm event. Figure 4 shows the timetable of the surveys and rainfall. Appendix G shows Spatial plots for all parameters measured during these surveys. The pre-storm plot captured a condition when some light drizzle had fallen before arrival. The "during" plot was produced from data collected on the third day of the storm after 1.7 inches of rain had fallen during heavy squall conditions. Because of the near continuous rainfall over several tide cycles, a large freshwater signature covered most of the inner portion of the bay during this survey, evidenced by the relatively lower salinity seen at the top right of the plot. The salinity distribution during the storm shows freshwater along the northern shore of the base, with a smaller signal on the southern shore. The minimum salinity was observed in the northwest corner of the base, just to the east of where the discharge from outfall 18 enters the bay, and where a number of relatively large drainages also discharge. The maximum reduction in salinity at this location (from 33.2 to 28.5) by freshwater input was 14%.

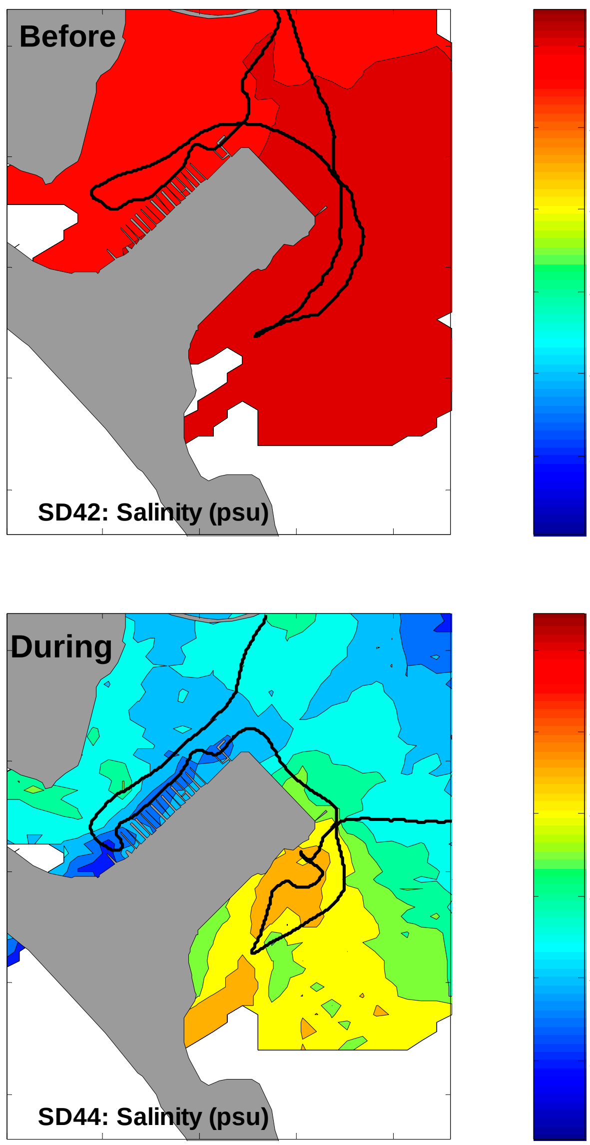


Figure 47. Surface salinity mapping before and during storm event (SDB4) at Naval Amphibious Base Coronado. There was no mapping performed after the storm.

7.5 NAVAL AIR STATION NORTH ISLAND

7.5.1 Storm Water Toxicity

Nine storm water outfall samples were tested, not necessarily for all species, for toxicity at Naval Air Station North Island. Figure 48 shows the 100% storm water effluent toxicity data. Table 35 provides a statistical summary of the results. Appendices B and C provide all toxicity data.

Overall, topsmelt appeared to respond similarly to mysids at these sites (Figure 48). First-flush samples ranged between 57 and 100% survival and averaged 83% for the two species. No mortality was observed in the composite samples. For topsmelt, 43% of the first-flush samples would have failed the 90% survival requirement, while no composites would have failed. Topsmelt and mysids in first-flush samples would have failed the 70% survival requirement 14% and 10% of the time, respectively. None of the composite samples would have failed the 70% requirement for both species.

For Naval Air Station North Island samples, 80% of NOECs (combined for topsmelt and mysids) were 100% storm water effluent. One of the 15 dilution series results run on first-flush samples had a NOEC of 25%. All the composite samples had a NOEC of 100%. These data suggest that a receiving water mixture with less than a 25% storm water fraction would result in no observable toxicity.

Mussel larval development was more sensitive and more variable than the permitted species in first-flush outfall samples that ranged from 0% to 89% normal development. The single composite sample tested with mussels did not significantly disrupt larval development. This sample also showed no toxicity to topsmelt or mysids. Though the study was not designed to compare outfalls, a qualitative review of paired data showed that toxicity in samples from the two outfalls was highly variable, with no clear pattern of relative magnitude of effects in one outfall versus the other. NOECs for mussels ranged from 6.25 to 69% (the maximum effluent concentration tested). These data suggest that a receiving water mixture with less than a 6% storm water fraction would result in no observable toxicity.

As described earlier, method variability in toxicity testing is an important consideration for evaluating results. Table 36 shows the PMSD for Naval Air Station North Island industrial storm water dilution series toxicity tests, including baseline TIE results. PMSD values ranged from 8 to 19% for topsmelt and averaged 14%. PMSD for mysid tests ranged from 5 to 15% and averaged 10%. The mussel embryo-larval development tests ranged from 2 to 5% and averaged 3%. The mysid results all fell well within EPA guidelines for test acceptability (EPA, 2000a). The topsmelt and mussel data also met the PMSD test acceptability criteria for comparable endpoints (inland silverside survival and mussel survival and normal development). These differences are described later in the discussion section.

7.5.2 Receiving Water Toxicity

Thirteen receiving water samples were tested, not necessarily for all species, for toxicity at Naval Air Station North Island. Survival was very high for topsmelt and mysids exposed to bay waters, with a combined average survival of 98%. All topsmelt and mysid bay water data were statistically indistinguishable from lab controls ($p<0.05$). Mussel larval development was also very high, averaging 95%, with no samples being statistically lower than the controls.

Table 35. Statistical summary of toxicity data in Naval Air Station North Island first-flush (FF) or composite (Comp) undiluted storm water or in receiving water (Bay) samples. Results are expressed as percent survival for topsmelt and mysids and as percent normal embryo-larval development for mussels. “# <90% and % Failing” refers to the number and percentage of samples that did not meet the 90% survival criterion in the permit.

NI	Topsmelt Survival (%)			Mysid Survival (%)			Mussel Normal Development (%)		
	FF	Comp	Bay	FF	Comp	Bay	FF	Comp	Bay
n	7	2	12	5	1	8	5	1	13
Min	65	100	90	57	100	93	0	96	90
Mean	86	100	98	79	100	99	18	96	95
Max	100	100	100	97	100	100	89	96	98
RSD	14	NA	3	21	NA	3	224	NA	2
# <90%	3	0	NA	3	0	NA	NA	NA	NA
% FAILING	43%	0%	NA	60%	0%	NA	NA	NA	NA

NA Not applicable

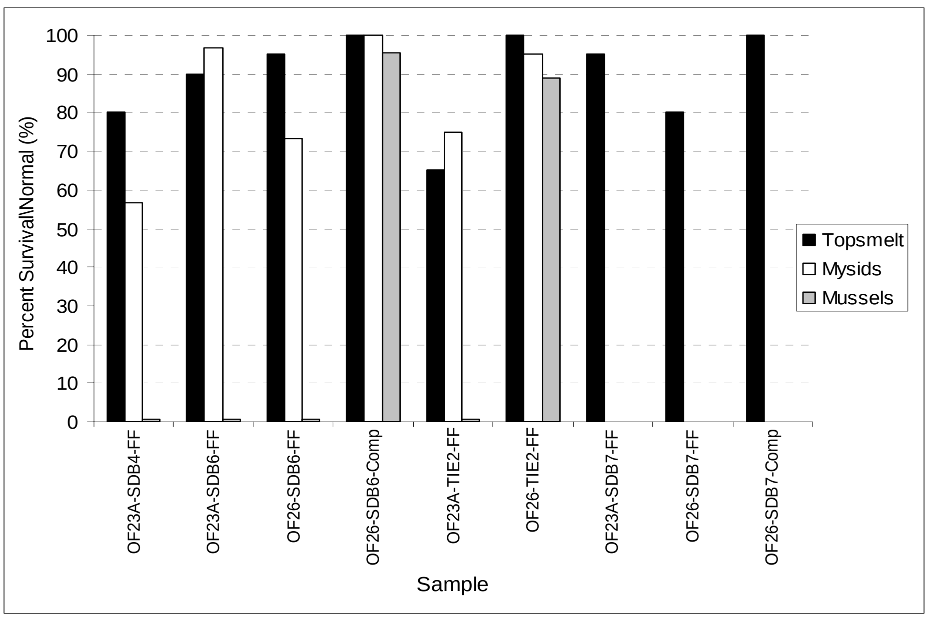


Figure 48. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Air Station North Island.

Table 36. Percent Minimum Significant Difference (PMSD) for Naval Air Station North Island toxicity tests.

PMSD	Topsmelt	Mysids	Mussels
n	6	6	6
Min (%)	8	5	2
Mean (%)	14	10	3
Max (%)	19	15	5

7.5.3 TIE

A Toxicity Identification Evaluation was performed on first-flush samples collected from each of the two outfalls at Naval Air Station North Island during the storm event on 19 March 2005. First-flush samples were collected during a very minimal rainfall event in which only 0.07 inches of rainfall fell. The TIE was performed by Nautilus Environmental LLC, San Diego. The report for this effort is included as Appendix F. Figure 49 and Figure 50 show the manipulations performed for each outfall sample. Toxicity screening results showed that there was insufficient toxicity (>20% relative to control) to perform a TIE at outfall 26 with any species. A review of the water quality data made upon receipt of the samples indicated very high conductivity (21 mmhos/cm) and hardness (>1000) that likely played a role in minimizing toxicity. These values suggest that the samples may have been partially mixed with residual seawater in the catchment, though the sampling personnel did not observe this when sampling. Toxicity was sufficient to perform a TIE at outfall 23A with all three species. Figure 49 and Figure 50 also show the results of the TIE. The cause of toxicity to mysids and topsmelt at outfall 23A was surfactants. These were not uniquely identified, but were attributed to a class of MBAS compounds. Though the toxicity data for these compounds is limited, Nautilus Environmental LLC has previously identified these compounds at the toxicant agent at concentrations above the 1 mg/L found in this sample. The toxicant agents to mussel embryo development were a combination of copper and zinc (50%) and surfactants (50%). The TIE established that copper and zinc were additive in their toxicity.

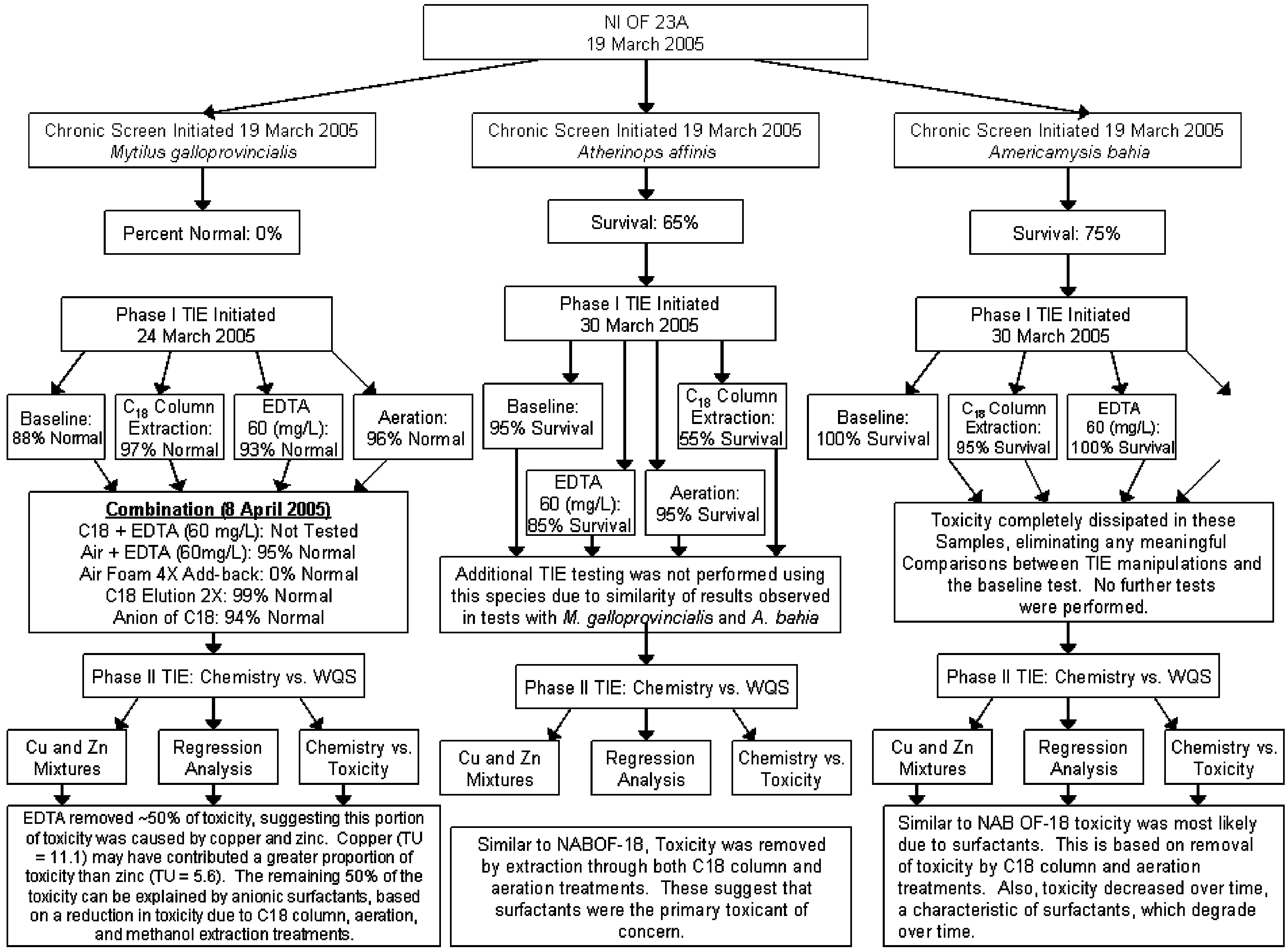


Figure 49. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Air Station North Island outfall 23A.

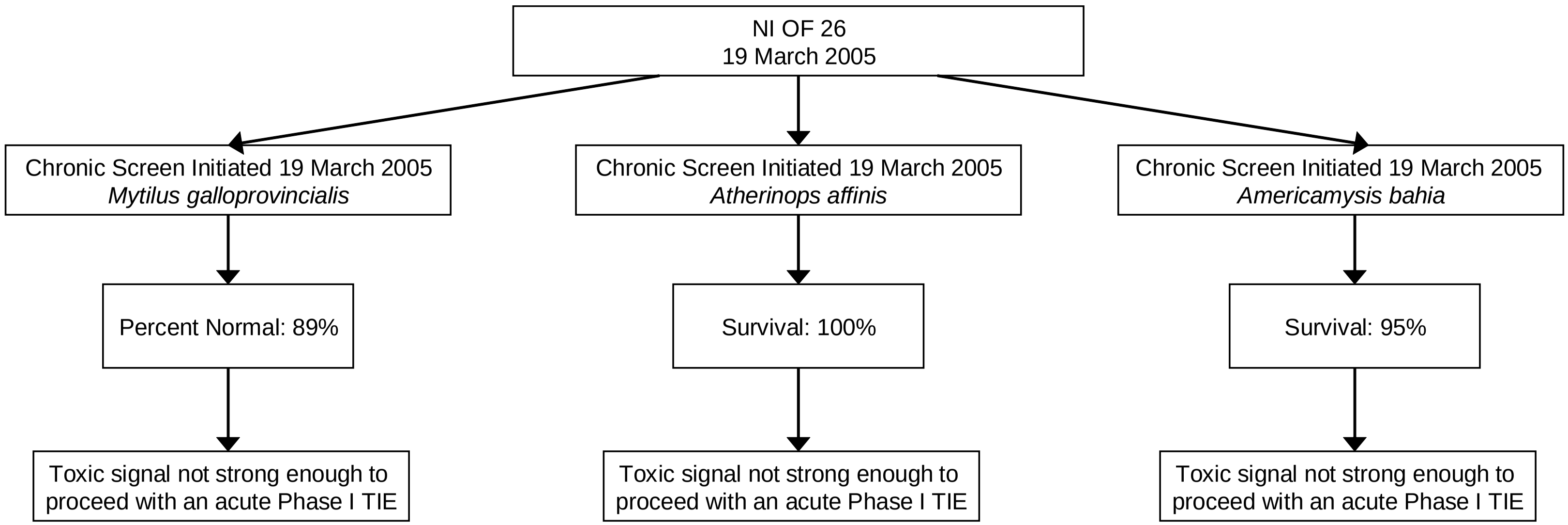


Figure 50. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Air Station North Island outfall 26.

7.5.4 Chemistry

TSS/DOC. A total of 16 and 14 samples were analyzed for TSS and DOC, respectively, at Naval Air Station North Island. Table 37 shows a statistical summary of the TSS and DOC data. Appendix D shows all individual sample data. TSS in storm water ranged from ~10 to over 200 mg/L and averaged about 90 mg/L. First-flush samples were slightly lower in TSS concentrations than corresponding composite samples, which is reflected in the averages. The maximum TSS level was measured in the first-flush sample collected at outfall 23A during the (SDB4) first-flush of the year storm event in October 2004. The second highest level of 162 mg/L was measured in the composite sample collected from outfall 26 during the SDB7 storm event in April 2005. Bay samples were an order of magnitude or more lower in TSS than the outfall samples, and ranged from ~3 to 13 mg/L. The average value for bay samples collected before the storm increased by 40% during storms, though this increase was driven primarily by one sample pair and was not statistically significant (95%).

DOC in first-flush samples was nearly a factor of 10 higher than in the composite samples. This is opposite of what was observed at the other bases. The highest level was measured in the composite sample at outfall 26 during the SDB7 storm event in April 2005. Receiving water samples had about the same DOC levels as the composite samples at roughly 3 mg/L. Bay water samples collected during storms averaged about 50% higher than the pre-storm samples though the increase was not statistically significant.

Table 37. Statistical summary of TSS and DOC data at Naval Air Station North Island. Sample types include first-flush (FF) and composite (Comp) storm water outfall samples as well as receiving water (Bay) samples collected before and during storm events.

TSS (mg/L)	Outfalls		Bay	
	FF	Comp	Before	During
n	5	2	4	5
Min	9.1	22	2.9	4.2
Mean	87	92	4.1	7.4
Max	201	162	5.5	12.7
RSD	97%	NA	29%	50%
DOC (mg/L)				
n	4	2	4	4
Min	3.8	0.9	1.7	1.9
Mean	21	3.4	2.0	3.1
Max	49	6.0	2.4	4.3

Metals. Fifteen samples were analyzed for total and dissolved metals at Naval Air Station North Island, which included six storm water outfall and nine receiving water samples. Three of the outfall samples and all nine bay samples were analyzed for only copper and zinc. Table 38 shows a statistical summary of the outfall metals data. Appendix D shows all individual sample data. The data are summarized by first-flush and composite samples and by total and dissolved metals.

Nearly half of the total copper (40%) and all total zinc concentrations in first-flush storm water samples were above their respective performance goals in the NPDES permit of 63.6 and 117 μg/L. Only dissolved copper and zinc were elevated in outfall samples above their acute saltwater WQS, with the remaining dissolved metals all well below WQS (EPA, 2000b). The comparison made for mercury was to the human health WQS of 0.05 μg/L, as discussed previously. Dissolved copper and zinc exceeded their acute WQS by a maximum factor of 15 and 9, respectively, in first-flush samples. The comparable ratio in composite samples was reduced to six for copper and was less than one for zinc (concentrations below WQS).

Maximum copper and zinc concentrations measured in storm water were 172 and 1,125 μg/L, respectively. These levels were measured in the first-flush of the year sample (SDB4) at outfall 23A (Figure 51). The next highest levels were observed in the composite sample collected at outfall 26 during the SDB7 storm event. This sample also had elevated TSS, DOC and metals. The amount of dissolved phase copper and zinc in outfall samples was quite variable, ranging from 9 to 79%. The relative amount of dissolved zinc in first-flush samples was higher than in paired composite samples but there was no consistent pattern for copper. Table 39 shows a summary of the bay seawater copper and zinc data. Appendix D shows all individual sample data. Bay water dissolved copper (5.2 μg/L) and zinc (21 μg/L) were highest in the sample collected outside outfall 23A during the first-flush of the year storm event (SDB4). This sample exceeded chronic WQS for copper, but not for zinc. The two outfall samples collected during the SDB6 storm event also had copper concentrations of 3.3 and 4.1 μg/L that exceeded the 3.1 μg/L WQS. All bay concentrations of zinc were below its chronic saltwater WQS. Similar to other areas of the bay, copper and zinc were found primarily in the dissolved phase (62 and 84%, respectively).

Table 38. Statistical summary of first-flush (FF) and composite (Comp) storm water metals data at Naval Air Station North Island. Values for the total and dissolved metal are shown. NPDES performance goals and acute WQS are also shown. Grayed-out cells are values equal to the MDL.

OF FF Total (μg/L)	**Ag**	**Cu**	**Pb**	**Hg**	**Zn**	**Al**	**As**	**Cd**	**Cr**	**Fe**	**Mn**	**Ni**	**Se**	**Sn**
n	2	5	2	2	5	2	2	2	2	2	2	2	2	2
min	0.04	33.4	3.78	0.012	129	290	0.648	0.55	1.47	388	15.1	3.83	1.47	0.5
mean	0.075	81.4	12.8	0.014	529	869	0.934	0.91	5.54	1473	29.7	7.815	1.47	1.48
max	0.109	172	21.9	0.016	1125	1448	1.22	1.26	9.61	2557	44.2	11.8	1.47	2.45
RSD	NA	73%	NA	NA	87%	NA	NA	NA	NA	NA	NA	NA	NA	NA
NPDES Performance Goal		63.6			117.0									
OF FF Dissolved (μg/L)														
n	2	5	2	2	5	2	2	2	2	2	2	2	2	2
min	0.04	3.69	0.201	0.004	33.4	11.1	0.208	0.06	0.295	12.4	0.15	1.41	1.47	0.5
mean	0.04	38.6	0.212	0.005	327	14.1	0.588	0.21	0.658	16.4	1.36	2.43	1.47	0.5
max	0.04	74.3	0.223	0.006	778	17.1	0.968	0.37	1.02	20.4	2.57	3.45	1.47	0.5
RSD	NA	70%	NA	NA	102%	NA	NA	NA	NA	NA	NA	NA	NA	NA
OF COMP Total (μg/L)														
n	2	2	2	2	2	2	2	2	2	2	2	2	2	2
min	0.072	41.0	10.8	0.021	87.3	540	2.62	1.14	3.65	756	51	5.93	1.61	0.74
mean	0.191	65.2	44.2	0.035	317	2147	7.06	3.75	11.9	3262	123	10.5	20.3	0.82
max	0.311	89.3	77.5	0.049	546	3753	11.5	6.35	20.2	5767	194	15.0	38.9	0.89
RSD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OF COMP Dissolved (μg/L)														
n	2	2	2	2	2	2	2	2	2	2	2	2	2	2
min	0.04	18.9	0.512	0.0021	36.6	19.8	1.15	0.79	1.31	22.1	7.12	4.62	1.47	0.5
mean	0.04	24.0	1.01	0.0038	58.1	70.4	6.08	0.84	1.61	62.6	15.4	5.29	19.9	0.5
max	0.04	29.1	1.50	0.0055	79.5	121	11.0	0.88	1.90	103	23.6	5.95	38.3	0.5
RSD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
WQS Acute (μg/L)	1.9	4.8	210		90		69	42	1100			74	290	

Table 39. Statistical summary of total and dissolved bay seawater metals data at Naval Air Station North Island. Chronic WQS are also shown.

Bay Total (μg/L)	**Cu**	**Zn**
n	9	9
min	2.31	6.30
mean	5.10	15.5
max	9.7	29
RSD	49%	53%
Bay Dissolved (μg/L)		
n	9	9
min	1.68	5.06
mean	2.92	12.5
max	5.2	21
RSD	39%	46%
WQS Chronic (μg/L)	3.1	81

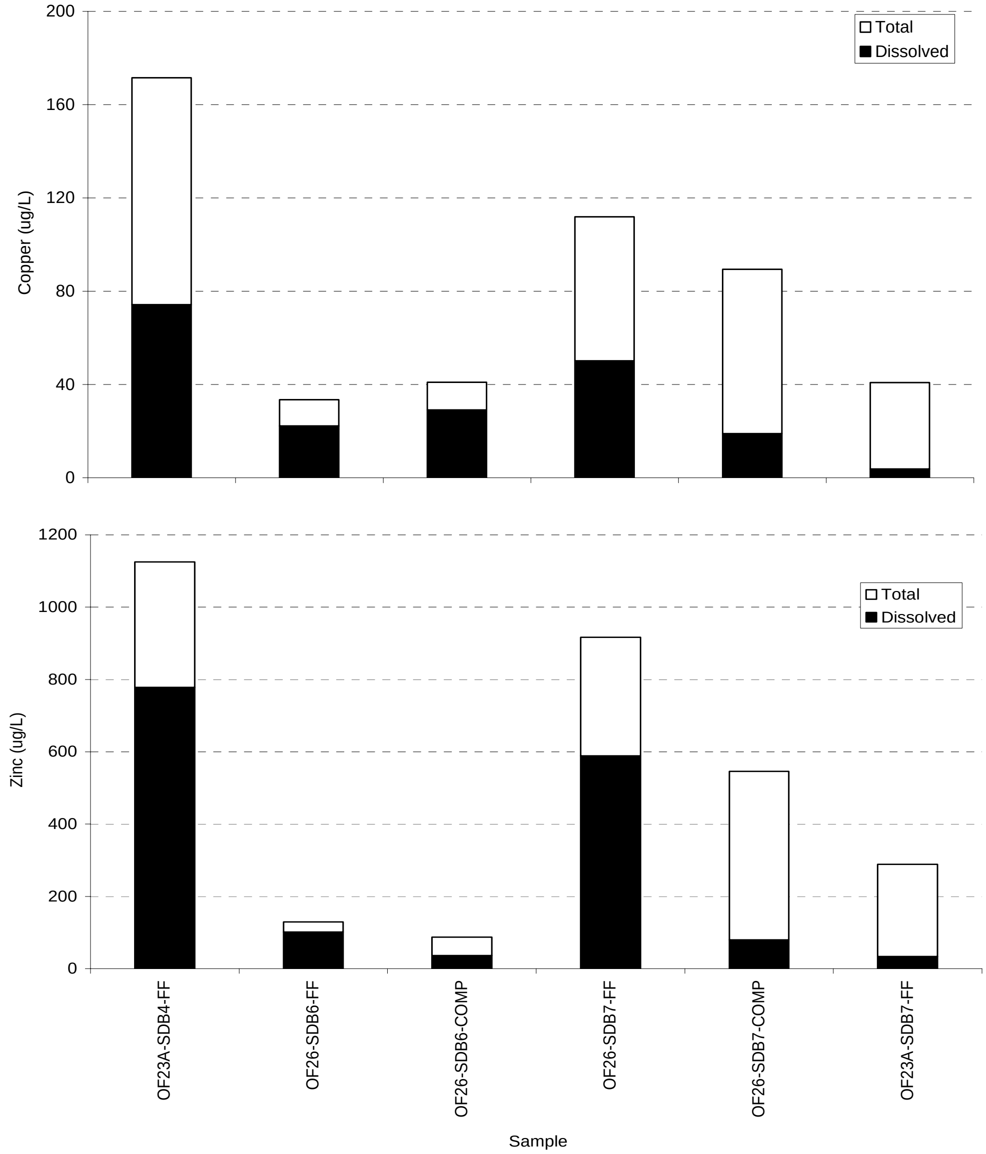


Figure 51. Total and dissolved copper and zinc concentrations measured in Naval Air Station North Island in first-flush (FF) and composite (Comp) storm water samples.

PAH. Thirteen samples were analyzed for PAH at Naval Air Station North Island. The total includes six storm water outfall and seven receiving water samples. Table 40 shows a statistical summary of storm water and bay water samples that is based on the summation of the 16 priority pollutant PAH data. Appendix D shows all individual sample data. The sum of priority pollutant PAH concentrations in outfall samples ranged from ~100 to 10,700 ng/L, the maximum value representing the highest level observed at any base in the study. This maximum concentration was measured in the composite sample collected from outfall 26 during the SDB7 storm event. The associated first-flush sample was nearly a factor of seven lower in PAH. The composite sample was also elevated in DOC, TSS, and metals. The data collected from outfalls and receiving water sites showed considerable variability (Figure 52).

Receiving water summed priority pollutant PAH ranged from 24 to 1369 ng/L. PAH in samples collected in bay samples outside OF23A before and during storm events was actually higher than levels measured in the associated first-flush storm water sample. PAH in first-flush, composite, and in bay water samples outside outfall 26, were quite variable from storm to storm. The observed variations were also not consistent with trends in one type of sample opposite to the trends observed in another. The reason for this high degree of variability is not known.

Only about 3% of priority pollutant PAHs in the outfall samples was below a MDL, which ranged from 0.4 to 1.5 ng/L, depending on the specific analyte. Analytes not detected were given a value equal to one-half the MDL in the summation. About 38% of priority pollutant PAH analytes in bay water samples were below a MDL.

Fluoranthene (one of four samples) and pyrene (four of four samples) exceeded minimum acute thresholds for individual PAH analytes shown in Table 11 at Naval Air Station North Island outfall 26. These included measurements made in two first-flush and two composite samples. All the receiving water samples contained PAH concentrations below the minimum chronic threshold values shown in Table 11.

The relative PAH composition of first-flush and composite samples collected from outfall 26 was nearly identical and showed a mixed petrogenic and pyrogenic source signal. There was a relatively higher petrogenic signal in the first-flush sample collected during the SDB6 storm event, though the corresponding composite sample was more similar to the other outfall samples. The relative PAH composition of first-flush samples collected from outfall 23A during the SDB6 storm event showed a relatively higher petrogenic signal than the first-flush sample collected during the SDB7 storm event. No composite samples were collected from this outfall because of logistical constraints.

Receiving water samples collected outside of both outfalls before the SDB6 storm event showed a nearly identical low-level mixture of pyrogenic and petrogenic PAH (Figure 55). Samples collected during both storm events had a similar PAH composition, though there was a slight elevation in phenanthrene, fluoranthene, pyrene, and chrysene in these samples. These samples had a distinctly different composition than that of storm water and did not appear to be altered appreciably by the storm discharge. The difference in composition suggests sources other than storm water may have been responsible for the observed variability.

Table 40. Statistical summary of the sum of priority pollutant PAH data at Naval Air Station North Island. The summation used one-half the MDL for analytes not detected in the sample. Sample types include first-flush (FF) and composite (Comp) storm water outfall samples as well as receiving water (Bay) samples collected before (PRE) and during (DUR) storm events.

Sum Priority Pollutant PAH (ng/L)	Outfalls		Bay	
	FF	COMP	PRE	DUR
n	4	2	3	4
Min	96	2204	11	24
Average	1784	6484	239	744
Max	5119	10764	692	1369
RSD	129%	NA	165%	74%

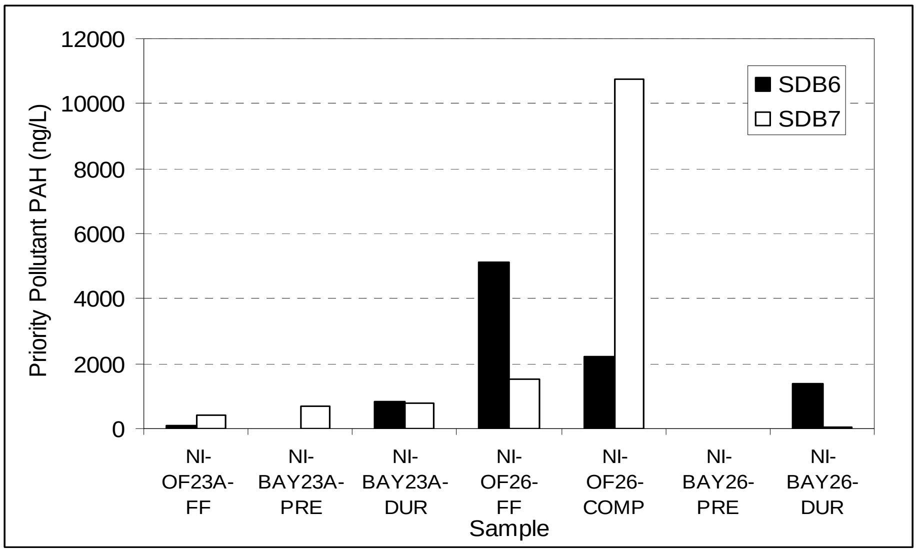


Figure 52. Summed priority pollutant PAH data for Naval Air Station North Island samples collected during storms SDB6 and SDB7. Analytes not detected were given a value equal to one-half the MDL in the summation. Sample types include first-flush (FF) and composite (COMP) outfall (OF) samples as well as bay (BAY) samples collected before (PRE) and during (DUR) storms.

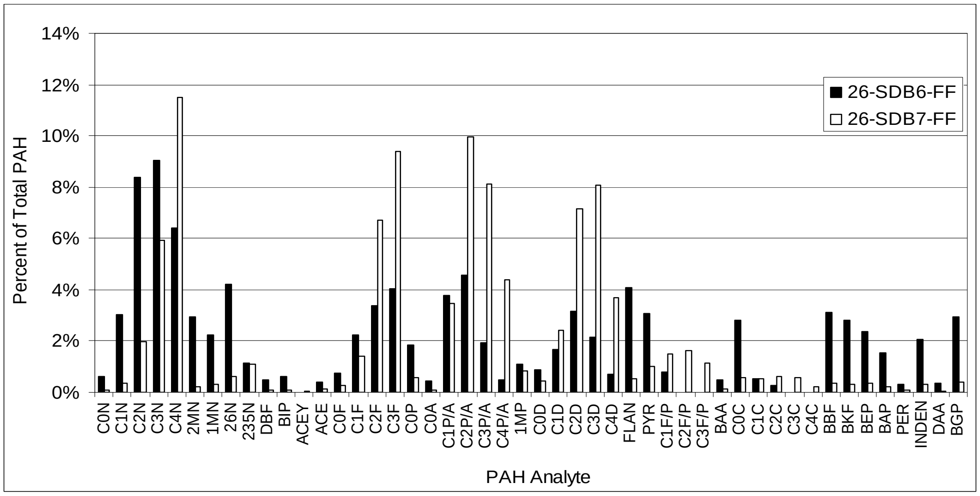


Figure 53. Relative PAH composition in first-flush samples collected from Naval Air Station North Island outfall 26 during the SDB6 and SDB7 storm events. Table 6 shows analyte IDs.

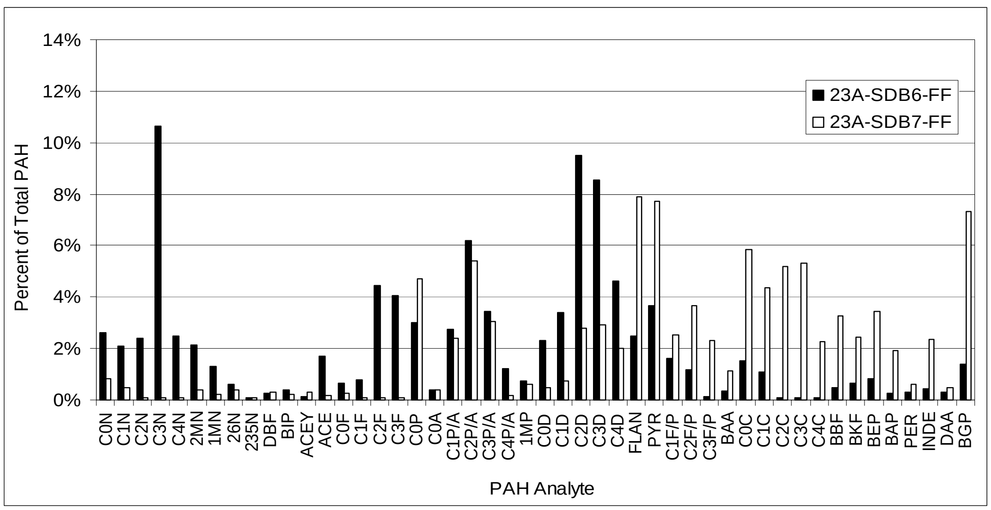


Figure 54. Relative PAH composition in first-flush samples collected from Naval Air Station North Island outfall 23A during the SDB6 and SDB7 storm events. Table 6 shows analyte IDs.

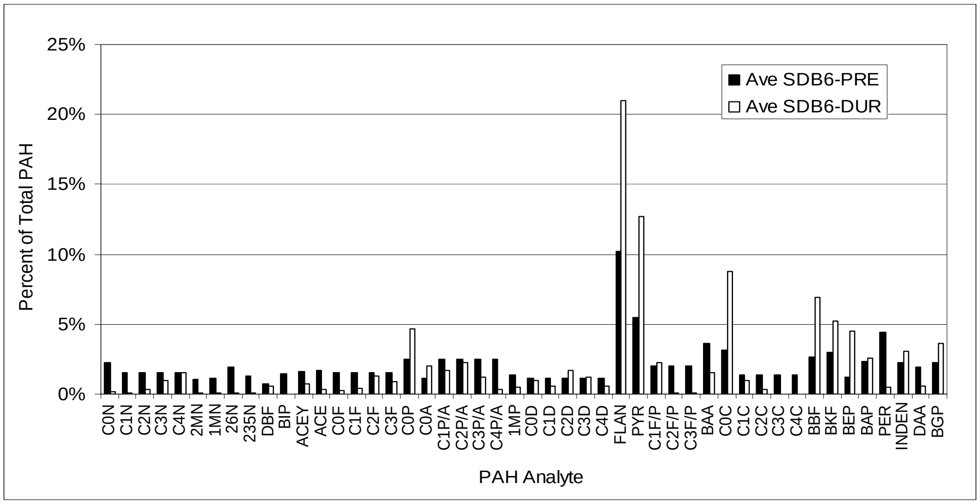


Figure 55. Average relative PAH composition in receiving water samples collected before and during the SDB6 storm event outside Naval Air Station North Island outfalls 23A and 26. Table 6 shows analyte IDs.

PCB. Nine samples were analyzed for PCB at Naval Air Station North Island. The total includes five storm water outfall and four receiving water samples. Table 41 shows a statistical summary of PCB data. Appendix D shows all individual sample data. The sum of PCB concentrations in storm water samples ranged from 2.9 ng/L (all congeners below detection) to a maximum of 742 ng/L. The maximum concentration was measured in the composite sample collected from outfall 26 during storm SDB7 and was the maximum found in any sample collected in the study. This sample was elevated in other contaminants as well. Except for this sample, nearly all PCB congeners were below or near the detection limit that ranged from 0.07 to 0.66 ng/L, depending on the congener. PCB levels measured in storm water all fell below the minimum acute toxicity thresholds (EPA, 1987).

Nearly all PCB congeners in receiving water samples were below detection. The maximum bay water summed PCB concentration calculated from these data was 4.4 ng/L. All values were below the chronic PCB WQS of 30 ng/L (EPA, 2000b).

Table 41. Statistical summary of PCB data at Naval Air Station North Island. “Sum PCB” is the summation of all congeners measured in the sample. The summation used one-half the MDL for congeners not detected in the sample. Sample types include first-flush (FF), composite (COMP) storm water outfall samples and bay samples collected before (PRE) and during (DUR) a storm event. Toxicity threshold benchmarks are also shown.

Sum PCB (ng/L)	Outfalls		Bay	
	FF	COMP	PRE	DUR
n	3	2	2	2
min	2.9	5.2	2.8	2.8
mean	4.4	374	3.2	3.6
max	6.0	742	3.6	4.4
RSD	34%	NA	NA	NA
Threshold	Acute 10,000		Chronic 30	

Pesticides. Nine samples were analyzed for chlorinated pesticides at Naval Air Station North Island. Table 42 shows these data. Appendix D shows all individual sample data. Though most analytes were below MDLs that ranged from 0.3 to 1.2 ng/L, depending on the analyte, the two composite samples collected at outfall 26 during the SDB6 and SDB7 storm events had multiple pesticides above detection limits. Pesticide levels were a maximum in the composite sample at outfall 26 during SDB7, consistent with other contaminants measured in the sample. Including these maximum concentrations, none of the chlorinated pesticides measured in storm water samples exceeded an acute WQS (Table 42).

All pesticide concentrations measured in receiving water samples were below detection except for four analytes in the sample collected during the SDB7 storm event outside outfall 26 (Table 42). This sample had a 4',4' DDT concentration that exceeded its chronic WQS (EPA, 2000b). The remainder of the analytes was below chronic WQS.

Table 42. Chlorinated pesticide data collected at Naval Air Station North Island . Grayed-out cells contain values that were *above* the MDL, with all other data at the MDL. Sample types include first-flush (FF) and composite (Comp) storm water samples, and receiving water (BAY) before (PRE) and during (DUR) storm event samples. Acute and chronic water quality standards are also shown. The WQS shown for g-chlordane is actually for the sum of chlordane isomers.

Pesticide (ng/L)	SDB6-OF23A-FF	SDB6-OF26-FF	SDB7-OF23A-FF	SDB6-OF26-COMP	SDB7-OF26-COMP	Acute WQC (ng/L)	SDB6-BAY23A-PRE	SDB6-BAY23A-DUR	SDB6-BAY26-PRE	SDB6-BAY26-DUR	Chronic WQS (ng/L)
2,4'-DDD	0.63	0.62	0.62	0.62	7.52		0.62	0.62	0.62	0.63	
2,4'-DDE	1.16	0.52	0.52	0.52	0.52		0.52	0.52	0.52	0.53	
2,4'-DDT	0.37	0.37	0.37	0.37	5.98		0.37	0.37	0.37	0.37	
4,4'-DDD	0.73	3	3	2.1	6.55		0.72	0.72	0.73	1.19	
4,4'-DDE	0.53	0.52	0.52	0.82	9.29		0.52	0.52	0.52	0.71	
4,4'-DDT	0.45	0.45	0.45	4.58	16.1	130	0.45	0.45	0.45	3.37	1
aldrin	0.3	0.3	0.3	0.3	0.3	1300	0.3	0.3	0.3	0.3	
a-chlordane	0.29	0.29	0.29	1.7	8.56		0.29	0.29	0.29	0.47	
g-chlordane	0.31	0.31	0.31	0.31	14.36	90	0.31	0.31	0.31	0.31	4
a-BHC	0.26	0.26	0.26	0.26	0.26		0.26	0.26	0.26	0.26	
b-BHC	0.36	0.36	0.36	0.36	0.36		0.36	0.36	0.36	0.36	
d-BHC	0.3	0.3	0.3	0.3	1.62		0.29	0.3	0.3	0.3	
Lindane	0.38	0.38	0.38	0.38	0.37		0.37	0.38	0.38	0.38	
cis-nonachlor	0.5	0.49	0.49	0.49	3.16		0.49	0.49	0.49	0.5	
trans-nonachlor	0.31	0.31	0.31	1.62	6.48		0.31	0.31	0.31	0.65	
Chlorpyrifos	0.39	0.39	0.39	0.39	0.39		0.39	0.39	0.39	0.39	
oxychlordane	0.3	0.3	0.3	0.3	0.3		0.3	0.3	0.3	0.3	
dieldrin	0.59	0.58	0.58	0.58	2.53	710	0.58	0.58	0.58	0.59	1.9
endosulfan I	0.21	0.21	0.21	0.21	0.21	34	0.21	0.21	0.21	0.21	8.7
endosulfan II	0.53	0.53	0.53	0.53	5.98	34	0.52	0.53	0.53	0.53	8.7
endosulfan sulfate	0.5	0.5	0.5	0.5	33.23		0.49	0.49	0.5	0.5	
endrin	0.58	0.57	0.57	0.57	0.57	37	0.57	0.57	0.57	0.58	23
endrin aldehyde	0.65	0.65	0.65	0.65	6.25		0.64	0.65	0.65	0.65	
endrin ketone	0.68	0.68	0.68	0.68	0.67		0.67	0.68	0.68	0.68	
heptachlor	8.67	0.45	0.45	0.45	0.44	53	0.44	0.45	0.45	0.45	36
heptachlor epoxide	1.21	1.2	1.2	1.2	1.19	53	1.19	1.2	1.2	1.21	36
Hexachlorobenzene	0.64	0.63	0.63	0.63	0.62		0.28	0.63	0.63	0.64	
methoxychlor	0.75	9.57	9.57	6.99	15.05		0.74	0.74	0.75	0.75	
Mirex	0.48	0.47	0.47	0.47	0.47		0.47	0.47	0.47	0.48	

7.5.5 Plume Mapping

Plume mapping was performed at Naval Air Station North Island on three occasions, during the SDB4, SDB6, and SDB7 storm events. Figure 4 shows the timetable of the surveys and rainfall. Three surveys were conducted during the SDB4 storm event. The event began with a 0.1-inch rainfall on 17 October 2004. First-flush samples were collected at that time. The first plume mapping survey did not begin until the 18 October, when it became clear that the bulk of the storm was on its way. The “Pre”-SDB4 mapping survey was conducted as it began to rain on the 18 October. The “During” surveys were conducted during the next 2 days, when up to 1.7 inches of rain fell over the time period. No “After” surveys were conducted because of logistical constraints.

Figure 56 shows spatial maps of surface salinity from surveys made before and during the SDB4 storm event. Appendix G shows spatial plots for all parameters measured during these surveys. The pre-storm plot captured a condition when some light drizzle had already fallen. The pre-storm plot captured a condition when some light drizzle had fallen before arrival. The “during” plot was produced from data collected on the third day of the storm after 1.7 inches of rain had fallen during heavy squall conditions. Because of the near continuous rainfall over several tide cycles, a large freshwater signature covered most of the inner portion of the bay during this survey, evidenced by the relatively lower salinity seen throughout the spatial map of the “during” survey. The salinity was generally lower during the storm, with a maximum decrease of about 6%. There was no clear evidence of freshwater plumes along the shoreline, with the lowest salinity observed further out from shore to the north and to the east of the base. This was consistent with the whole south bay showing a lower salinity after multiple days of rain. This overall decrease was about a 2% reduction in salinity.

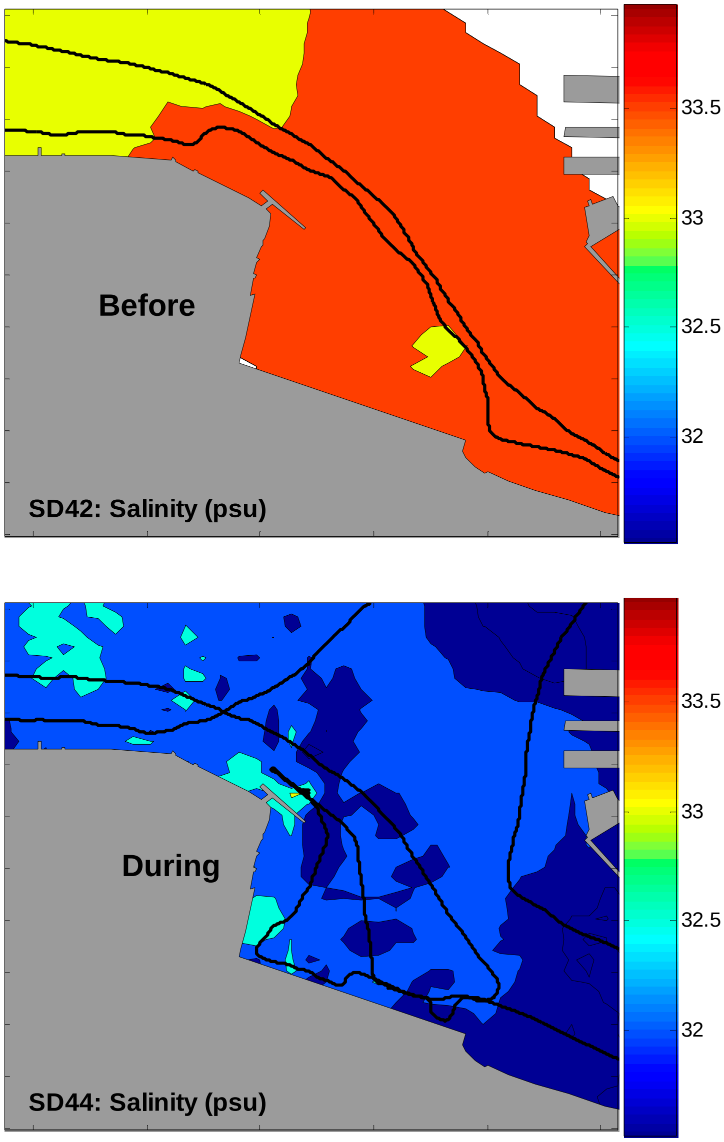


Figure 56. Surface salinity mapping before and during storm event (SDB4) at Naval Air Station North Island. There was no “after” storm mapping.

7.6 FLOATING BIOASSAY STUDY

Effluent toxicity, when adequately related to ambient conditions, can give a valid assessment of receiving water impact (EPA, 1991a). One method to link effluent WET tests to ambient impacts is to perform dilution series tests that bracket receiving water conditions to identify when there is no observable toxic impact. This method requires knowledge of receiving water exposure conditions. Two methods were used during this study to evaluate receiving water exposures. Plume mapping surveys conducted throughout this study provided large-scale, multiple snapshots of receiving water exposure conditions before, during, and after rainfall events. These large-scale snapshots showed that maximum exposures were in the range of 4 to 14%, were limited in size, and dissipated quickly. The second method, using a special floating bioassay system, provided a highly detailed characterization of actual exposure conditions.

As described earlier, the technical approach in this study was to simultaneously measure toxicity and chemistry in storm water and receiving waters. In this special effort, toxicity and chemistry of receiving waters were measured on site, immediately outside Naval Station San Diego outfall 14 (Figure 57) during the SDB45 storm event. The MESC was used to monitor water quality conditions and to supply surface seawater to multiple test organisms throughout a 96-hour period just before, during, and after the storm event. The WET tests were therefore performed using actual exposure conditions present outside the outfall and evaluated with the high-resolution measurement of actual water quality conditions. Results of this effort are fully detailed in Appendix H.

Like most other results observed throughout this study, storm water discharges showed some toxicity in storm water samples, with no toxicity observed in the tests conducted in the receiving water. In this case, first-flush storm water was significantly toxic to mysids (63% survival) and mussel larvae (1% normal development) in 100% storm water effluent, but not to topsmelt (90% survival). All chemicals measured in first-flush samples were below acute WQS or other benchmarks described in Table 10 and Table 11, except for dissolved copper (45 μg/L) and zinc (175 μg/L). Total zinc (362 μg/) was also above the permit performance goal. The combination of copper and zinc combined was likely the cause of observed toxicity, though this cannot be confirmed.

No toxicity was observed in any receiving water toxicity tests. The reason for this can be seen in the bay monitoring data summarized in Figure 58. Though storm water discharge was sufficient to reduce salinity from its pre-storm value of 33.5 psu to near zero during the most intense rainfall periods, the low-salinity conditions were maintained for very short periods of time; on the order of minutes or tens of minutes. Over the full 96-hour exposure period, salinity averaged 32.4 psu, which translates into a storm water percentage that was less than 4%, with some portion of that reduction related to direct rainfall. Dissolved copper and zinc concentrations measured in receiving waters also showed short-lived variations. Maximum dissolved copper concentrations (5.5 μg/L) were 40% higher than pre-storm levels, while zinc concentrations (16 μg/L) peaked at a factor of two higher. These maximum levels were lower by factors of 8 and 23, respectively, from those measured in first-flush storm water. Though copper levels exceeded an acute WQS, the excursion was limited in duration. Copper did exceed chronic WQS throughout the period, though the levels, mostly below 4 μg/L, were below those observed to cause toxicity in receiving waters as a result of complexation reactions with DOC (Rosen, Rivera-Duarte, Kear-Padilla, and Chadwick, 2005; Arnold, 2005).

The data collected from this special study showed that storm discharges were rapidly mixed, even when the discharge was large enough to reduce salinity to near zero during the most intense conditions. Significant reductions in chemical concentrations occurred on the order of minutes or tens of minutes, thereby limiting plume exposure well below the 48- or 96-hour exposures used in standard bioassays. The issue of limited exposure has previously been identified by Hall and Anderson, 1988; Katznelson et al., 1995; and Mancini and Plummer, 1986; all cited in Burton, Pitt, and Clark, 2000). Using 100% storm water effluent to evaluate toxicity at the end-of-pipe with 2- and 4-day exposure times greatly overestimates the actual exposure conditions observed in the receiving environment. There is presently no WET test guidance on how to evaluate short-term exposure conditions presented by storm water runoff.

Figure 57. RV ECOS tied up along Naval Station San Diego quay wall outside outfall 14 during the special floating laboratory bioassay conducted in October 2004. The sensors and pump intake were ~ 15 feet away from the outfall. Note sheet runoff over quay wall.

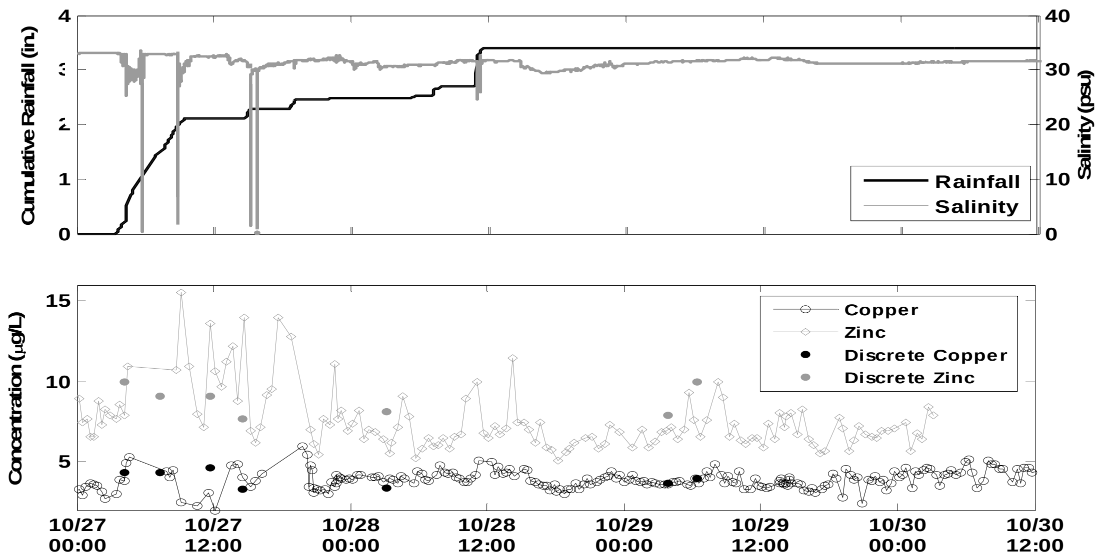


Figure 58. MESC full-storm monitoring data for receiving water salinity, cumulative rainfall (upper panel) and dissolved copper and zinc (lower panel) collected during the special floating bioassay laboratory study at Naval Station San Diego outfall 14. Dissolved copper and zinc data include results from the continuous trace metal analyzer (open symbols) and discrete samples analyzed.

As previously stated, the goal of this study was to develop a robust dataset of storm water and receiving water toxicity that can be used to support a scientifically based acute toxicity threshold for industrial storm water discharges from U.S. Navy facilities. Three simultaneous measurement components were used to meet these goals, including: toxicity and chemistry measurements in storm water discharges, toxicity and chemistry measurements in receiving waters, and plume mapping surveys to measure exposure conditions in receiving waters. These multiple lines of evidence were used to fully characterize storm water discharges and directly relate them to observed receiving water quality impacts.

May 8, 2013
Item No. 7
Supporting Document No. 7

8. DISCUSSION

The study was designed to collect a sufficient quantity of high-quality data that was representative of the full range of expected storm and discharge conditions. Therefore, the principal evaluation was based on sample data pooled from all four bases. Pooling the data provides the widest range in drainage sizes and activities, rainfall amounts, intensities, and antecedent dry weather, and the most complete range in toxicity and chemistry results. Though the evaluation also included some comparisons amongst the bases, the study was not designed to, and did not, collect, sufficient data to statistically compare outfalls or evaluate variability as a result of antecedent dry weather, rainfall total, or intensity.

Evaluation of this dataset included a discussion of how representative the collected data are of conditions expected to be found at Navy industrial sites. The magnitude and extent of storm water toxicity was evaluated using summary statistics, comparisons of first-flush and composite sample results, consideration of no observable effects concentrations, and comparisons by facility. The evaluation also includes a discussion of WET test methods used to identify a toxic result, including t-testing, percent minimum significant difference, and a comparison to the NPDES permit requirement. The causes of toxicity were focused on the toxicity identification evaluations and comparisons of chemistry results with effect levels. Impacts to receiving water quality were focused on the magnitude and extent of toxicity and chemistry observed in the receiving water, as well as on the magnitude, extent, and duration of storm water exposure conditions using results of the plume mapping and a special floating bioassay laboratory study.

The study captured nearly, if not the full range, of rainfall and discharge conditions likely to occur at these sites, and captured rainfall events that were slightly above normal historical daily rainfall totals (Figure 59). The study captured drought conditions between 2002 and 2004, followed by the third wettest season on record during the 2004 through 2005 wet season. Measurements made during this study included extrema in rainfall totals as well antecedent dry period. This included sampling at Naval Station San Diego during a record 3.5-inch rainfall in October 2004 and sampling the very first-flush of the year at all four bases after a record 183 days of antecedent dry conditions. Though first-flush sampling by its nature is independent of total rainfall for an event, composite samples were collected over a tenfold range in rainfall totals, from 0.23 inch during SDB1 to 2.1 inches during the special floating bioassay study SD45. Bay samples were collected over a slightly wider range of rainfall totals, capturing a condition after a 3-inch rainfall had fallen over 10 days (TIE1A) and a 6-inch rainfall had fallen during a 2-week period (SDB5), an amount comparable to 60% of a normal annual total storm input to the bay. These sampling conditions were representative of bay conditions that had a chance to accumulate and integrate sources and impacts.

The drainage areas and outfalls monitored during the study were chosen to be representative of the range in industrial areas of the bases that are reasonably similar at all four bases. The drainage areas monitored contained various industrial activities including, but not limited to, fuel storage and dispensing, hazardous substance storage, materials storage, metal fabrication, painting, recycling, vehicle repair and maintenance, sandblasting, scrap metal yards, and vehicle repair and maintenance. The drainages sampled had a wide range in size, from 0.5 to 75 acres. Though only 10% of the total industrial area of these bases was monitored, they contained the typical activities and land uses that are carried out at these bases. Comparing results amongst the bases provided a sense of how applicable these data were to other similar facilities.

The pooled data set provided ample toxicity, chemistry, and plume mapping data to perform a successful characterization and evaluation. A total of 136 discrete samples were collected during this study. From these samples, 333 total toxicity tests were performed, including 131 tests conducted on storm water outfall samples and 202 tests performed on receiving waters. Most samples had all three bioassays performed, providing a wide range in species and endpoint sensitivities. Nearly all the outfall samples were run with three to five dilutions to evaluate the magnitude of toxicity and to calculate NOECs and PMSDs. Though only one set of TIE analyses were performed at each outfall, the analysis of four broad classes of chemicals consisting of as many as 124 total analytes in storm water samples provided a sufficient data suite to evaluate which contaminants were likely the cause of observed toxicity. The inclusion of data from 17 plume mapping surveys conducted before, during, and after storm events provided a quality dataset from which to evaluate magnitude, extent, and duration of receiving water impacts. Thus, the pooled data provide a robust scientific dataset that is representative of the range of storm and discharge conditions that are found at these facilities.

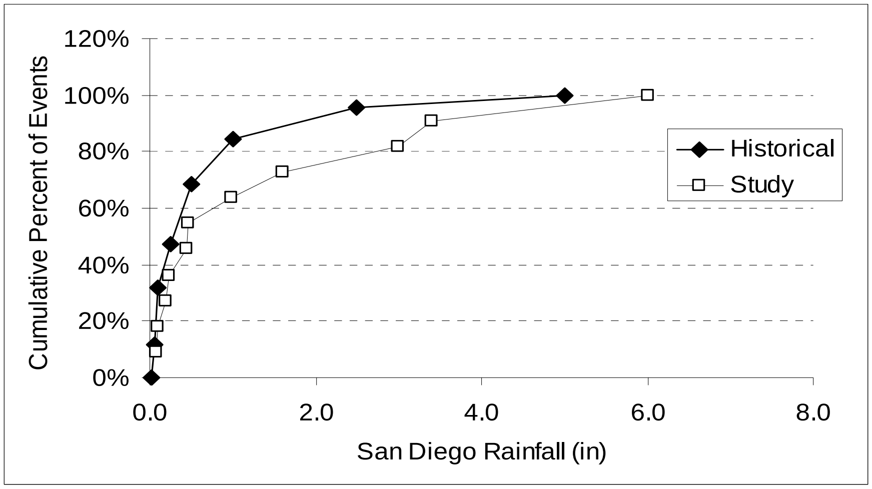


Figure 59. Historical daily rainfall data for San Diego (1948–1990) and rainfall data for storm events captured in this study.

8.1 STORM WATER TOXICITY

The toxicity requirement in the NPDES permit for all Navy bases bordering San Diego Bay is as follows:

> "…in a 96-hour static or continuous flow bioassay (toxicity) test, undiluted storm water runoff associated with industrial activity shall not produce less than 90% survival, 50% of the time, and not less than 70% survival, 10% of the time, using standard test species and protocol."

The topsmelt and mysid acute toxicity tests meet the NPDES requirement. The mussel embryo-larval development test was added to the study because it is considered a chronic endpoint in WET testing (EPA, 1995) and provides one of the most sensitive endpoints available for assessing receiving water toxicity. Though not explicitly stated in the above requirement, the permit requires that samples of undiluted storm water runoff include only those collected during the first hour of flow (first-flush). Though composite samples are not collected as part of the permit process, they were collected during this study to provide data representative of the complete storm discharge for comparison to a grab sample that is representative of a single moment in time. Though mysids were generally more sensitive than topsmelt (Figure 60), results from both species were combined for many of the following evaluations because they are interchangeable endpoints within the NPDES permit.

Ninety-two storm water samples were tested for acute toxicity using topsmelt or mysids (Table 43). This total included 64 first-flush and 28 composite tests. Overall, the toxicity of undiluted storm water measured in first-flush samples was higher, had a larger range, and was more variable than toxicity measured in composite samples (Figure 61). The acute toxicity of undiluted first-flush storm water discharging from the four Navy facilities ranged across the full extent possible, from 0 to 100%, and averaged 72% survival (RSD = 46%). Composite sample results showed a narrower range of results, 60 to 100%, and averaged 91% survival (RSD = 15%). These data take into account combined test results from the mysid and topsmelt bioassays. This general finding confirms that the initial volume discharged at the start of rainfall tends to be more toxic than the total volume that is discharged during a storm event. There were, however, a few instances where toxicity in first-flush samples equaled that in the corresponding composite sample.

The combined topsmelt and mysid results shown in Table 43 and Figure 60 show that 58% (37 of 64 tests) of first-flush samples failed the 90% survival threshold in the NPDES permit. Only 25% (7 of 28 tests) of composite samples would have failed this threshold if it applied. First-flush samples also did not meet the 70% permit threshold, failing 28% (8 of 64 tests) of the time, while composite samples failed this threshold once, representing 4% of samples. These failure rates were pooled for all bases over multiple years and may not necessarily be compared directly to permit requirements because the permit does not state specifically what “50% of the time” or “10% of the time” mean.

Though the permit sets a cutoff value at 90% survival as an acceptable result, it does not accurately identify results that would be declared acutely toxic using the standard statistical approach used in WET testing (EPA, 2002; Wang, Denton, and Shukla, 2000). The standard method to declare a test result as toxic is to statistically compare (t-test) the result to controls run with the test, provided the controls meet test acceptability criteria (EPA, 2002). Establishing a quantifiable difference between the control and treatment is fundamental to the issue of identifying toxicity. This is because of variations in organism quality and even small variations in testing procedures that affect within-test variability on a random basis. It is particularly important if control performance (e.g., survival) is allowed to vary within acceptable limits. As control performance varies, the statistical comparison will always evaluate the treatment response in the context of the actual control performance, and retain a consistent level of sensitivity regardless of the level of control survival. Using this standard method, 34% (22 of 64 tests) of first-flush samples were identified as toxic compared to the 58% identified by the permit cutoff value. The 90% survival requirement in the permit therefore classifies about 40% of test results as a failure, though they are not toxic using standard WET data evaluation procedures.

The observed reduction of acute toxicity in composite samples compared to first-flush samples indicates that the potential for toxic impact in receiving waters is less than might be predicted from the first-flush grabs alone. Because of the sampling method, there is no way to determine what percentage of the storm discharge was represented by first-flush samples. However, the potential for an acute impact generally declined with time and the volume of storm water discharged. This observation was at least partially responsible for limited toxicity observed in the receiving environment (Figure 61).

The dilution series tests performed on storm water effluent samples provided NOEC data that were used to estimate what receiving water concentrations, once entrained with storm water, would not show an adverse impact. As described previously, the NOEC represents the highest effect concentration in the dilution series that was not significantly different from the control response, and is thus an indicator of the receiving water concentration, once mixed with storm water, which does not result in a toxic effect. The dilution series tests were run with pre-storm bay water as the diluent to ensure that the results would account for any added background toxicity that may be present in the bay as well as reflect any complexation capacity that receiving waters may have to mitigate toxicity.

The vast majority (75%) of storm water samples (first-flush and composite) had topsmelt and mysid NOEC values equivalent to 100% effluent. These samples were not significantly toxic and storm water discharges to the receiving environment would not have resulted in adverse impacts. The minimum NOEC for the remaining 25% of topsmelt and mysid results was 10%. This suggests that receiving waters with a storm water fraction less than 10% would not have an adverse impact. The fact that all 137 (Figure 61) receiving water samples were not toxic to either topsmelt or mysids indicates that the receiving water concentrations were always below a storm water fraction of 10%.

The chronic mussel embryo-larval development test was run on storm water primarily to compare with receiving water results. Results in undiluted storm water showed a similar degree of variability (0 to 89% normal development) as was seen in the acute tests and, as expected, showed a higher level of toxicity, averaging 5% normal development. About 10% of 40 mussel bioassays run with storm water had a NOEC equivalent to the maximum effluent concentrations tested, which ranged from 61 to 69% effluent. The minimum NOEC in any of the mussel dilution series tests was <6.25% effluent measured in the first-flush samples collected at three of the four bases during the first-flush of the year event (SDB4). These data indicate that receiving waters with a storm water fraction less than about 6% would show an adverse impact, though the exact amount was not determined. Two of these samples, at Naval Station San Diego and Naval Amphibious Base Coronado, did exhibit receiving water toxicity to mussels.

Overall storm water toxicity levels varied significantly from base to base, though the differences can only be attributed to differences in the specific drainage areas monitored rather than the bases taken as a whole. Figure 62 shows the combined toxicity results, including first-flush and composite samples for mysids and topsmelt, for each base. Toxicity decreased in the relative order NAB>NAV>NI~SUB. The differences between Naval Amphibious Base Coronado and all three of the other bases, as well as the difference between NAV and SUB, were statistically significant at the 95% confidence level.

Figure 62 shows how each base would measure up to meeting the “90%, 50% of the time” and the “70%, 10% of the time” permit requirement in first-flush samples. Only Naval Air Station North Island would have met the “90%, 50%” threshold if “50% of the time” was applied base by base. However, Naval Air Station North Island would have failed the “70%, 10%” threshold. Only Submarine Base Coronado would have met the “70%, 10%” threshold if applied on this basis. A comparable evaluation for composite storm water samples shows that all bases except Naval Amphibious Base Coronado would have met both permit thresholds. Naval Amphibious Base Coronado composite samples would not have met either of the two requirements.

Table 43. Toxicity data summary for first-flush and composite samples by base. Values include the number of tests conducted, the number of tests failing the NPDES benchmarks of 70% and 90%, the number of tests failing the 90% requirement and significantly different from controls using a t-test, and those that were outside the 90th percentile PMSD value for the test.

First-Flush Data (counts)

Base	Topsmelt				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	10	4	6	4	4
SUB	10	0	4	0	0
NAB	7	2	3	2	2
NI	7	1	3	1	1
Total	34	7	16	7	7

Base	Mysids				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	10	5	7	6	5
SUB	10	2	7	4	2
NAB	5	3	4	4	3
NI	5	1	3	1	2
Total	30	11	21	15	12

Base	Combined				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	20	9	13	10	9
SUB	20	2	11	4	2
NAB	12	5	7	6	5
NI	12	2	6	2	3
Total	64	18	37	22	19

Composite Data (counts)

Base	Topsmelt				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	7	0	1	0	0
SUB	3	0	1	0	0
NAB	3	1	1	1	1
NI	2	0	0	0	0
Total	15	1	3	1	1

Base	Mysids				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	8	0	1	1	0
SUB	3	0	3	2	1
NAB	1	0	0	0	0
NI	1	0	0	0	0
Total	13	0	4	3	1

Base	Combined				
	# Tests	<70%	<90%	<90% & sig	>PMSD
NAV	15	0	2	1	0
SUB	6	0	4	2	1
NAB	4	1	1	1	1
NI	3	0	0	0	0
Total	28	1	7	4	2

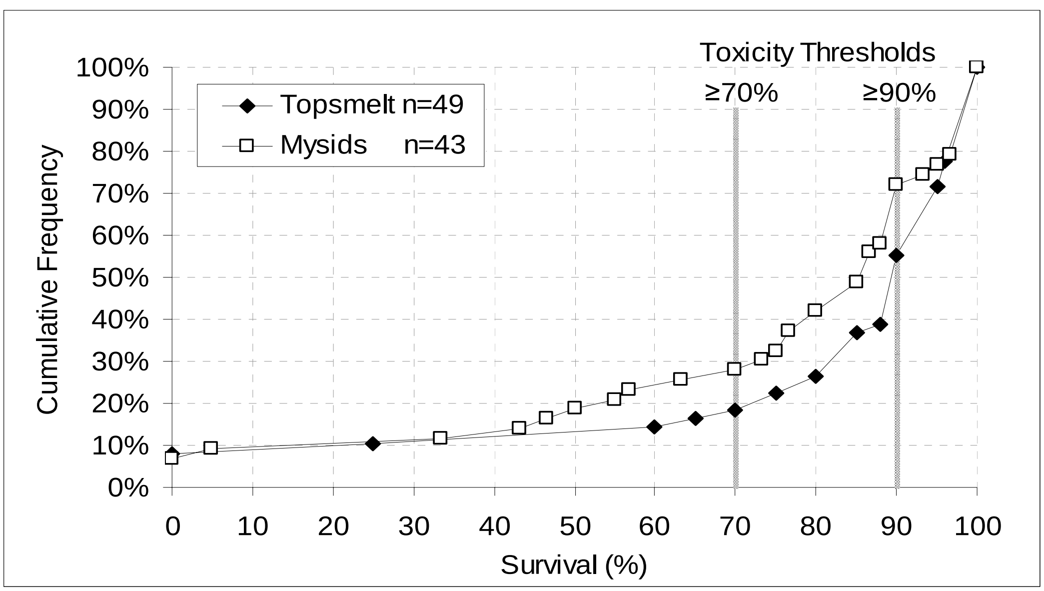


Figure 60. Mysid and topsmelt bioassay results in 100% storm water measured as percent survival in first-flush and composite storm water samples. The NPDES permit thresholds for first-flush samples are also shown.

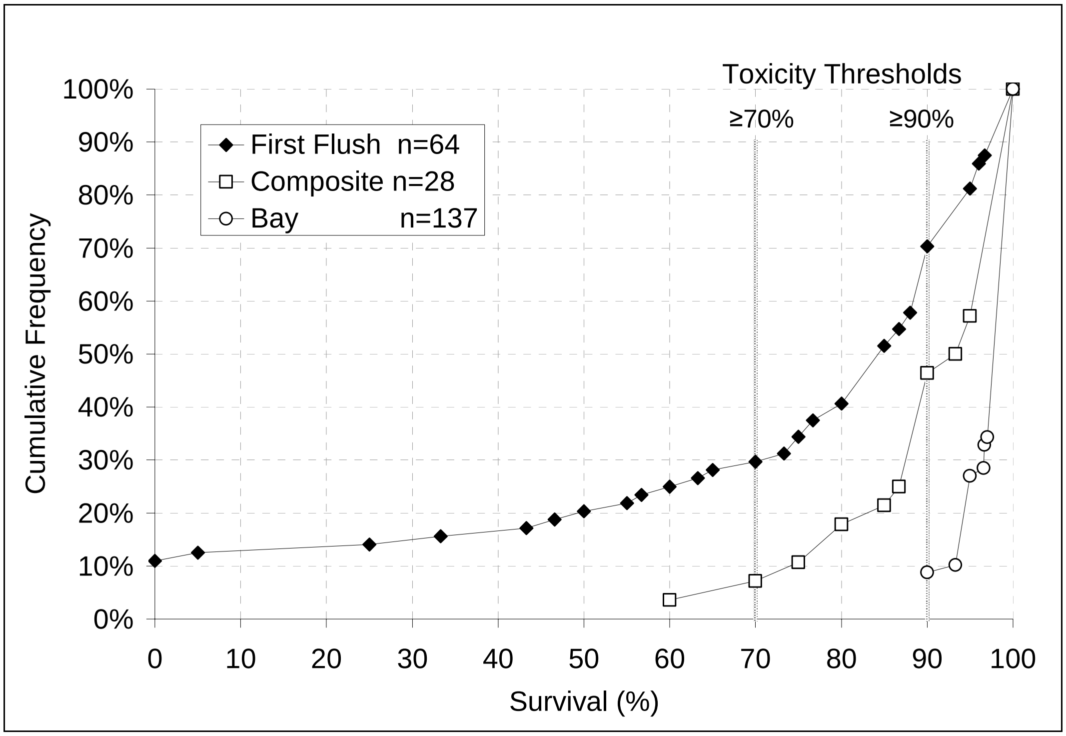


Figure 61. Combined mysid and topsmelt bioassay results in 100% storm water measured as percent survival in first-flush, composite and receiving water (Bay) samples collected from all bases. The NPDES permit thresholds for first-flush samples are also shown.

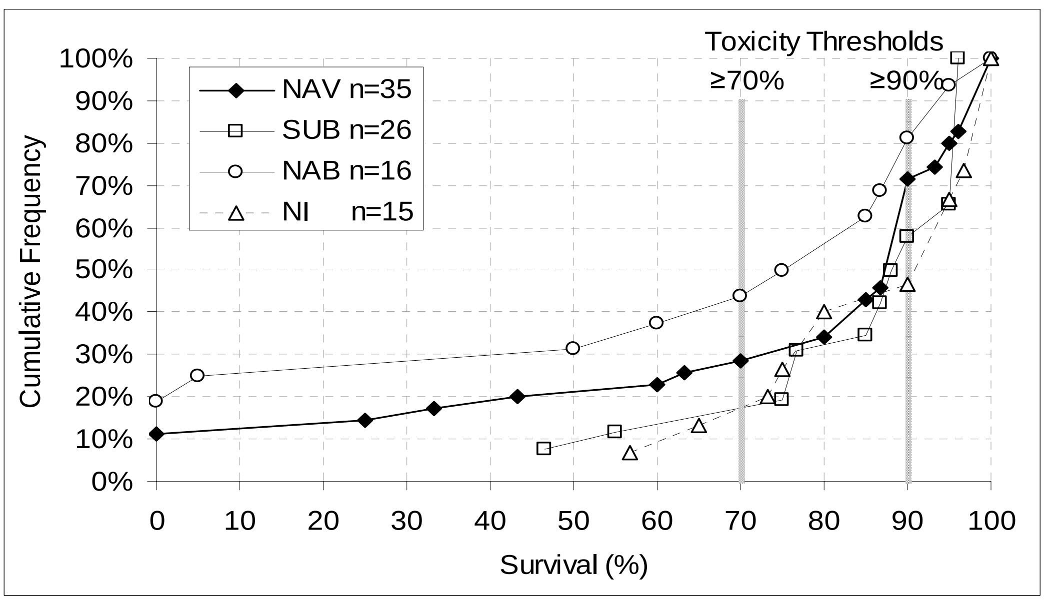


Figure 62. Combined mysid and topsmelt toxicity (as percent survival) in 100% storm water measured in first-flush and composite samples collected at the four bases Naval Station San Diego (NAV), Naval Submarine Base San Diego (SUB), Naval Amphibious Base Coronado (NAB), and Naval Air Station North Island (NI).

The EPA has spent considerable effort developing and refining toxicity-based measures for monitoring and maintaining water quality. These include development of test procedures that will provide the desired level of sensitivity in identifying adverse effects in discharges, as well as an indication of the potential for adverse effects in the receiving environment. As part of this program, the EPA has developed test procedures specifically aimed at achieving the desired level of sensitivity in terms of detecting adverse effects (e.g., the number of replicates required per test concentration) and, based on extensive studies, has quantitatively established an acceptable range of test sensitivity for each procedure. Implicit in this approach is that there must be a difference between the control and treatment; in other words, toxicity is evident only if it can be distinguished from the control.

This sensitivity is usually described as the minimum significant difference (MSD), which is defined as "the smallest difference between the control and another test treatment that can be determined as statistically significant in a given test, and the PMSD is the MSD represented as a percentage of the control response" (EPA, 2000a). By placing an upper limit (90^{th} percentile) on the PMSD, the EPA has, in effect, taken the position that toxicity tests that fall outside of this range do not exhibit sufficient sensitivity to detect adverse effects and, therefore, must be repeated. The EPA has also placed a lower bound (10^{th} percentile) on the PMSD, in this case trying to avoid rare situations in which the test exhibits high statistical sensitivity and can detect very small differences between the control and treatment with results that are not likely repeatable or not of biological significance. The evaluation and use of PMSD in WET testing can be found throughout the literature (Erickson and McDonald, 1995; Thursby, Heltshe, and Scott, 1997; Shukla et al., 2000; Wang, Denton, and Shukla, 2000; Phillips et al., 2001; Denton, Fox, and Faulk, 2003).

PMSD incorporates method variability specific to each test species and endpoint. PMSD data were calculated, compiled, and tabulated for each bioassay test species (Table 44). The data are also shown in Figure 63 through Figure 65 as probability distributions in which the PMSD is plotted as a cumulative frequency distribution. Shown along with these data are the PMSD results from the EPA WET variability guidance document (EPA, 2000a) as well as recent results provided by Nautilus Environmental, LLC. The EPA data were derived solely from reference toxicant data from as many as five laboratories, while the data from this study included storm water and reference toxicant tests from two laboratories. The Nautilus data included results from storm water, other effluents, and reference toxicant data. Most data were derived from dilution series tests typically having four replicates for topsmelt, three replicates for mysids, and five replicates for mussels. The EPA document did not have topsmelt data, and therefore, inland silversides, another fish survival endpoint, are shown for comparison purposes only. The mussel data from EPA included a slightly more variable endpoint of survival and development rather than just the normal development endpoint used in this study or by Nautilus.

The 10^{th} and 90^{th} percentile results are highlighted in the table because they are the lower and upper bounds for test method variability and indicate acceptable limits on the sensitivity of a test to detect a difference from controls (EPA, 2000a). The lower bound is established by the 10^{th} percentile value of the distribution, meaning that this level of sensitivity will be achieved only 10% of the time, and consequently, will not be repeatable most of the time by other laboratories or even the same laboratory. Similarly, the upper bound is established by the 90^{th} percentile value of the distribution, meaning that most laboratories will be able to identify the same sample as toxic, and repeat the result.

The study's 90^{th} percentile PMSD for topsmelt, based on 54 test results, was 24%. The comparable value, calculated from the Nautilus data set containing 100 test results, was 26%. Because EPA did not provide topsmelt data, results for 48 inland silverside tests with a 90^{th} percentile PMSD of 41% were used for comparison (EPA, 2000a). The study data were generally lower than the Nautilus data

(Figure 63), though both groups had a similar 90th percentile value. This agreement suggests that a sample size of 54 was sufficient to predict a 90th percentile PMSD (Phillips et al., 2001). The EPA's inland silverside endpoint data showed relatively higher method variability and a considerably higher 90th percentile value. Because PMSD is test-species-specific, this result is shown only for comparison only.

The study's 90th percentile PMSD for mysids, based on 47 test results, was 15%. The comparable value calculated from the Nautilus data set containing 100 test results was 29%. The comparable EPA value was 26% based on a sample size of 32. The study data were lower than the Nautilus and EPA results, indicating the test method variability was better than observed by the other laboratories. The lower values probably reflect the fact that all of the EPA and 50% of the Nautilus dataset for mysids were derived from reference toxicant results, while only 20% of the study dataset was composed of reference toxicant data. The bias may therefore have been a result of variability increasing with increasing toxicity that occurs with reference toxicant tests.

The study's 90th percentile PMSD for mussels, based on 48 test results, was 22%. The comparable value calculated from the Nautilus data set containing 100 test results was 26%. The comparable EPA value was 42% based on 34 test results, though as mentioned above, the endpoint used was for survival and development. These results indicate that the study method variability in the study was at least as good as or better than observed by the other laboratories.

As stated previously, establishing a quantifiable difference between the control and treatment is fundamental to the issue of identifying toxicity. This issue was addressed above when evaluating storm water toxicity results relative to the permit requirement and to individual tests that could be declared toxic on the basis of a t-test (Table 43). This table also included the number of tests that would be declared toxic using the upper bound 90th percentile PMSD, a value that 90% of laboratories would also declare as toxic. Using this criterion for identifying a toxic result, 30% (19 of 64 tests) of first-flush samples were identified as toxic compared to the 58% (37 of 64 tests) identified as failing the 90% survival requirement. The 90% survival requirement in the permit therefore classifies twice as many test results as a failure than would be declared toxic by most laboratories. A similar comparison for composite samples showed 7% (2 of 28 tests) of samples declared toxic compared with 25% (7 of 28) using the permit cutoff, a difference of a factor of four.

In summary, acute storm water toxicity was highly variable, spanning the full range of impact, from 0 to 100% survival of test organisms. The toxicity of first-flush storm water samples, representing the discharge at one moment in time, was higher than in composite samples that were representative of the entire discharge. A base-by-base evaluation showed that toxicity generally deceased in the relative order NAB>NAV>NI~SUB. The 90% survival requirement in the NPDES permit failed for 58% of first-flush samples. However, the permit requirement did not accurately identify when samples were acutely toxic or not. When using a science-based approach to WET test methods and statistical data evaluation, toxicity of first-flush storm water would have been declared toxic 30% of the time, while composite samples would have been identified as toxic 7% of the time. Using the no observable effects concentration from dilution series testing showed that a storm water fraction of less than 6% present in the receiving environment would not result in adverse impacts.

Table 44. PMSD data for individual test species and endpoints. The data shown are the number of test results, the lower (10^{th}), median (50^{th}), and upper (90^{th}) percentiles of the distribution. Along with the study results are data from EPA (2000b) and recent results from the contract laboratory, Nautilus Environmental, LLC. Note that some EPA data (EPA, 2000a) are for slightly different endpoints and are included for comparison purposes only.

Topsmelt Survival PMSD			
	EPA*	Study	Nautilus
n	48	54	100
10th Percentile	7	6	9
50th Percentile	20	15	16
90th Percentile	41	24	26

* EPA values are for Inland Silversides for comparison

Mysid Survival PMSD			
	EPA	Study	Nautilus
n	32	48	100
10th Percentile	5	4	5
50th Percentile	15	9	15
90th Percentile	26	15	29

Mussel Embryo-Larval Development PMSD			
	EPA+	Study	Nautilus
n	34	48	100
10th Percentile	7	3	3
50th Percentile	20	9	9
90th Percentile	42	22	26

+ EPA values are for normal and survival endpoint

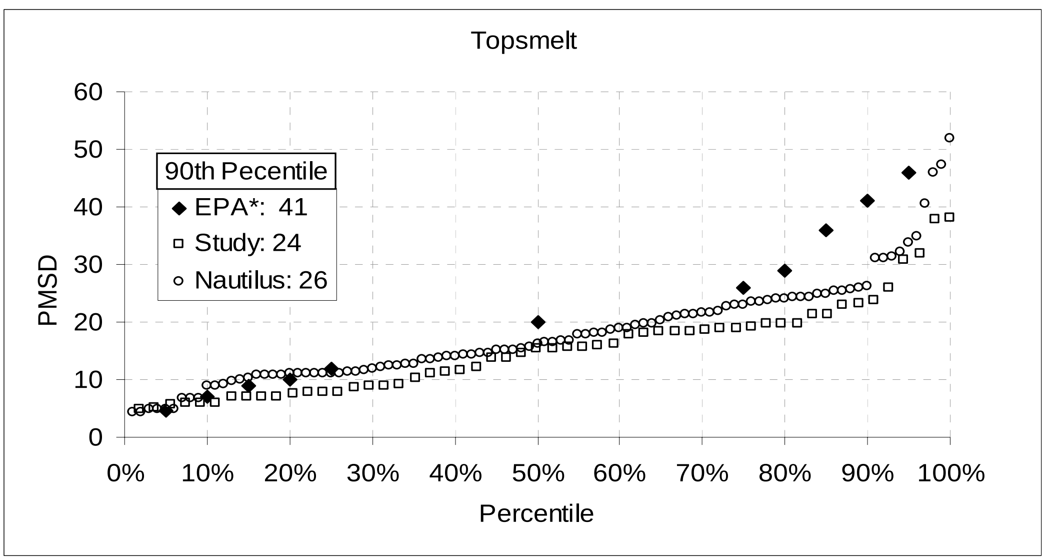


Figure 63. PMSD probability distribution for topsmelt derived from data in this study and additional data from Nautilus Environmental, LLC. EPA* data (EPA, 2000a) for inland silversides are shown for comparison.

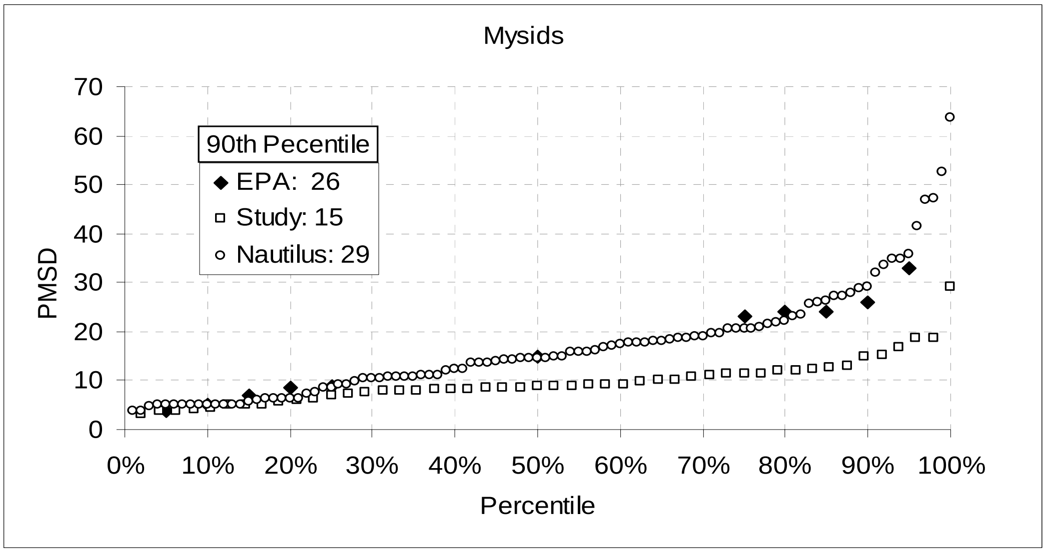


Figure 64. PMSD probability distribution for mysids derived from data in this study (EPA, 2000b) and additional data from Nautilus Environmental, LLC.

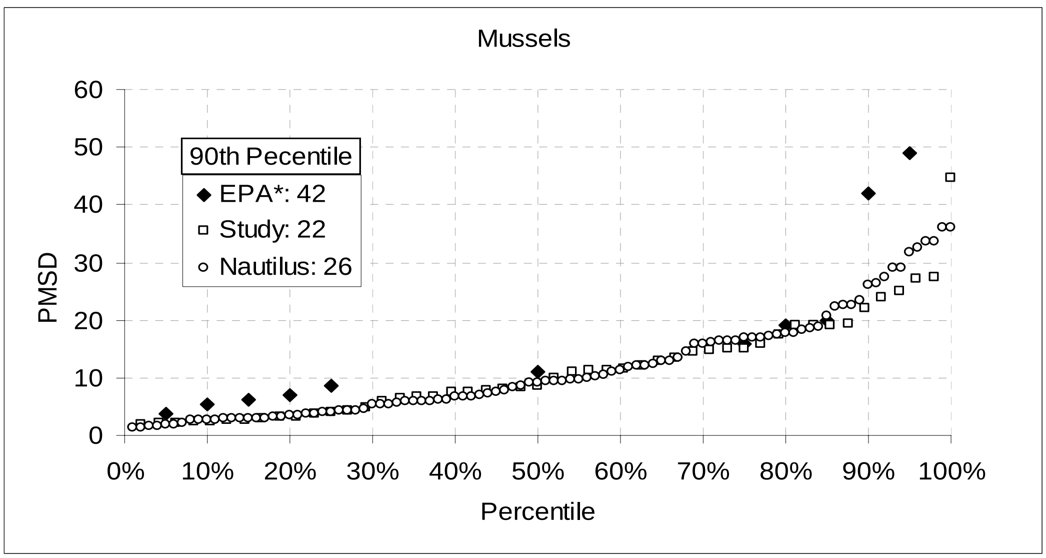


Figure 65. PMSD probability distribution for mussel embryo-larval development derived from data in this study and additional data from Nautilus Environmental, LLC. The EPA* data (EPA, 2000a) were for a survival and development endpoint which is different than just the normal development endpoint used in the study and by Nautilus.

8.2 CAUSES OF TOXICITY

The causes of toxicity in storm water samples were evaluated using results of the toxicity identification evaluation as well as chemistry results. TIEs were conducted on a single first-flush storm water sample collected from 10 of the 14 drainage areas evaluated at the four bases. The limited number of samples analyzed was a direct result of the exceptionally high costs involved in conducting these tests. Additionally, of the 10 samples evaluated, only one was sufficiently toxic to all three species tested. The TIE dataset generated, while substantial for a single project, was somewhat limited in total number of measurements. Though TIE procedures are good at identifying and confirming the basic contaminant groups such as metals, non-polar organics, and volatile compounds that cause toxicity in a sample, the ability to identify the specific contaminant(s) within these groups usually requires evaluation of sample chemistry. This step is somewhat circular, but provides the best information available for identifying the cause of toxicity. The extensive chemistry data collected as a part of the study provided a good basis for confirming results of the TIEs for the likely causes of industrial storm water toxicity at these facilities.

Results of the TIE indicated that the primary and consistent toxicants of concern to mussel embryo-larval development in all storm water samples were copper and zinc, either alone or in combination (Table 45).. At Naval Submarine Base San Diego outfall 11B, the surfactant nonylphenol was identified as a partial causative agent to mussels on the basis of anecdotal information regarding its toxicity threshold. However, recently released saltwater aquatic life criteria (EPA, 2006) indicated the sample had a concentration (0.18 μg/L), which was well below the acute criterion of 7.0 μg/L, which suggests that nonylphenol likely was not the partial causative agent. This suggests that the additional cause of toxicity in the sample is still unknown.

Most mysid and topsmelt (or inland silversides) TIE baseline tests did not exhibit sufficient toxicity to perform a TIE. Four samples were evaluated for toxicity to mysids and two to topsmelt (Table 45). Two of the four mysid evaluations showed copper and or zinc as the primary toxicant of concern. The other two storm water samples collected from Naval Amphibious Base Coronado outfall 18 and at Naval Air Station North Island outfall 23A identified the surfactant MBAS as the likely causative agent. The data cited in the Nautilus TIE reports and from their own anecdotal experience suggest that MBAS surfactant levels above 1 mg/L frequently result in toxic responses. These levels were exceeded in the samples from Naval Amphibious Base Coronado outfall 18 (1.9 mg/L) and at Naval Air Station North Island outfall 23A (1.1 mg/L). The two samples that were toxic to topsmelt were also from collected from naval Amphibious Base Coronado outfall 18 and at Naval Air Station North Island outfall 23A. MBAS was identified as the likely causative agent of toxicity to topsmelt, but the analysis could not be completed nor confirmed because of the loss in sample integrity with time.

Fifty-one storm water outfall samples were collected and analyzed for chemistry. All of these samples were analyzed for total and dissolved copper and zinc, with 38 of these also run for a full suite of total and dissolved metals (this does not include metal scans performed as part of the TIEs). Organic compounds were run primarily on composite samples and chlorinated pesticides were not initially identified as CoCs, so this resulted in 37 PAH, 31 PCB, and 18 pesticide sample analyses. Analyses for surfactants were only conducted as part of the TIE analyses and were conducted only after non-polar organics were identified as causative agents. The storm water chemistry results indicated were highly variable, typical of industrial and urban storm water runoff (Burton, Pittt, and Clark, 2000; Burton and Pitt, 2002). Of the analytes measured, only copper and zinc (Figure 66 and Figure 67) were at concentrations consistently above acute WQS. One set of samples at Naval Air Station North Island also had two PAH analytes above an acute WQS. All other chemicals were measured at levels well below acute WQS or below levels known to cause acute toxicity as described earlier.

Because both copper and zinc were additive in their toxic effect, their concentration data were converted into acute toxic units (TU_A) to assess their potential in explaining storm water toxicity. The TU_A is a way to normalize the concentration data so that they can be placed on the same scale for comparison. TU_A is calculated by dividing the dissolved metal concentration in the sample by the average concentration of dissolved metal that causes a LC50 in reference toxicant tests conducted with the same metal. A TU_A of 1, therefore, suggests that the concentration of metal in the sample should be sufficient to cause a 50% reduction in survival. The average concentration of copper and zinc that causes a LC50 varies with species. Reference toxicant data collected during this study were used to determine a LC50 and to compute TU_A for each species. The average LC50 data from these reference tests are shown in Table 46.

Figure 68 and Figure 69 show the dose-response relationship between mysid and topsmelt survival with summed TU_A for copper and zinc. The plots are based on results for the samples containing 100% storm water only. Both plots showed a general decreasing trend in survival with increasing TU_A. The response to the combined copper and zinc dose explained about 40% (R^2 of 0.4) of the variability in the data. These storm water data showed a slightly higher LC50 ($TU_A > 1.0$) than was calculated for the average reference toxicant data, suggesting that storm water has a slightly reduced toxic potential than observed with laboratory water. This toxicity reduction likely occurred as a result of complexation reactions with the very high DOC (~11 mg/L) found in storm water (Rosen et al., 2005; Arnold, 2005). Though the relationship does not explain most of the variability, the combined chemicals had a stronger relationship with survival than either of the chemicals alone. None of the other chemicals showed a trend with the toxicity data.

Because of the high sensitivity of the mussel embryo-larval development test to copper and zinc, a similar dose-response plot comparing percent normal larval development with TUs was made using all the dilution series results rather than just the 100% storm water effluent sample. Copper and zinc concentrations in the 100% storm water sample were therefore adjusted by the amount of dilution used to produce the dilution series test concentrations. Figure 70 shows the results. The linear regression was generated only for TU_A values less than 6.2, as doses above this amount always resulted in 0% normal development. The response to the combined copper and zinc dose explained about half (R^2 of 0.5) of the variability in the data. The combination of chemicals had a stronger relationship with survival than either of the chemicals alone. While these data are not the strongest dose-response relationships, none of the other chemicals showed any type of trend with the toxicity data.

A comparison of storm water chemistry data by facility showed the same relative trends as was observed for toxicity (Figure 62). The generalized order of NAB>NAV>SUB=NI that was observed for toxicity also was observed for average copper and zinc concentrations. This general trend was also seen in the organics data, even though there was no relationship between these compounds and toxicity.

In summary, the TIE and chemistry together identified copper and zinc as the primary toxicants of concern at all 10 drainage areas. Their concentrations were always above acute WQS and though individually they were not always high enough to be acutely toxic to topsmelt or mysids, they were nearly always high enough to be toxic to mussel larvae. The TIEs also identified surfactants as causative agents at three sites. While the sources of copper and zinc include some industrial activities and structural materials at these facilities, they are also derived from the ubiquitous sources that include atmospheric deposition and automobiles (Tsai, Hoenicke, Hansen, and Lee, 2000; CALTRANS, 2003; Sabine, Schiff, Lim, and Stolzenbach, 2004; Moran, 2004; Rosselot, 2005a; Rosselot 2005b). The ultimate source(s) of surfactants at these bases is not known, though they are commonly found in natural fats and oils, petroleum fractions, detergents, and some herbicides. Though the list of CoCs was based on likely contaminants to be found at these facilities, the list was not exhaustive. However, the TIEs would have identified any other contaminants causing toxicity that were not measured independently in the chemistry scans.

Table 45. Toxicity Identification Evaluation summary for first-flush storm water samples collected at each base. The table identifies the primary causative agents of toxicity to each species and endpoint for each sample.

Base	Outfall	Species/Endpoint		
		Mussel Embryo-Larval Development	Mysid Survival	Inland Silverside[a] or Topsmelt[b] Survival
NAV	9	Copper, zinc	Not toxic	Not toxic[a]
NAV	11	Copper, zinc	Not toxic	Not toxic[a]
NAV	14	Copper, zinc	Not toxic	Not toxic[a]
SUB	11B	Copper, surfactants	Not toxic	Not toxic[a]
SUB	23CE	Copper, zinc	Zinc	Not toxic[a]
SUB	26	Copper, zinc	Not toxic	Not toxic[a]
NAB	9	Copper, zinc	Copper, zinc	Not toxic[b]
NAB	18	Copper, zinc, surfactants	Surfactants	Surfactants[b]
NI	23A	Copper, zinc, surfactants	Surfactants	Surfactants[b]
NI	26	Not toxic	Not toxic	Not toxic[b]

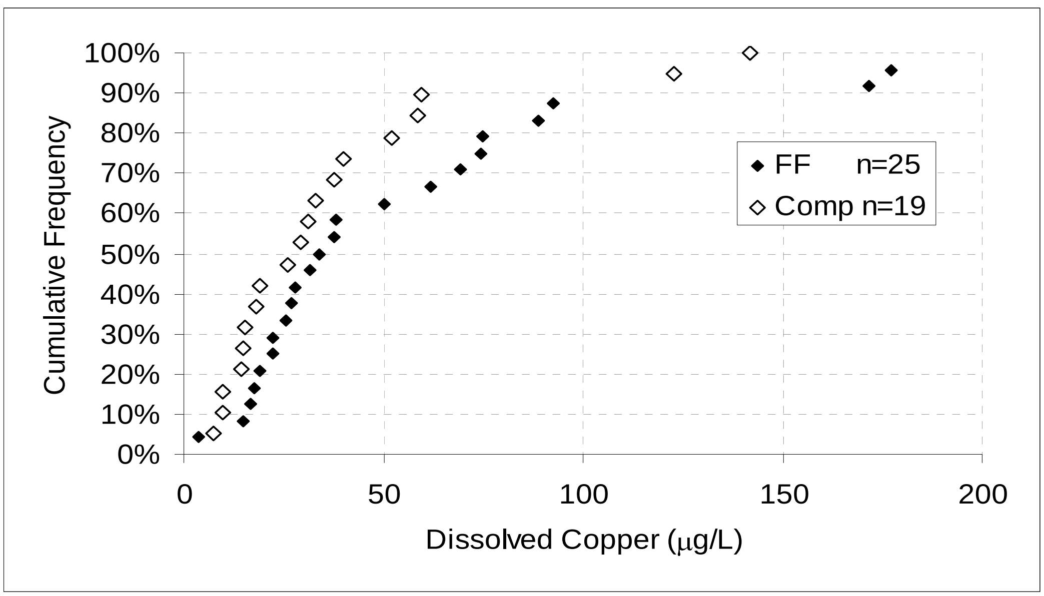


Figure 66. Cumulative frequency distribution plot of dissolved copper measured in all first-flush (FF) and composite (Comp) storm water samples.

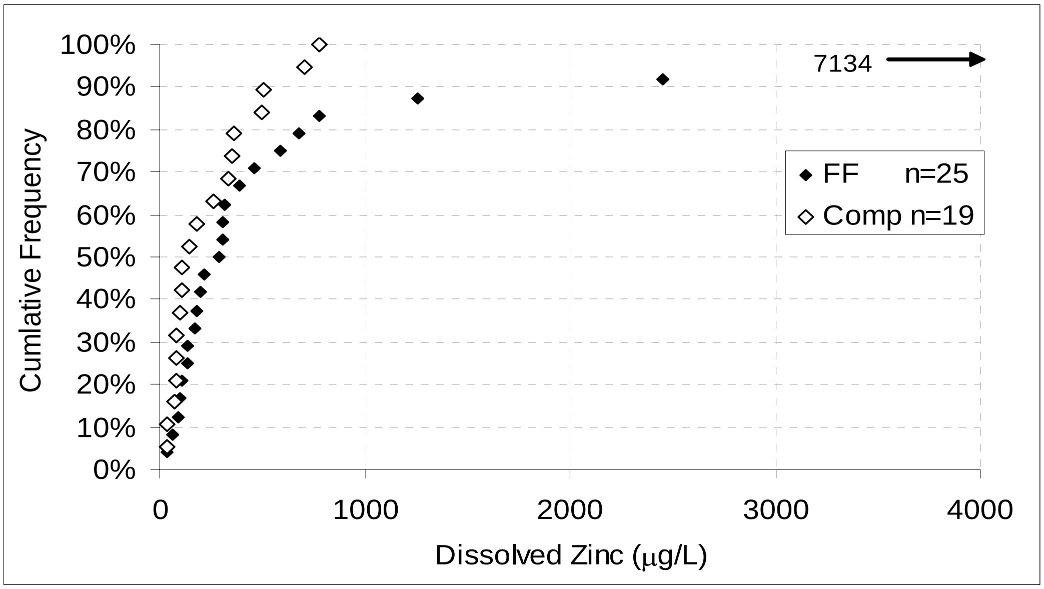


Figure 67. Cumulative frequency distribution plot of dissolved zinc measured in all first-flush (FF) and composite (Comp) storm water samples. One value was off-scale at 7134 μg/L.

Table 46. Average LC50/EC50 values from reference toxicant data collected during this study. These values were used to compute TU_A .

	Mysids	Topsmelt	Mussel Embryos
Dissolved Copper (μg/L)	233	163	9.6
Dissolved Zinc (μg/L)	647	880	160

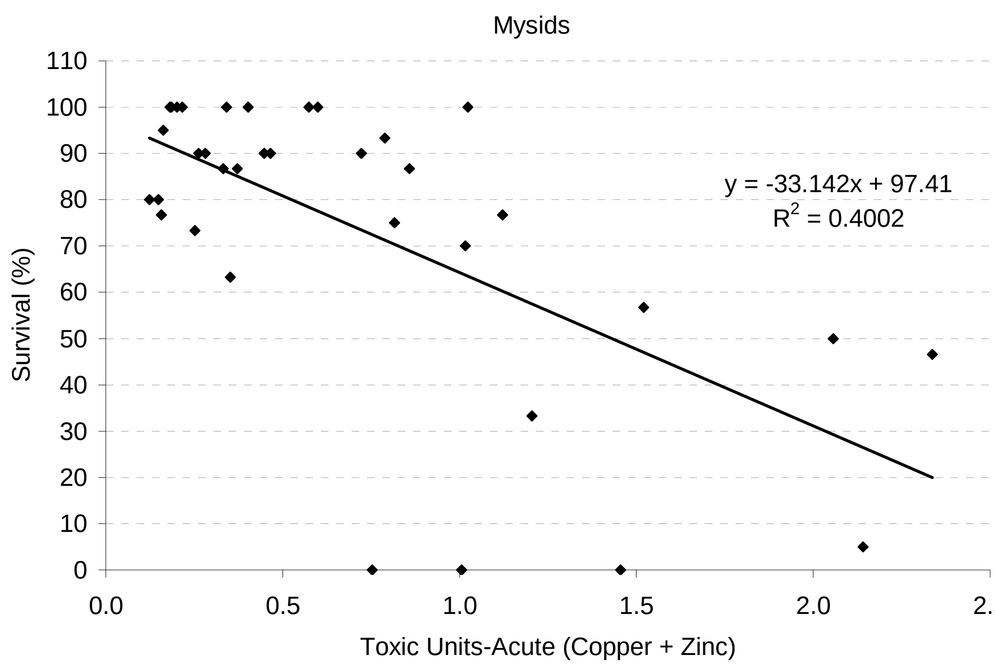


Figure 68. Mysid survival as a function of summed copper and zinc TU_A.

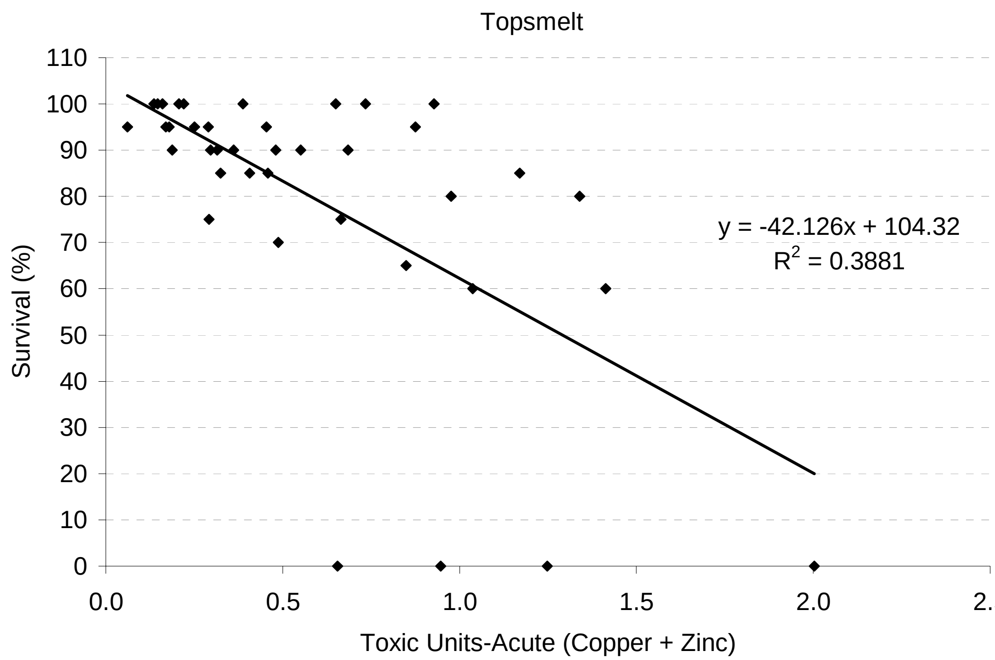


Figure 69. Topsmelt survival as a function of summed copper and zinc TU_A.

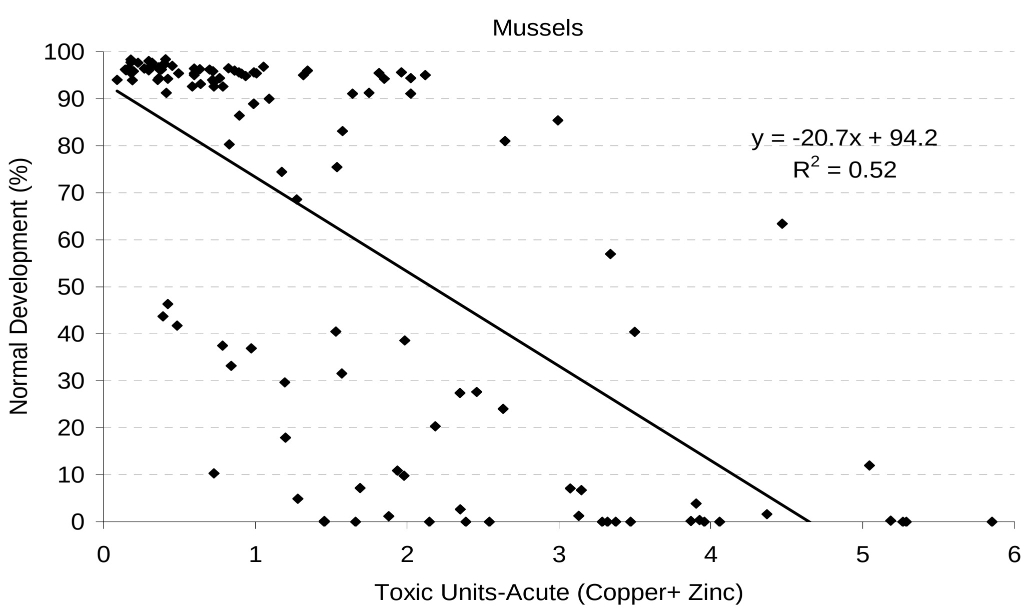


Figure 70. Normal mussel embryo-larval development as a function of summed copper and zinc TU_A. The regression was determined for data points with a TU_A <6.2.

8.3 RECEIVING WATER IMPACTS

Receiving waters were evaluated for chemistry and toxicity to evaluate the magnitude of toxic response directly in the receiving water resulting from the storm water discharges. They were also evaluated for exposure conditions by mapping the spatial and temporal distribution of storm water plumes as they mixed with bay waters. These data, along with those collected on storm water, provide an ability to gauge the ability of the WET tests performed on undiluted storm water to predict impacts on receiving water quality for which they were designed.

During this study, a total of 202 individual toxicity bioassays were performed on 85 individual receiving water samples. This total includes bay water sampled before (27 samples) and during (35 samples) storm events at all locations. Sampling was also conducted after (23 samples) storm events mostly at Naval Station San Diego and Naval Submarine Base San Diego. One set of “after” samples was also collected outside one outfall at each base immediately after a storm event (SDB5). These samples captured a receiving water condition after it had rained ~6 inches during the previous 14 days, which is ~60% of normal annual rainfall, and thus represented a fairly extreme condition for accumulated sources. The vast majority (80%) of receiving water samples were collected within a few feet of the outfall discharge pipe, though as discussed previously, three stations sampled were further away from the discharge, up to 50 feet, as a result of obstructions or very shallow water when sampling by boat. There were also two stations, one at Naval Station San Diego (Bay 14A; see Figure 5) and Naval Submarine Base San Diego (26A; see Figure 10) that were purposefully sampled away from the shoreline to evaluate gradients in storm discharge.

None of the receiving water samples were toxic to topsmelt or mysids. Survival for these two species ranged from 90 to 100% and averaged 98% (Figure 71). Mussel embryo-larval normal development in receiving waters averaged 91%. Two of the mussel embryo-larval development tests showed significant toxicity (Figure 72). These two “during” samples were collected during the first-flush of the year storm event (SDB4) that had a record 183-day antecedent dry period, and thus represented an extreme discharge condition. The two samples were collected outside of Naval Station San Diego outfall 14 and Naval Amphibious Base Coronado outfall 9. Comparable receiving water samples collected outside of Naval Submarine Base San Diego outfall 11B and off Naval Air Station North Island outfall 23A during the same storm did not exhibit toxicity.

The receiving water samples from these two sites had the highest levels of copper (14 and 17 μg/L) and zinc (176 and 182 μg/L) measured in the study. These concentrations exceeded acute and chronic WQS. The associated first-flush storm water samples analyzed from the two sites also had the highest combination of copper (172 μg/L) and zinc (7134 μg/L) concentrations measured in the study. These levels were a factor of 5 to 30 times more than the average concentrations measured at those sites at all other times. Even at these high levels, the topsmelt and mysid survival data were not the lowest measured during the study. The storm water samples had dilution series NOEC values of <6.25% for mussels and 25% for topsmelt and mysids, the lowest NOEC values measured in the study. The mussel NOEC values suggest that only a small fraction of storm water was needed to cause an adverse impact in the receiving environment, a result related to the very high copper and zinc levels.

The storm water and receiving water samples collected from the other two bases (Naval Submarine Base San Diego outfall 11B and Naval Amphibious Base Coronado outfall 23A) during the first-flush of the year storm event were also the highest observed at those sites during the entire study. Receiving water dissolved copper concentrations at the two sites did exceed acute and chronic WQS, though dissolved zinc was below acute and chronic WQS. Dissolved copper in the receiving water was as high as 8 μg/L, without an associated toxic effect. The lack of toxicity at these copper concentrations was consistent with recent data that show copper complexation with DOC as a mechanism for reducing potential toxicity (Rosen et al., 2005; Arnold, 2005). DOC levels measured in bay samples during this study as well as previously by Blake, Chadwick, Zirino, and Rivera-Durate (2004) and Rosen et al. (2005) generally ranged between 1 and 4 mg/L. These DOC concentrations should have been sufficient to effectively complex copper and reduce its toxic effect.

The fact that samples during this storm event contained the highest copper and zinc levels measured in the study at each of the four bases suggests that the historically long antecedent dry period was a major contributing factor.

Less than 1% of 202 toxicity tests conducted on receiving water samples in this study exhibited toxicity. The limited nature of the impact was primarily a result of low chemical exposure in the receiving water, but as described above, also included some level of metal complexation. The three components that characterize exposure conditions include magnitude, extent, and duration. The plume mapping surveys and the special floating bioassay study were used to characterize receiving water exposure under various discharge conditions.

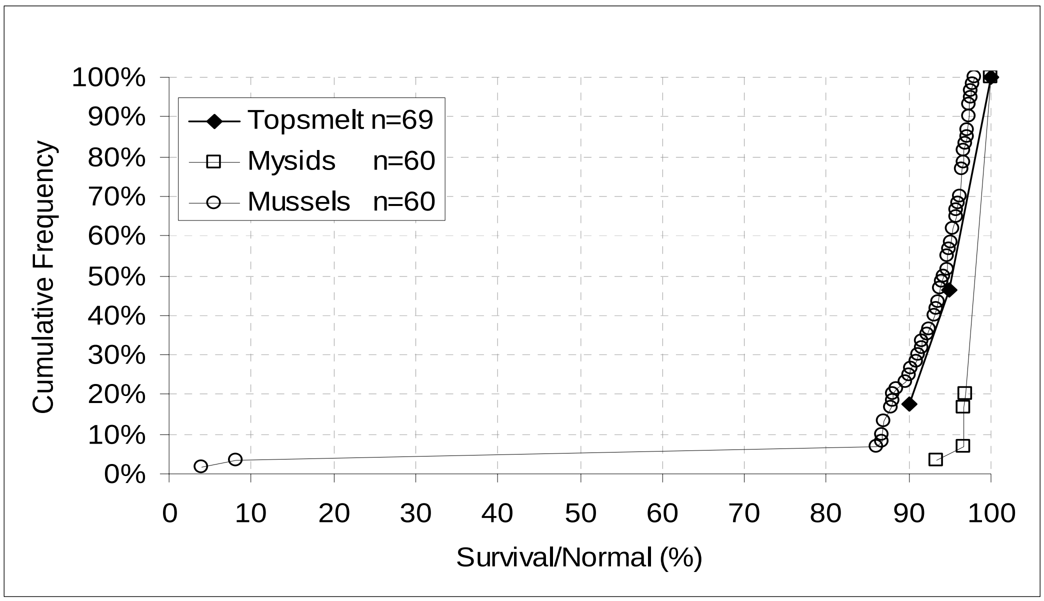


Figure 71. Topsmelt, mysid, and mussel bioassay results measured in receiving waters. The plot shows combined results for samples taken before, during, and after storm events. All results were for 100% receiving water.

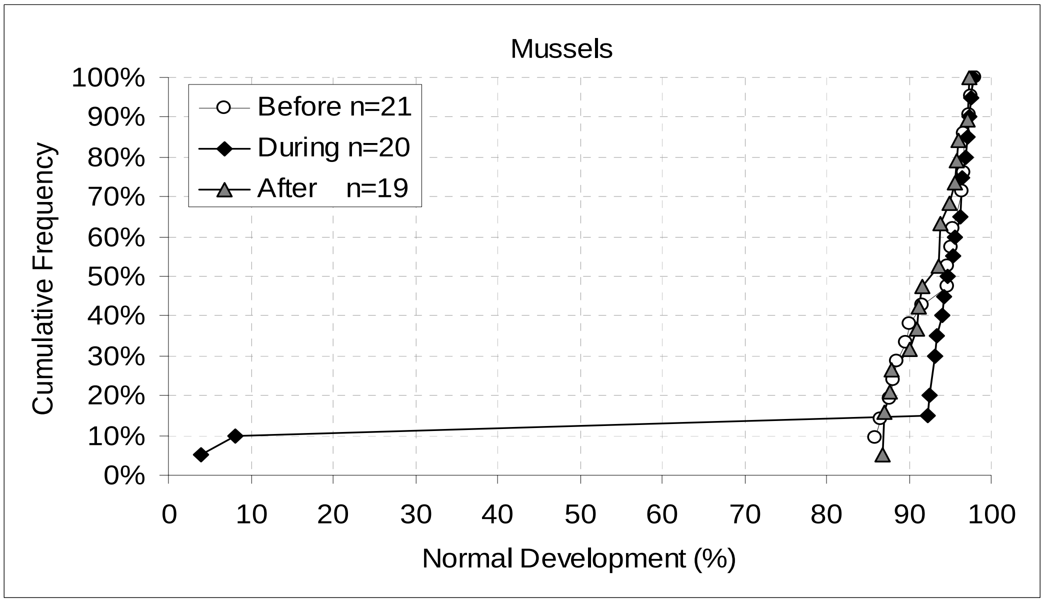


Figure 72. Mussel embryo-larval development results for receiving water samples collected before, during, and after storm water events. All results were for 100% receiving water. Two samples were significantly toxic.

The large scale mapping surveys consistently showed that storm water plumes were limited in their spatial extent, with maximum storm water signals mostly found immediately along the shoreline of each base, with a decreasing gradient that typically extended only as far as the pier heads. The plumes were also confined to the top two meters of the water column, a result of the discharges being made just above or just below the water surface, depending on tide height. The mapping data showed that plumes were highly transitory, showing changes with tide stage and relaxing back to pre-storm conditions relatively quickly, usually within 24 hours at all bases. The mapping surveys showed that exposure conditions in the receiving environment were minimal in their spatial extent, and were relatively short-lived.

The magnitude of the storm water signatures, as measured by salinity during the mapping surveys, were less than 14%, with most typically around 5%. The maximum storm water signatures were mostly found immediately along the shoreline and decreasing to levels of about 1% storm water or more out at the pier heads. A comparison of first-flush concentrations of copper and zinc with those measured in the receiving water showed that, on average, receiving water levels were reduced by a factor of 15 and 29, respectively. These calculate as a storm water fraction ranging from 3 to 6%. The salinity and chemistry data collected from the mapping surveys indicate that storm water from these facilities generated small magnitude discharges, even along the immediate shoreline.

The high-resolution monitoring conducted during the floating bioassay study showed that the magnitude of the exposure can be much larger, though considerably shorter lived than indicated by the large-scale mapping data. The salinity data during this special effort showed storm water fractions approaching 100% immediately at the point of discharge under the most intense rainfall conditions. However, these larger magnitude conditions were very short-lived, on the order of minutes to tens of minutes. Over the full 96-hour exposure period, the average storm water fraction was less than 4%. The maximum dissolved copper data measured during this survey (5.5 μg/L) exceeded its acute WQS of 4.8 μg/L, again for a time frame of tens of minutes. Again using the reduction of copper and zinc levels measured in the first-flush storm water samples relative to the maximum levels measured in the receiving water, the maximum storm water fraction was between 4 and 20%. Like the average exposure computed using salinity, the chemistry data monitored over the full 96-hour monitoring period averaged between 4 and 6%.

In summary, storm water discharges to San Diego Bay resulted in less than 1% of 202 samples showing a toxic impact to one of the most sensitive toxicity endpoints available. The two receiving water samples that showed a toxic result were collected during the same storm event, one that represented a first-flush of the year after a historically long antecedent dry period. This exceptionally long dry condition resulted in extrema in copper and zinc levels at all four bases. At two of the bases, the amount of copper and zinc were high enough to result in receiving water concentrations above acute and chronic WQS and cause toxicity once storm water was mixed in the receiving environment. In these two cases, the associated first-flush storm water samples were toxic to topsmelt and mysids. In the other 200 cases, the data showed no receiving water toxicity, whether or not the first-flush sample was significantly toxicity to topsmelt and mysids. The lack of relationship between the measurements of toxicity in first-flush samples with toxicity observed in the receiving environment was a result of limited receiving water exposure conditions. Both the mapping surveys and the special floating bioassay study clearly showed that storm water discharges from Navy facilities were limited in magnitude, minimal in their spatial extent, and very short-lived. Thus, toxicity measured in first-flush undiluted storm water overestimates the exposure conditions measured in the receiving water and thereby overestimates the potential for toxic impacts to receiving waters.

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Item No. 7
Supporting Document No. 7

9. CONCLUSIONS

The goal of this study was to develop a robust dataset of storm water and receiving water toxicity that can be used to support a scientifically based acute toxicity threshold for storm water discharges from Navy facilities. The approach taken was to simultaneously measure toxicity and chemistry in storm water and receiving waters and to characterize receiving water conditions before, during, and after storm discharges. This approach allowed the magnitude and extent of storm water toxicity to be evaluated and directly related to the magnitude and extent of receiving water toxicity.

The study provided a robust high-quality dataset to evaluate industrial storm water toxicity from Navy facilities bordering San Diego Bay. The dataset was composed of 333 toxicity tests using topsmelt and mysid survival and mussel-embryo-larval development as endpoints. It included the analysis of total and dissolved metals, PAH, PCB, and chlorinated pesticides on 136 discrete storm water and receiving water samples. It also included 17 plume mapping surveys conducted before, during, and after storm events around each base as well as a special floating bioassay study to assess exposure conditions in the receiving environment. The study dataset represents the largest and most comprehensive evaluation of storm water toxicity and impacts of marine waters to date.

The study captured nearly, if not the full range, of rainfall and discharge conditions likely to occur from these facilities. The study captured discharges during drought conditions, during near-record wet conditions, and included measurements during record rainfall event and a record antecedent dry period. The drainage areas monitored had a wide range in size (0.5 to 75 acres) and contained a various industrial activities, most of which are similar at each base. Thus the study effectively characterized the bounds of variability inherent in storm water discharges.

The study established that acute storm water toxicity was highly variable, spanning the full range of impact, from 0 to 100% survival of topsmelt and mysids. This variability was likely tied to variability in contaminant levels, though the relationship between chemistry and toxicity was not very strong. The toxicity of first-flush storm water samples, representing the discharge at one moment in time, was higher than in composite samples that were representative of the entire discharge. The 90% survival requirement in the NPDES permit failed for 58% of first-flush samples and for 25% of composite samples. However, the permit requirement did not accurately identify when samples were acutely toxic or not. When using a science-based approach to WET test methods and statistical data evaluation, including t-testing and consideration of method variability, toxicity of first-flush storm water would have been declared toxic 30% (cf. 58%) of the time while composite samples would have been identified as toxic 7% (cf. 25%) of the time.

The toxicity identification evaluation and chemistry data together identified copper and zinc as the primary toxicants of concern at all 10 drainage areas evaluated. Their concentrations were always above acute WQS, and though individually they were not always high enough to be acutely toxic to either topsmelt or mysids, they were nearly always high enough to be toxic to mussel larvae. The TIEs also identified surfactants as causative agents at three sites. Though not every possible contaminant was measured directly in the study, the TIEs would have identified any other contaminants causing toxicity that were not measured independently in the chemistry scans.

Less than 1% of 202 receiving water toxicity tests exhibited toxicity. This toxicity was observed only to one of the most sensitive toxicity endpoints available. The two receiving water samples that showed a toxic result were collected during the same storm event, one that represented a first-flush of the year after a historically long antecedent dry period. In the other 200 cases, the data showed no receiving water toxicity, whether or not the associated first-flush samples were significantly toxic to topsmelt and mysids. The lack of relationship between the measurements of toxicity in first-flush samples with toxicity observed in the receiving environment was a result of limited receiving water exposure conditions. The mapping surveys and the special floating bioassay study clearly showed that storm water discharges from Navy facilities were limited in magnitude, minimal in their spatial extent, and very short-lived. Thus, toxicity measured in first-flush undiluted storm water overestimates the exposure conditions measured in the receiving water and thereby overestimates the potential for toxic impacts.

In summary, this study provides one of the most extensive datasets on storm water runoff ever conducted, effectively characterizing the bounds of variability inherent in these types of discharges and their impacts to receiving water quality. Using multiple lines of evidence, the data showed that first-flush storm water can be acutely toxic, primarily as a result of copper and zinc concentrations in the discharge. The data also showed that the total storm discharge, represented by composite samples, was generally less toxic and had lower contaminant concentrations. Most importantly, there was no relationship between toxicity measured in storm water (end-of-pipe) and toxicity measured in the receiving water. These results show that WET testing on storm water as required in the permit cannot be used to infer toxicity in the receiving environment.

This study was conducted to support a scientifically based acute toxicity threshold for storm water discharges. To ensure that an acute toxicity threshold for storm water discharges will accurately identify and be protective of water quality impacts in the receiving environment, the proposed Navy alternative toxicity threshold should include the following:

- The use of appropriate WET test methods and data evaluation when declaring a test result as toxic
- Acknowledgment of WET method variability and the minimum significant difference that laboratory testing can provide in declaring a toxic result
- Consideration of realistic exposure conditions when using WET test to infer toxicity in the receiving water

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San Diego Port Tenants Association

ATTACHMENT II

STATE OF CALIFORNIA
STATE WATER RESOURCES CONTROL BOARD

ORDER: WQ 98 - 07

In the Matter of the Petitions of
NATIONAL STEEL AND SHIPBUILDING COMPANY
AND
CONTINENTAL MARITIME OF SAN DIEGO, INC.
for Review of Waste Discharge Requirements
Orders 97-36 and 97-37 of the
California Regional Water Quality Control Board,
San Diego Region

SWRCB/OCC Files A-1119 and A-1120

BY THE BOARD:

On October 15, 1997, the Regional Water Quality Control Board, San Diego Region (Regional Water Board), adopted Waste Discharge Requirements Order 97-36, General NPDES Permit CAG039001 and Waste Discharge Requirements Order 97-37, General NPDES Permit CAG039002 (permits), for shipyard facilities in San Diego Bay. The permits regulate process and storm water discharges from ship construction, modification, repair and maintenance facilities, and activities. The permits constitute general national pollutant discharge elimination system (NPDES) permits pursuant to section 402 of the federal Clean Water Act (CWA).

On November 14, 1997, the State Water Resources Control Board (State Water Board) received petitions from two facilities subject to the permits, National Steel and

Shipbuilding Company and Continental Maritime of San Diego, Inc. (petitioners). The petitioners contested issuance of the permits and certain provisions thereof.[1]

The petitioners requested stays of the permits. Following the State Water Board's refusal to issue stays, court review was sought and a superior court commanded the State Water Board to set aside its dismissal of the stay requests and to reconsider the stay requests, and stayed the effectiveness of the permits in the interim. (*NASSCO et al.* v. *California State Water Resources Control Board et al.*, San Diego County Superior Court No. 718025.) Because this order considers the merits of the petitions, the court's order to reconsider the stay requests is now moot. Following issuance of this order, the permits shall be effective, as modified herein.

The petitioners also requested a hearing before the State Water Board. The comments that were excluded by the Regional Water Board, and were the basis for the hearing request have been entered into the record and considered in this order. The hearing request is hereby denied.

I. BACKGROUND

The petitioners own and operate shipyards in San Diego Bay. The shipbuilding and repair industry is engaged in construction, conversion, alteration, repair, and maintenance of

[1] National Steel and Shipbuilding Company is subject to Order 97-36 and Continental Maritime is subject to Order 97-37. Both the permits and the petitions are virtually identical. For purposes of this review, the State Water Board has consolidated the petitions and is reviewing both in this order. The order is based on the record before the Regional Water Board when it adopted the permits. In addition, the petitioners have submitted declarations that include comments on the permits that were not entered in the Regional Water Board's records. Various parties and interested persons have submitted further comments and evidence regarding the petitions and responses thereto. Many of these entities including the petitioners, the Environmental Health Coalition (EHC), the United States Navy, the Regional Water Board, and the U.S. Environmental Protection Agency (U.S. EPA) submitted comments after the deadline for comments established by the State Water Board. All of these documents, with one exception, have been made a part of the record. (Water Code § 13320(b).) The exception is evidence submitted by EHC on June 1, 1998. This evidence consists of affidavits prepared for litigation in a separate matter. In light of the lateness of the submittal, and the fact that the matters asserted in the affidavits were covered in thorough fashion before the Regional Water Board, these affidavits will not be considered as a part of the record.

military and commercial ships and vessels. Their activities include formation and assembly of steel hulls and superstructures, application and repair of paint systems, installation and repair of mechanical, electrical and hydraulic systems, repair of damaged vessels, pipe fitting, boiler cleaning, and electroplating and metal finishing.

These activities can generate wastes including spent abrasives, paint, marine organisms, rust, bilge water, blast wastewater, oils, lubricants, grease, fuels, sludge, solvents, thinners, demolition waste, trash, asbestos, sewage, hydrocarbon or chlorinated solvents, electroplating and metal finishing wastes, acid wastes, caustic wastes, and aqueous wastes. Because the shipyards are located right on San Diego Bay, there is a potential for wastes to enter the Bay. Activities that can result in discharges to San Diego Bay include floating dry dock deballasting, submergence and emergence, graving dock floodwaters, gate leakage, hydrostatic relief flow, leaks from floodwaters and gates, and hydrostatic relief flows. Shipyard facilities sometimes directly discharge cooling water, fire protection system water, boiler and cogeneration feedwater, steam condensate water, saltbox water, integrity and hydrostatic testing water, and water from hosing down dry docks and hulls. Discharges may occur in a variety of ways including direct and indirect dischargers of wastewaters, and discharge of storm waters containing pollutants.

Prior to issuance of the general permits that are the subject of this order, the Regional Water Board had adopted individual permits for process wastewater discharges from each shipyard. The facilities were also subject to the statewide General Permit for Discharges of Storm Water Associated with Industrial Activities (Order 97-03-DWQ). The general permits issued by the Regional Water Board govern all discharges to San Diego Bay from the shipyards including process wastewater and storm water. They therefore take the place of the earlier individual NPDES permits and the facilities are no longer subject to the statewide General Permit.[2]

The two permits issued by the Regional Water Board are virtually identical except that one applies to shipyards that are assigned a greater threat to water quality and complexity rating, and the other is for shipyards with a lower rating. Both permits require the use of best management practices (BMPs) to limit discharges of both process wastewater and storm water to San Diego Bay.

The Regional Water Board staff worked on these permits for at least two years and circulated several early drafts to the petitioners. The Regional Water Board staff and the petitioners met on several occasions, and the petitioners submitted dozens of comments throughout this time including their own versions of draft permits and comments on various issues of the proposed permits. The Regional Water Board held a workshop on April 9, 1997, at which the petitioners were allowed to comment extensively. The Regional Water Board held a public status meeting on May 21, 1997. On July 14, 1997, the Regional Water Board held a public hearing on the draft permits that had been circulated to the public. There was extensive comment from the petitioners, other dischargers, and the public. The Regional Water Board also allowed further written comments until August 20, 1997. Again the petitioners submitted extensive comments. On October 2, 1997, the Regional Water Board distributed final draft permits and prepared a response to comments. The Regional Water Board did not allow

[2] The statewide General Permit allows Regional Water Boards to adopt permits that apply in lieu of the statewide permit. These may be individual NPDES permits or general permits for specific industries or geographic areas.

comments on October 2, 1997 drafts and adopted them without further public comment on October 15, 1997.

II. CONTENTIONS AND FINDINGS[3]

1. Contention: The petitioners contend that the Regional Water Board violated their due process rights by not allowing comments on the October 2, 1997 draft permits.

Finding: The petitioners and the Regional Water Board staff met numerous times from 1995 until the permits were adopted in October 1997. During that time, the petitioners reviewed and commented upon several draft permits and submitted their own versions of a permit. The Regional Water Board itself held a workshop, a status meeting, and a hearing. Extensive testimony was allowed on the draft permits at all of these meetings. At the hearing held August 13, 1997, the discussion centered on a July 14, 1997 draft permit. In addition to these public meetings, the petitioners were allowed to submit voluminous comments on the various draft permits including comments after the close of the hearing until August 20, 1997. Many other entities besides the petitioners also submitted comments including other dischargers, environmental groups, and resource agencies.

On October 2, 1997, the Regional Water Board staff distributed final draft permits. The staff also prepared an extensive document summarizing comments and responding to those comments, either by describing revisions to the permits, or by explaining why the permits were not revised as requested. The Regional Water Board adopted the draft permits at its October 15, 1997 meeting. At that meeting, the Regional Water Board did not allow further

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[3] All other contentions raised in the petitions that are not discussed in this order are dismissed. (Cal. Code Regs., tit. 23, § 2052; *People* v. *Barry* (1987) 194 Cal.App.3d 158 [239 Cal.Rptr. 349].)

testimony. The petitioners claim that because they could not adequately comment on the October 2, 1997 draft permits, they were denied due process under the California and United States Constitutions.

The Regional Water Board complied with the federal procedural requirements for adopting NPDES permits (40 Code of Federal Regulations (C.F.R.) Part 124) and with Water Code section 13377. The Regional Water Board circulated the draft permits for at least 30 days, held a hearing on contested permits, made revisions to the draft permits in response to comments, and prepared a document containing response to comments. The revisions in the October 2, 1997 drafts, while extensive, were responsive to the various comments staff had received from the petitioners and other interested persons.

The petitioners argue that several permit conditions were changed significantly in the October 2, 1997 drafts. However, each of these terms was the subject of significant comment and discussion throughout the permit review period. For example, the petitioners themselves requested that the permits specifically authorize the discharge of ship launch grease. When the permits were revised to authorize such discharge, petitioners objected that an accompanying monitoring provision was added, ascertaining the new monitoring requirement to be a significant change for which they have a right to comment. The Regional Water Board appropriately required monitoring of an authorized discharge.

If the Regional Water Board had been unwilling to make revisions to the draft permits in response to comments, it would not have met the requirements of the federal regulations and of section 13377, which commands the Regional Water Boards to follow the federal regulations in adopting NPDES permits. Thus, the petitioners' argument is in effect an attack on the constitutionality of section 13377. As we have stated in the past, the State Water Board will not review arguments that a statute which it implements is constitutionally infirm. (Cal. Const., art. III, § 3.5. See State Water Board Orders WQ 86-13, p. 4 and 85-10, p. 5.)

While petitioners may argue that the Regional Water Board could have simply allowed further comment on the October 2, 1997 drafts, and then adopted them on October 15, 1997,such a process would have then possibly necessitated further revisions to the drafts and, as required by the federal regulations, further responses to comments. The federal regulations clearly required no more than one public comment period and hearing and not the endless process the petitioners claim is required. The extensive process of negotiating privately with the petitioners and then allowing public comments at a workshop and a hearing, along with a lengthy public comment period, already resulted in delays in reissuance of permits that had expired five years before. It is clear from the record in this matter that the petitioners had more than ample opportunities to comment on the permit drafts and the major issues therein, and that they took full advantage of those opportunities.

The specific revisions to the October 2, 1997 drafts that the petitioners complain of include changing the toxicity limitation and testing to delete the dilution factor. The petitioners' August 20, 1997 comments included detailed criticisms of the toxicity limitation and monitoring. The petitioners asked for inclusion of a dilution allowance, and the final permits clarified that there would be no dilution credit allowed. This revision addressed a comment by the petitioners and is explained in the Regional Water Board's response to comments.

The petitioners had requested that the terms "high risk areas" and "industrial process water" be defined. The October 2, 1997 draft permits included definitions of these terms, and the response to comments detailed the rationale for the definitions including the use of a definition of "industrial process water" derived from State Water Board Order No. WQ-88-4.. Again, these were not new issues in the October 2, 1997 drafts.

The petitioners claim that the October 2, 1997 draft permits newly required submission of complete individual NPDES permit applications each year. First, the issue of a permit application was discussed throughout the permit process. The Regional Water Board staff considered whether to issue individual permits or general permits, and the environmental groups argued for individual permits. Their greatest concern was having current information on the shipyards which must be included in the application for individual permits. The Regional Water Board resolved this issue by issuing general permits, but by requiring the petitioners to submit the information that would have been required in individual applications. This was not a new issue raised for the first time in the October 2, 1997 drafts. Second, the general permits do not require the petitioners to submit entirely new applications each year. The permits require only that each year the shipyards update the information. This requirement is reasonably related to the earlier discussions and comments.

In summary, the "new" requirements and provisions that the petitioners complain of had been issues that were discussed extensively by all parties and interested persons, and were all the result of comments that the Regional Water Board was required to consider and to respond to. The Regional Water Board was not required to hold a second hearing to discuss the comments and outcome of the draft produced as a result of the hearing.

The petitioners have cited several cases but none of these support their contention that the Regional Water Board denied them due process. The California Supreme Court found that the State Bar denied due process when it did not explain to an applicant the reasons he was denied full reimbursement from a Bar-operated fund. (*Saleeby* v. *State Bar* (1985) 39 Cal.3d 547.) The Regional Water Board provided extensive responses to all of the petitioners' comments.[4]

In an Illinois case cited by the petitioners, the state issued an NPDES permit that included significant changes from the earlier draft permit. (*Village of Sauget* v. *Pollution Control Board* (1990) 207 Ill. App.3d 974.) The draft permit had been considered as uncontested during the public comment period, and any changes were due to comments from U.S. EPA submitted long after the close of the public comment period. The permittee never saw any comments from U.S. EPA until months after they were submitted, and there was never a hearing on the permit. The Regional Water Board, on the other hand, allowed extensive comments which were made available to all persons, and held a lengthy public hearing and a workshop. The revisions to the July drafts were based on the comments, and the Regional Water Board responded to all comments. The Illinois case presented the permittee with unanticipated major revisions to what was an uncontested draft permit. That case is not analogous to the adoption of these permits.

The petitioners also assert that the Regional Water Board did not comply with the procedural regulations in place at the time of the August 13, 1997 hearing. A review of the transcript reveals, however, that the petitioners were allowed to make lengthy presentations by numerous speakers, that they were afforded the opportunity to present questions for the staff to

[4] It is obvious that the State Bar's failure to provide any sort of a hearing cannot be compared with the petitioners' inability to speak at the October meeting, which followed a public workshop and hearing.

answer,[5] and that they made no objection to the hearing process at the meeting. The record fails to support any contention that the Regional Water Board did not follow the regulations.

2. Contention: The petitioners contend that the permits are not supported by adequate findings or evidence. Specifically, the petitioners assert that the Regional Water Board improperly inserted numeric effluent limitations in the permits.

Finding: The petitioners argue that the Basin Plan for the San Diego Region specifies that permits for shipyards cannot contain numeric limitations, that the permits violate this provision, and that they do not contain findings to support the inclusion of numeric limitations. The Basin Plan, however, does not prohibit the use of numeric limitations in permits for shipyards. Instead, it states that control of waste discharges is accomplished by BMPs, and that "numerical effluent limitations are not practical." (Basin Plan, at 4-51.) In fact, a prohibition against numeric effluent limitations at any facilities subject to NPDES permits would contravene U.S. EPA regulations, which require such limitations in some instances.[6] Moreover, the permit findings extensively discuss the threat to water quality posed by shipyards and form the basis for numeric effluent limitations.[7]

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[5] In opening the hearing, the Chairman stated: " 'At the conclusion of the dischargers' direct testimony, I will allow reasonable time for dischargers to ask questions pertaining to the staff presentation. All questions will be addressed to me as the Chairman of the Board." The petitioners chose not to ask any questions. In light of the great concerns petitioners voice in their petitions regarding the need to question staff, it is difficult to understand why they chose not to ask any questions at all. They raised no objection to the Chairman's statement that questions would be addressed to him, and we cannot see how that stricture would have affected their ability to pursue their questions.

[6] See, 40 C.F.R. § 122.44. The U..S. EPA in fact has commented that the Regional Water Board should have included numeric effluent limitations for copper and zinc, pursuant to this regulation. The petitioners mistakenly claim that the Regional Water Board complied with this recommendation and included numeric limitations for these constituents.

[7] In light of the information available to the Regional Water Board in adopting the permits and its actions therein, the Board should reconsider this Basin Plan language at its next triennial review.

The permits include numeric effluent limitations for oil and grease, settleable solids, turbidity, pH, and temperature. These limitations do not apply to storm water. The limitations are the same as those in the California Ocean Plan (1997). While the Ocean Plan is not applicable to enclosed bays and estuaries, such as San Diego Bay, the Water Quality Control Policy for the Enclosed Bays and Estuaries of California (1974; Bays and Estuaries Policy) is applicable.[8] The beneficial uses of bay waters are similar if not identical to those of the ocean. Bay waters are in hydrologic continuity to waters of the open ocean, but are generally subject to less dilution. It is appropriate to apply effluent limitations at least as stringent in San Diego Bay as in the ocean.

The numeric effluent limitations are also consistent with data presented in a U.S. EPA technical document, *Development Document for Proposed Effluent Limitations Guidelines and Standards for Shipbuilding and Repair*. The numeric limitations for these parameters are appropriate. The petitioners imply that the permits contain numeric effluent limitations for other parameters, including Receiving Water Limitations. These are not numeric effluent limitations, and the limitations are consistent with the State Water Board's prior decisions addressing receiving water limitations.[9]

The permits do include effluent limitations that provide that effluent shall not exceed a daily maximum chronic toxicity of 1 Toxic Unit Chronic. (TUC; Discharge

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[8] The petitioners appear to confuse the Bays and Estuaries Policy, which is still in effect, with the Bays and Estuaries Plan, which was vacated. To the extent that the petitioners argue that the Regional Water Board included concepts from the vacated Plan, it is appropriate to use any technical documents in developing permit terms, while not relying on the Plan as including regulatory standards.

[9] See, e.g., State Water Board Orders 91-03 and 96-03.

Specifications B.7. and B.9.) This limitation would be appropriate for a treated industrial discharge, where volumes and types of effluent are relatively constant. But the discharges from the shipyard are intermittent and are controlled by BMPs rather than by treatment. Under these conditions, the use of a daily maximum is not an appropriate measure of chronic toxicity. Instead, the permit should require that a monthly median of chronic toxicity of process wastewater shall not exceed 1 TUC. Chronic toxicity for storm water is not a valid measurement of the impacts of storm water on receiving waters. The chronic toxicity limitation for storm water will be deleted.

The petitioners also contend that the requirement for chronic toxicity testing for intermittent discharges is inappropriate. Because of the intermittent nature of storm water discharges, and the fact that BMPs rather than treatment is employed, chronic toxicity testing of storm water discharges can be difficult and unreliable and can take longer than the storm event being measured. It is appropriate to measure only acute toxicity and not chronic toxicity for storm water discharges. As an alternative, the Regional Water Board could consider requiring further actions in the event that acute toxicity is identified. These could include a Toxicity Identification Evaluation, which would determine the cause of toxicity, and subsequent improvement of BMPs. While the chronic toxicity requirements and monitoring are not appropriate for storm water, the acute toxicity requirements and monitoring in the permits are appropriate.

The petitioners contend that the effluent limitations should have allowed for a mixing zone. The Regional Water Board could have considered a mixing zone, but because the discharges are intermittent and there are numerous potential discharge points, establishing a mixing zone is impractical and technically questionable. Establishing a mixing zone involves considering the conditions in the receiving water, the conditions of the discharge and the characteristics of the point of discharge. These factors are all quite variable in the case of shipyards. It was appropriate for the Regional Water Board not to include a mixing zone.

The petitioners also contend that the fact sheet is inadequate and does not cite to specific evidence. The fact sheet is extensive and does contain adequate explanations to support the permits. The petitioners argue that the Regional Water Board was required to have site-specific evidence for all assumptions in the permit, such as the assumption that hydrostatic relief may contain pollutants. Such evidence is not a requirement for NPDES permit provisions which can be based on general knowledge of industrial sites, including available documents and best professional judgment. Moreover, in the case of general permits, the basis of the permit is the type of discharge or facility, and the permit is not based solely on particular entities that will be regulated.

Provision E.7. of the permits requires that the shipyards take necessary measures to prevent storm water runoff associated with industrial activity from commingling with other storm water runoff. The petitioners claim that this requirement is not based on substantial evidence. But as pointed out by the petitioners, this provision is related to the "first flush" requirement, which prohibits discharge of the first flush of storm water runoff from "high risk areas." (Prohibition A.9.) As is demonstrated in the findings and the Fact Sheet, the "first flush" of storm water from shipyards may contain significant pollutants. As a practical matter, compliance with Prohibition A.9 will require segregation of industrial storm water from other storm water. Moreover, the segregation requirement does not specify the manner of compliance.

(It only suggests the use of berms as an example.) This is a reasonable requirement in light of the threat to water quality posed by runoff from industrial activities at shipyards and the beneficial uses to be protected in San Diego Bay. While the "first flush" requirement applies to "high risk areas" and the segregation requirement applies more generally to areas associated with industrial activity, the dischargers can choose either to segregate two different waste streams or to apply the "first flush" requirements to all industrial storm waters.

Discharge Specification B.11 of the permits requires the petitioners to implement the "first flush" prohibithin within 18 months of adoption of the permits. In order to allow the petitioners to demonstrate the need for an alternative "first flush" requirement, it is appropriate to allow the petitioners to conduct instensive monitoirng of discharges over the next year. If the monitoring demonstrates that an althernative "first flush" requirement is appropriate, the Regional Water Board shall reopen the permits accordingly. Specifically, the Regional Water Board may reconsider the definition of "first flush of storm water runoff" in the permits. In order to allow for this process to occur, Discharge Specification B.11 is hereby revised to allow 24 months from the date of this Order for compliance with Prohibition A.9.

3. Contention: The petitioners contend the monitoring and reporting requirements are too broad and burdensome and violate the provisions of Water Code section 13267(b)(1).

Finding: The petitioners claim that the monitoring requirements are too expensive and. specifically, that the requirements for monitoring sediment are burdensome. Section 13267(b)(1) provides: "The burden, including costs, of [monitoring] reports shall bear a reasonable relationship to the need for the report and the benefits to be obtained from the reports."

The storm water monitoring and reporting requirements in the permits are consistent with the monitoring and reporting requirements in the State Water Board's general industrial permit. The petitioners should have already been in compliance with the requirements and, therefore, they should not be encountering significant new costs. Moreover, in light of the size of shipyards, and the threat to water quality, the anticipated costs of compliance are reasonable.

Sediment testing was a requirement of the earlier shipyard permits, as amended in 1989. The testing requirements are reasonable.

4. Contention: The petitioners allege a variety of deficiencies in the permits, including that they do not clearly authorize specific discharges, exclude other discharges, and are generally too vague.

Finding: Given the voluminous record before the Regional Water Board, and the complexity of the regulated facilities, the Regional Water Board produced permits that are comprehensive, thorough, and responsive to comments from the petitioners and the public. While petitioners no doubt have real concerns over the cost of protecting San Diego Bay from pollutants associated with shipyard facilities, the time has come to move forward with regulation under the permits. The State Water Board finds that the permits are adequately clear and, in light of the complexity of the discharges, are as specific as possible.

IV. CONCLUSIONS

After review of the record and consideration of the contentions of the petitioners, and for the reasons discussed above, we conclude:

1. The Regional Water Quality Control Board complied with federal and state regulations in issuing the NPDES permits and accorded the petitioners due process of law.

2. The limitations in the permits are proper, except that the chronic toxicity limit for process wastewater should not be expressed as a daily maximum and there should be no chronic toxicity limit for storm water. The permits should not require chronic toxicity testing for storm water discharges.

3. The monitoring provisions are appropriate and proper.

4. The permits are not impermissibly vague.

5. The deadline for complying with the prohibitions against first flush discharges should be extended.

V. ORDER

IT IS ORDERED THAT Orders 97-36 and 97-37 are amended as follows:

1. Discharge Specification B.7 is amended to replace "daily maximum" with "monthly median".

2. Discharge Specification B.9 is deleted.

3. Discharge Specification B.11 is amended to replace "eighteen (18) months after the date of adoption of this Order" with "September 17, 2000."

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4. Monitoring and Reporting Program No. 97-36 is amended to delete "Chronic Toxicity" requirements from Table 5, at page M-16.

IT IS FURTHER ORDERED THAT in all other respects, the petitions are denied.

CERTIFICATION

The undersigned, Administrative Assistant to the Board, does hereby certify that the foregoing is a full, true, and correct copy of an order duly and regularly adopted at a meeting of the State Water Resources Control Board held on September 17, 1998.

AYE: John Caffrey
James M. Stubchaer
Marc Del Piero
Mary Jane Forster
John W. Brown

NO: None

ABSENT: None

ABSTAIN: None

Maureen Marché
Maureen Marché
Administrative Assistant to the Board

May 8, 2013
Item No. 7
Supporting Document No. 7