E. Information and Copying

The Report of Waste Discharge (RWD), related documents, tentative effluent limitations and special provisions, comments received, and other information are on file and may be inspected at the address above at any time between 8:30 a.m. and 4:45 p.m., Monday through Friday. Copying of documents may be arranged through the San Diego Water Board by calling (858) 467-2952.

Additional information can be found at the San Diego Water Board's website at: http://www.waterboards.ca.gov/sandiego/water_issues/programs/npdes/boatyards/boatyards.shtml

F. Register of Interested Persons

Any person interested in being placed on the mailing list for information regarding the General Permit should contact the San Diego Water Board, reference this facility, and provide a name, address, and phone number. If you wish to receive future e-mail notices and information on the issuance of the Tentative Order, please subscribe to our electronic email list at http://www.waterboards.ca.gov/resources/email_subscriptions/reg9_subscribe.shtml. Subscribe to "Boatyard General NPDES Permit."

G. Additional Information

Requests for additional information or questions regarding this General Permit should be directed to **Kristin Schwall** at **858-467-2345** or **kschwall@waterboards.ca.gov.**

ATTACHMENT G – DISCHARGE PROHIBITIONS CONTAINED IN THE BASIN PLAN

I. Basin Plan Discharge Prohibitions

A. The discharge of waste to waters of the State in a manner causing, or threatening to cause a condition of pollution, contamination or nuisance as defined in Water Code section 13050, is prohibited.

B. The discharge of waste to land, except as authorized by WDRs of the terms described in Water Code section 13264 is prohibited.

C. The discharge of pollutants or dredged or fill material to waters of the United States except as authorized by an NPDES permit or a dredged or fill material permit (subject to the exemption described in Water Code section 13376) is prohibited.

D. Discharges of recycled water to lakes or reservoirs used for municipal water supply or to inland surface water tributaries thereto are prohibited, unless this San Diego Water Board issues an NPDES permit authorizing such a discharge; the proposed discharge has been approved by the State of California Department of Public Health and the operating agency of the impacted reservoir; and the Discharger has an approved fail-safe long-term disposal alternative.

E. The discharge of waste to inland surface waters, except in cases where the quality of the discharge complies with applicable receiving water quality objectives, is prohibited. Allowances for dilution may be made at the discretion of the San Diego Water Board. Consideration would include stream flow data, the degree of treatment provided and safety measures to ensure reliability of facility performance. As an example, discharge of secondary effluent would probably be permitted if stream flow provided 100:1 dilution capability.

F. The discharge of waste in a manner causing flow, ponding, or surfacing on lands not owned or under the control of the Discharger is prohibited, unless the discharge is authorized by the San Diego Water Board.

G. The dumping, deposition, or discharge of waste directly into waters of the State, or adjacent to such waters in any manner which may permit it being transported into the waters, is prohibited unless authorized by the San Diego Water Board.

H. Any discharge to a storm water conveyance system that is not composed entirely of storm water is prohibited unless authorized by the San Diego Water Board. [The federal regulations, 40 CFR 122.26(b)(13), define storm water as storm water runoff, snow melt runoff, and surface runoff and drainage. 40 CFR 122.26(b)(2) defines an illicit discharge as any discharge to a storm water conveyance system that is not composed entirely of storm water except discharges pursuant to an NPDES permit and discharges resulting from firefighting activities.] [Section 122.26 amended at 56 FR 56553, November 5, 1991; 57 FR 11412, April 2, 1992].

I. The unauthorized discharge of treated or untreated sewage to waters of the State or to a storm water conveyance system is prohibited.

J. The discharge of industrial wastes to conventional septic tank/ subsurface disposal systems, except as authorized by the terms described in Water Code section 13264, is prohibited.

K. The discharge of radioactive wastes amenable to alternative methods of disposal into the waters of the State is prohibited.

L. The discharge of any radiological, chemical, or biological warfare agent into waters of the State is prohibited.

M. The discharge of waste into a natural or excavated site below historic water levels is prohibited unless the discharge is authorized by the San Diego Water Board.

N. The discharge of sand, silt, clay, or other earthen materials from any activity, including land grading and construction, in quantities which cause deleterious bottom deposits, turbidity or discoloration in waters of the State or which unreasonably affect, or threaten to affect, beneficial uses of such waters is prohibited.

O. The discharge of treated or untreated sewage from vessels to Mission Bay, Oceanside Harbor, Dana Point Harbor, or other small boat harbors is prohibited.

P. The discharge of untreated sewage from vessels to San Diego Bay is prohibited.

Q. The discharge of treated sewage from vessels to portions of San Diego Bay that are less than 30 feet deep at MLLW is prohibited.

R. The discharge of treated sewage from vessels, which do not have a properly functioning USCG certified Type 1 or Type II marine sanitation device, to portions of San Diego Bay that are greater than 30 feet deep at MLLW is prohibited.

ATTACHMENT H – STORM WATER POLLUTION PREVENTION PLAN

A. A Storm Water Pollution Prevention Plan (SWPPP) shall be developed, implemented, and maintained by the Discharger and incorporated into the Discharger's Best Management Practices (BMP) Plan. The SWPPP shall be designed to comply with Best Available Technology (Best Conventional Technology Currently Achievable (BAT/SCT)) and be certified in accordance with Attachment D, Standard Provisions, section V.B. The SWPPP shall be retained at the Discharger's facility and must be submitted to the San Diego Water Board Officer by 90 days from the effective date of this Order or issuance of a Notice of Enrollment.

B. The San Diego Water Board may notify a Discharger of any deficiencies found in the review of the SWPPP. Within 30 days of receipt of the San Diego Water Board's notification, the Discharger shall submit a time schedule to correct the deficiencies in the SWPPP. After making the required changes, the Discharger shall provide written certification that the changes have been made.

C. The Discharger shall amend the SWPPP whenever there is a change in operation or maintenance, which may affect the discharge of significant quantities of pollutants to surface waters. The SWPPP should also be amended if it is in violation of conditions of this General Permit or has not achieved the general objectives of preventing or reducing pollutants in its storm water discharge(s).

D. The SWPPP shall provide a description of potential sources which may be expected to add significant quantities of pollutants to storm water discharges, or which may result in industrial process water discharges to surface waters. The SWPPP shall include, at a minimum, the following items:

1. A map extending approximately one-quarter mile beyond the property boundaries of the Discharger showing:

   a. General topography,

   b. Surface water bodies, and

   c. The discharge points where the storm water discharges to surface waters.

   The requirements of this paragraph may be included in the site map required in the following paragraph if appropriate.

2. A site map showing:

   a. Storm water conveyance, retention, and/or discharge structures;

   b. An outline of the storm water drainage areas for each storm water discharge point and designation of the storm water discharge point where monitoring will be performed;

c. Paved areas, parking areas, and buildings;

d. Areas of pollutant contact, existing or potential;

e. Location of existing storm water structural control measures (i.e., berms, coverings, etc.);

f. Maintenance and repair areas; and

g. Enclosed hazardous materials storage areas.

3. A narrative description of the following:

a. Significant materials that have been treated, stored, disposed, spilled, or leaked in significant quantities in storm water discharges within the last three years;

b. Materials, equipment, and management practices employed to minimize contact of significant materials with storm water discharges;

c. Material loading, unloading, and access areas;

d. Existing structural and non-structural control measures (if any) to reduce pollutants in storm water discharges;

e. Methods of on-site storage and disposal of significant materials; and

f. Outdoor storage, manufacturing, and processing activities including activities that generate significant quantities of dust or particulates.

4. A list of pollutants that are likely to be present in storm water discharges in significant quantities and an estimate of the annual quantities of these pollutants in the storm water discharges.

5. An estimate of the size of the facility's maintenance and repair areas (in square feet), and the percent of impervious surface. The volume of storm water discharge can be estimated by multiplying the inches of rainfall (converted to feet by dividing by 12) by the square feet of surface area of the maintenance and repair areas, then multiplying the product by the impervious factor. The volume calculated, now in cubic feet, can be converted to gallons by multiplying by 7.5 (there are 7.5 gallons per cubic foot). For example,

(1 inch) / (12 inches per foot) = 0.083 feet

(0.083 feet) x (500 square feet) = 41.7 cubic feet

If the area under consideration is approximately 90% covered by asphalt, then the impervious factor is 90% or 0.90. Therefore, (41.7 cubic feet) x (0.90) = 37.5 cubic feet, and

(37.5 cubic feet) x (7.5 gallons per cubic foot) = 281 gallons

6. A list of significant spills or leaks of toxic or hazardous pollutants that have occurred within the last three years. This shall include:

a. Toxic chemicals (listed in 40 CFR Part 372) that have been discharged to storm water as reported on USEPA Form R; and

b. Oil or hazardous substances in excess of reportable quantities (see 40 CFR Part 110,117, or 302).

7. A summary of existing sampling data (if any) describing pollutants in storm water discharges.

8. The SWPPP shall describe the Discharger's storm water pollution prevention and control management measures as follows:

a. Storm Water Pollution Prevention Personnel. Identify the specific individuals (and job titles) that are responsible for developing, implementing, and revising the SWPPP.

b. Preventive Maintenance. Preventive maintenance involves inspection and maintenance of storm water conveyance system devices (clarifiers, oil water separators, catch basins, containment tanks, pumps/sumps, etc.), and inspection and testing of plant equipment and systems that could fail and result in discharges of pollutants in resulting storm water discharges.

c. Good Housekeeping. Good housekeeping requires the maintenance of clean and orderly facility areas that discharge storm water. Material handling areas shall be inspected and cleaned to reduce the potential for pollutants to enter surface waters.

d. Spill Prevention and Response. Identification of areas where significant materials may spill into or otherwise enter storm water discharge points. Specific material handling procedures, storage requirements, and cleanup equipment and procedures shall be identified, as appropriate. Internal reporting procedures for spills of significant materials shall be established.

e. Storm Water Pollution Prevention Practices. Storm water pollution prevention practices, other than those which control the source of pollutants, include measures such as installing oil and grit separators, diverting storm water into retention basins, etc. Based on assessment of the potential of various sources to contribute pollutants to storm water discharges in significant quantities, additional storm water pollution prevention practices to remove pollutants from storm water discharges may need to be implemented.

9. Pollution prevention measure or BMPs to be considered for implementation in the SWPPP shall include, but not be limited to the following:

Table H-1. Potential BMPs for Consideration

Category	Practices
Hydrowashing	• Collect and contain the discharges from the pressure washing area so they are not co-mingled with storm water discharges. • Use no detergents or additives • Implement diagonal trenches or berms and sumps to collect wash water
Surface Preparation, Sanding, and Paint Removal	• Enclose, cover, or contain blasting and sanding activities • Using the least hazardous blasting media economically available • Cover drains, trenches, and drainage channels; prohibit uncontained blasting or sanding activities over open water • Clean storm water conveyances of deposits of blasting debris and paint chips • Prohibit blasting or sanding activities during windy conditions • Inspect and clean sediment traps • Collect spent abrasives and store under a cover to await proper disposal
Painting and Coating	• Enclose, cover, or contain painting activities • If painting and blasting are performed outside use plastic barriers or tarpaulin curtains to surround the activity to contain debris, overspray, and spillage • Prohibit uncontained spray painting over open water • Prohibit spray painting during windy conditions • Mix paints and solvents in designated areas away from drains, ditches, piers, and surface waters, preferable indoors, under a shed • Have absorbent and other cleanup items readily available for immediate cleanup of spills; allow empty paint cans to dry before disposal; keep paint and paint thinner away from traffic areas • Train employees on proper painting and spraying techniques
Hull Cleaning	• All waste associated with hull maintenance and cleaning shall be collected and disposed of in accordance with all applicable laws and regulations.

Category	Practices
Engine Maintenance and Repairs	• Maintain an organized inventory of materials used in the maintenance shop • Dispose of greasy rags, oil filters, air filters, batteries, spent coolant, and degreasers properly • Minimize contamination of precipitation and surface runoff • Perform operations indoors • Label and track the recycling of waste material • Drain oil filters before disposal or recycling • Store cracked batteries in non-leaking secondary containers • Promptly transfer used fluids to proper containers • Do not leave full drip pans or other open containers around the shop • Empty and clean drip pans and containers • Do not pour liquid waste down floor drains, sinks, or outdoor storm drain inlets • Plug floor drains that are connected to the storm or sanitary sewer • Inspect maintenance area regularly • Train employees on proper waste control and disposal procedures • Prohibit hosing down the shop floor
Containerized Material Storage	• Store reactive, ignitable, or flammable liquids in compliance with the local fire code • Label all containerized materials • Identify potentially hazardous materials, their characteristics, and use • Control excessive purchasing, storage, and handling of potentially hazardous materials • Keep records to identify quantity, receipt date, service life, users, and disposal routes • Secure and carefully monitor hazardous materials to prevent theft, vandalism, and misuse of materials • Use temporary containment where required by portable drip pans; use spill troughs for drums with taps

Category	Practices
	• Mix paints and solvents in designated areas with secondary containment and away from drains, ditches, piers, and surface waters • Locate designated materials storage areas indoors or under a shed or otherwise minimize the contamination of precipitation and surface runoff
Work Areas for Boat Repair	• Clearly mark all work areas and perform work inside when possible • Clean storm water conveyances of deposits of abrasive blasting debris and paint chips.

10. **Employee Training.** Employee training programs shall be held with all personnel responsible for implementing the SWPPP. Training shall address pollution prevention, spill response, good housekeeping, and material management practices. Periodic dates for training shall be identified in the SWPPP and shall occur at least annually. Employee training is recommended to occur just prior to the wet season.

11. **Inspections.** All inspections, visual observations, and sampling as required in the MRP (Attachment E), shall be done by trained personnel. A tracking or follow-up procedure shall be implemented to address any deficiencies found during the inspections, etc.

12. The SWPPP may incorporate, by reference, the appropriate elements of other program requirements (e.g. Spill Prevention Control and Countermeasure [SPCC] plans under Section 311 of the CWA).

13. The SWPPP is considered a report that shall be available to the public under Section 308 (b) of the CWA.

14. The SWPPP shall include the signature and title of the person responsible for preparation of the SWPPP and include the date of initial preparation and each amendment thereto.

ATTACHMENT I – BOATYARD ANNUAL CHECKLIST

California Regional Water Quality Control Board

San Diego Region

Annual Report Checklist

Boatyard General Order No. R9-2013-0026

This annual report checklist is submitted by ________________________ (Discharger) for the Monitoring and Reporting Program for Order No. R9-2013-0026.

Annual Compliance Certification

___Yes No ___ The Discharger has complied with all conditions of this General Permit.

___Yes No ___ The Discharger has eliminated industrial process water discharges to waters of the United States in accordance with Discharge Prohibition III.C of this General Permit.

___Yes No ___ The Discharger has a storm water diversion system that will eliminate the discharge of the first-flush storm water runoff for each storm event, as defined in Attachment A, from its maintenance and repair area(s) to storm drains or surface water in accordance with Discharge Prohibition III. B of this General Permit.

___Yes No ___ The Discharger has implemented BMPs in accordance with its SWPPP, and the SWPPP has been amended in accordance with the SWPPP requirements, Section X. and Attachment H, of this General Permit.

___Yes No ___ The Discharger has isolated its maintenance/repair areas in accordance with Storm Water Discharge Requirements X.A. and X.F. of this General Permit.

___Yes No ___ The Discharger has not discharged any liquids other than storm water pursuant to Discharge Prohibition III.C.

___Yes No ___ The Discharger has notified each owner/operator of each vessel at the Discharger's leasehold of their obligation to prevent the discharge of waste and to comply with Basin Plan prohibitions regarding the discharge of sewage from vessels as stated in section X.G of this General Permit. In addition, the Discharger shall briefly report on any corrective actions taken against any vessel owner/operator(s).

Attach a discussion of the reasons any of the above are answered "No."

Spill and Illicit Discharge Log

___Yes No ___ A log of all spills and illicit discharges to surface waters is attached.

Chemical Utilization Records

___Yes No ___ The Discharger maintains records of hazardous materials used at its Facility over the previous 5-year period.

Receiving and Sediment Monitoring

This facility is ____ Category 1 or ____ Category 2 Monitoring.

___Yes No ___ Sampling was conducted this year. If yes, submit report in accordance with schedule in monitoring plan.

Storm Event Sampling

___Yes No ___ Sampling occurred during the first qualifying storm event. If yes, submit sample results. If no, reason:

____

____

___Yes No ___ Sampling occurred during the second qualifying storm event. If yes, submit sample results. If no, reason:

____

____

Storm and Non-Storm Water Monitoring

___Yes No ___ BMP Inspections were conducted weekly and a summary is attached.

___Yes No ___ Storm water discharges were visually observed for the first qualifying storm in each month of the wet season from October 1 through April 30 and a summary is attached.

___Yes No ___ All stored or contained storm water was visually observed and sampled before discharge to surface waters.

___Yes No ___ All storm water storage and containment areas are free of leaks and appropriately maintained based on monthly inspections.

___Yes No ___ All storm events that do not produce a discharge to surface water are recorded.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: ______________________ Print Name: ______________________

Title: ______________________ Date: ______________________

ATTACHMENT J – NO EXPOSURE CERTIFICATION FORM

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
SAN DIEGO REGION

NO EXPOSURE CERTIFICATION FORM		
FACILITY OPERATOR INFORMATION		
Name:		
Mailing Address Street:		
City:	State:	ZIP Code:
Operator Contact:	Phone:	
Email:		
FACILITY/SITE LOCATION INFORMATION		
Facility WDID (if applicable):		
Facility Name:		
Facility Address:		
City:	State:	ZIP Code:
County:		
Facility Contact:	Phone:	
Email:		
Latitude:	Longitude:	
Total acreage of facility associated with industrial activity:		
SIC Code (Primary):	SIC Code (Secondary, if applicable):	
Brief description of primary industrial activity:		
FACILITY BILLING INFORMATION		
☐ Same as Mailing Address	☐ Same as Facility Address	
Billing Address:		
City:	State:	ZIP Code:
Billing Contact:	Phone:	
Email:		

NO EXPOSURE CERTIFICATION REPORT **NOTE: THE NO EXPOSURE CERTIFICATION REPORT MUST BE PREPARED AND CERTIFIED BY A CALIFORNIA LICENSED PROFESSIONAL ENGINEER THE FIRST YEAR AND ANY TIME THERE IS A CHANGE AT THE FACILITY WHICH AFFECTS THE DISCHARGE OF STORM WATER EXPOSED TO INDUSTRIAL ACTIVITIES OR MATERIALS**	
Does the facility have secondary containment that is engineered to always prevent a discharge of collected rainfall (based on the historical rainfall record) and a simultaneous spill of any other industrial materials or liquids? Note: there must be proper disposal of any water or liquids collected from the containment (e.g., discharged in compliance with another NPDES permit, treated and discharged to the sanitary sewer, or trucked offsite to an appropriate disposal/treatment facility).	☐ Yes ☐ No
If secondary containment is claimed, how much secondary containment is available?	

The Discharger shall submit a NEC Report prepared by a California licensed professional Engineer that

A. Evaluates whether the following materials or activities are exposed to precipitation now or in the foreseeable future and have the potential to be discharged in storm water, aerially, or by other means:

1. Using, storing or cleaning industrial machinery or equipment, and areas where residuals from using, storing or cleaning industrial machinery or equipment remain and are exposed to storm water.
2. Materials or residuals on the ground or in storm water inlets from spills/leaks.
3. Materials or products from past industrial activity.
4. Material handling equipment (except adequately maintained vehicles).
5. Materials or products during loading/unloading or transportation activities.
6. Materials or products stored outdoors (except final products intended for outside use, e.g., new cars, where exposure to storm water does not result in the discharge of pollutants).
7. Materials contained in open, deteriorated or leaking drums, barrels, tanks, and similar containers.
8. Materials or products handled/stored on roads or railways owned or maintained by the discharger.
9. Waste material (except waste in covered, non-leaking containers [e.g., dumpsters]).
10. Application or disposal of process wastewater (unless otherwise permitted).
11. Particulate matter or visible deposits of residuals from roof stacks and/or vents not otherwise regulated (i.e., under an air quality control permit) and evident in the storm water outflow.

B. Include a technical description of any secondary containment and the capacity of the secondary containment.

C. A site map of facility including any structural Best Management Practices such as treatment facilities and/or secondary containment facilities.

CERTIFICATION STATEMENT
I certify under penalty of law that I have read and understand the eligibility requirements for claiming a condition of 'no exposure' and obtaining an exclusion from NPDES storm water permitting; and that there are no discharges of storm water contaminated by exposure to industrial activities or materials from the industrial facility identified in this document. I understand that I am obligated to submit a no exposure certification form annually to the San Diego Water Board and, if requested, to the operator of the local Municipal Separate Storm Sewer System (MS4) into which this facility discharges (where applicable). I understand that I must allow the San Diego Water Board, or MS4 operator where the discharge is into the local MS4, to perform inspections to confirm the condition of no exposure and to make such inspection reports publicly available upon request. I understand that I must obtain coverage under an NPDES permit prior to any point source discharge of storm water from the facility. I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based upon my inquiry of the person or persons who manage the system, or those persons directly involved in gathering the information, the information submitted is to the best of my knowledge and belief true, accurate and complete. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations
Print Name:
Print Title:
Signature:
Date:
Email:

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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SPAWAR
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San Diego, CA 92152-5001

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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.

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.

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.

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.

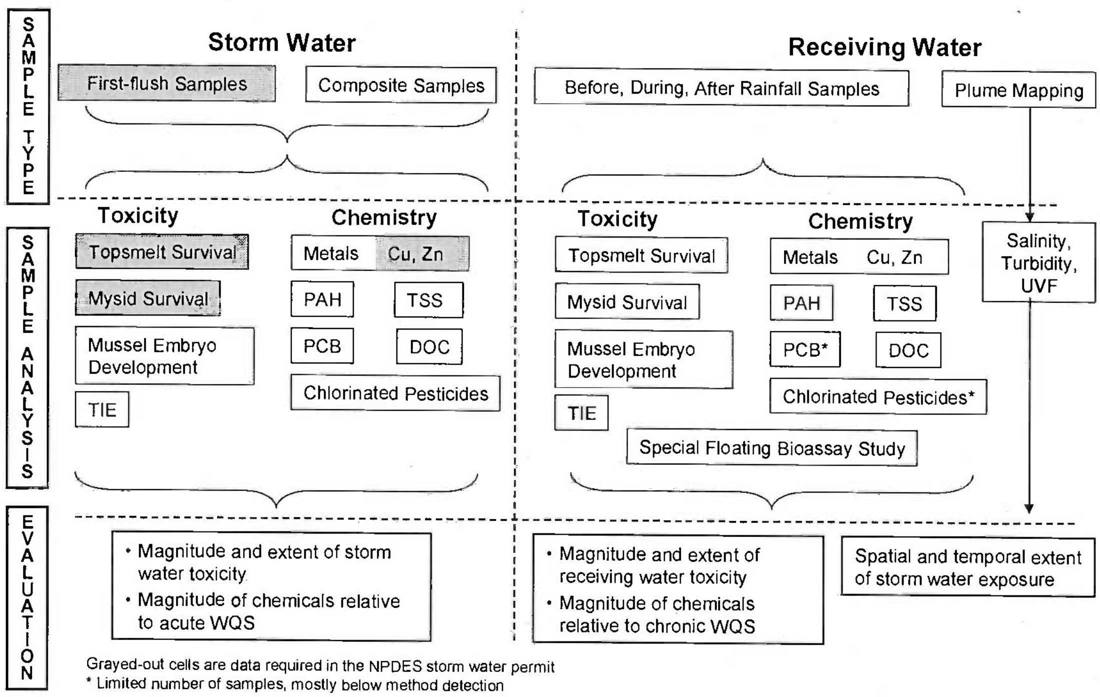


Figure 1. Schematic of technical approach that included simultaneous toxicity and chemistry measurements in storm water, toxicity and chemistry measurements in receiving waters, and storm water plume mapping.

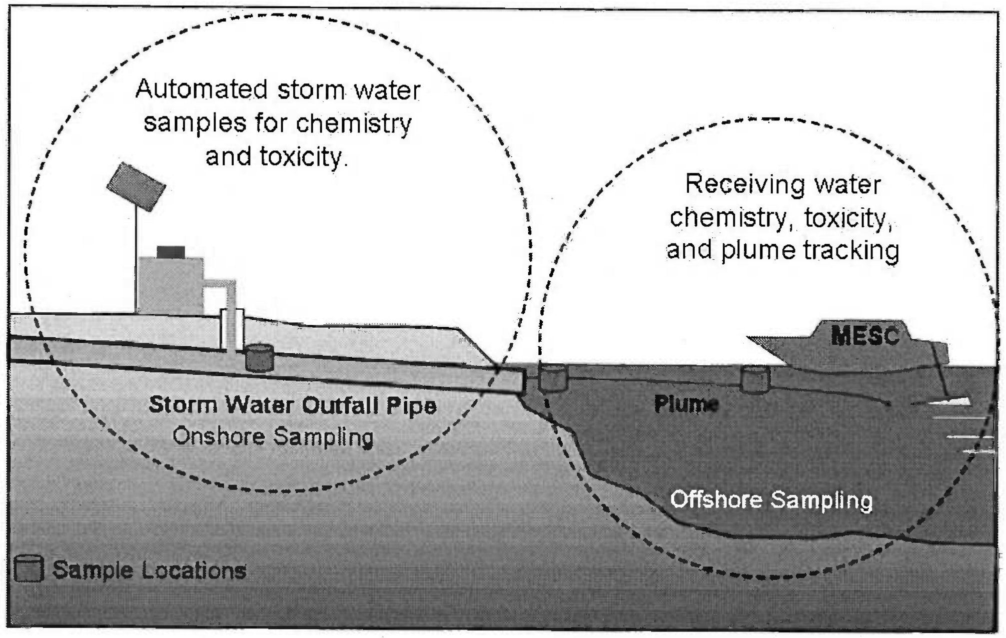


Figure 2. Graphical schematic for the technical approach that included simultaneous toxicity and chemistry measurements in storm water, toxicity and chemistry measurements in receiving waters, and storm water plume mapping. Receiving water sampling was conducted using the Marine Environmental Survey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

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.

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

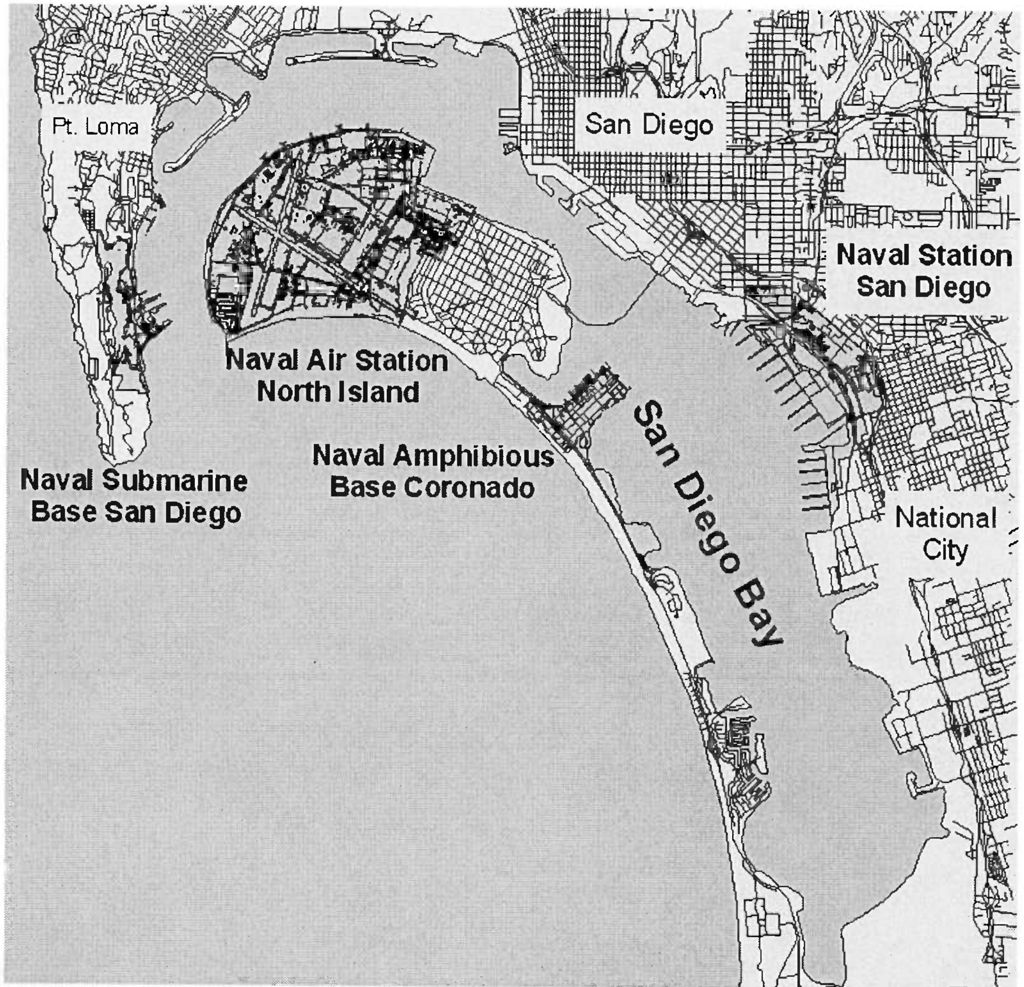


Figure 3. Navy bases bordering San Diego Bay sampled during the study, including Naval Station San Diego, Naval Submarine Base San Diego, Naval Amphibious Base Coronado, and Naval Air Station North Island.

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

Sample Dates	Base	Storm	[illegible]	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	[illegible]		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	[illegible]	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	[illegible]		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

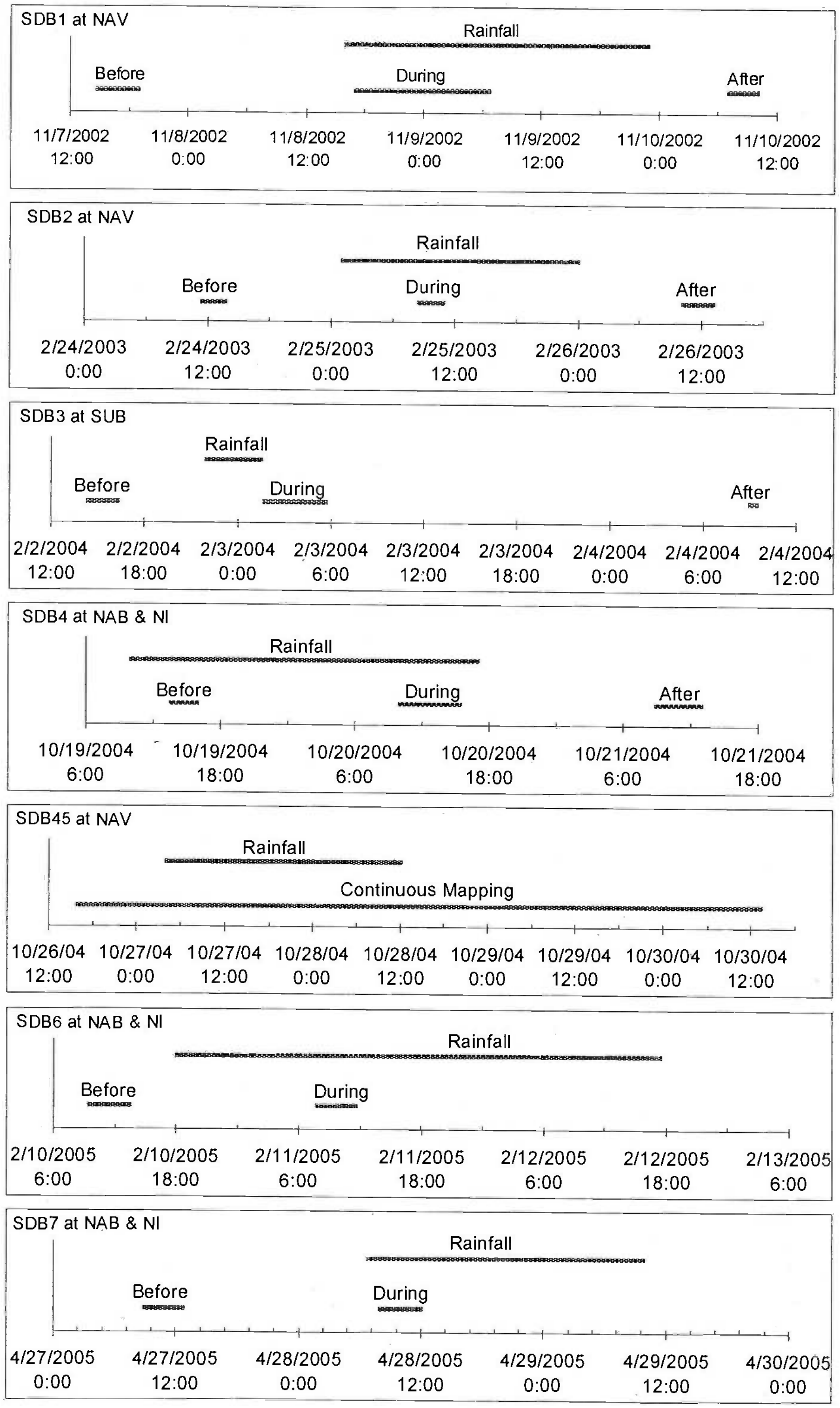


Figure 4. Summary timetable of 17 plume mapping surveys conducted before, during, and after rainfall events. The floating bioassay system was deployed during the SDB45 storm event.

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.

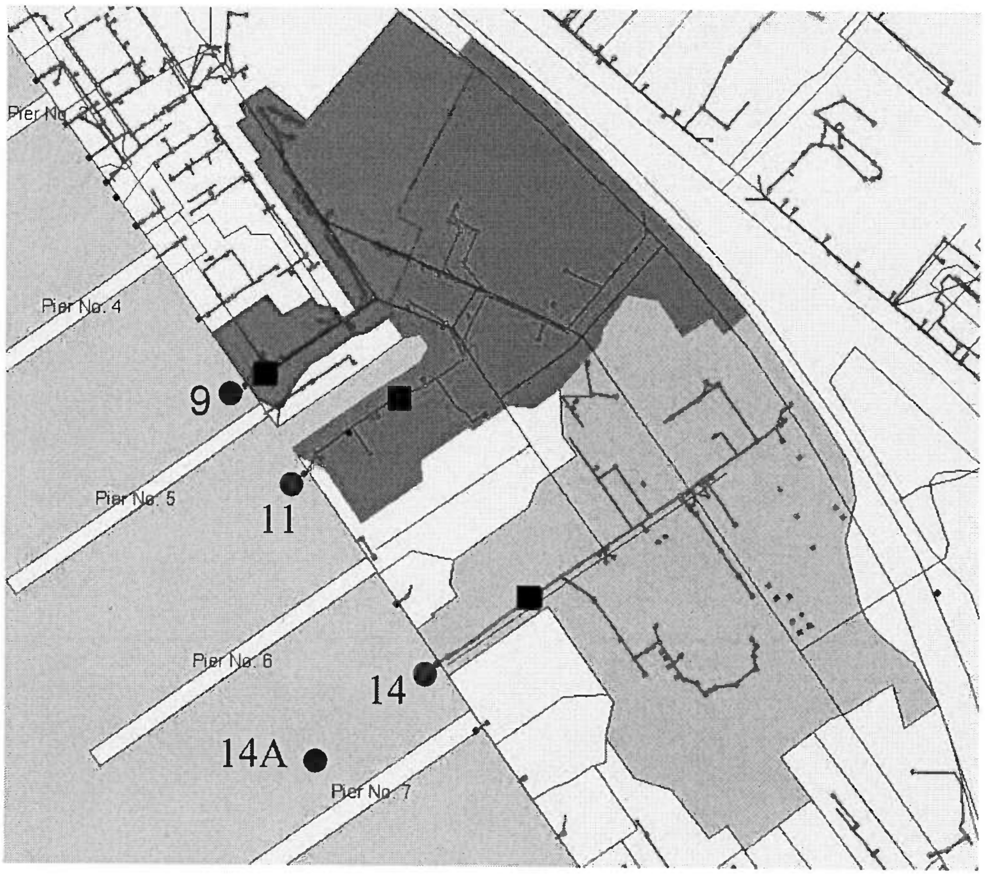


Figure 5. Detail of Naval Station San Deigo drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water locations are identified by the red circles and labeled with the associated outfall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

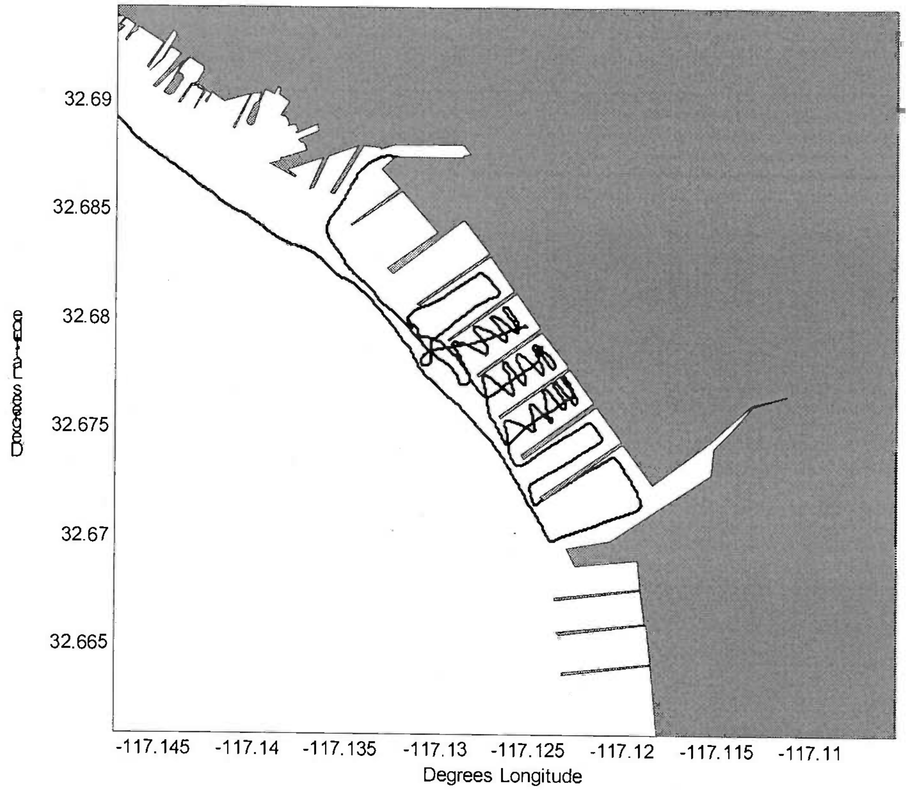


Figure 6. Example storm water plume mapping track used during storm event SDB1 at Naval Station San Diego. The track was repeated before, during, and after storm events. All plume mapping tracks are shown in Appendix G.

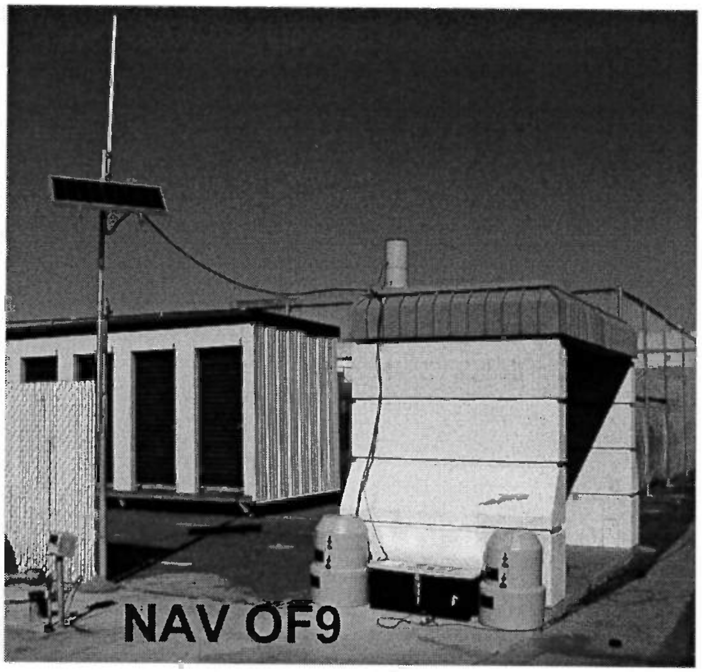
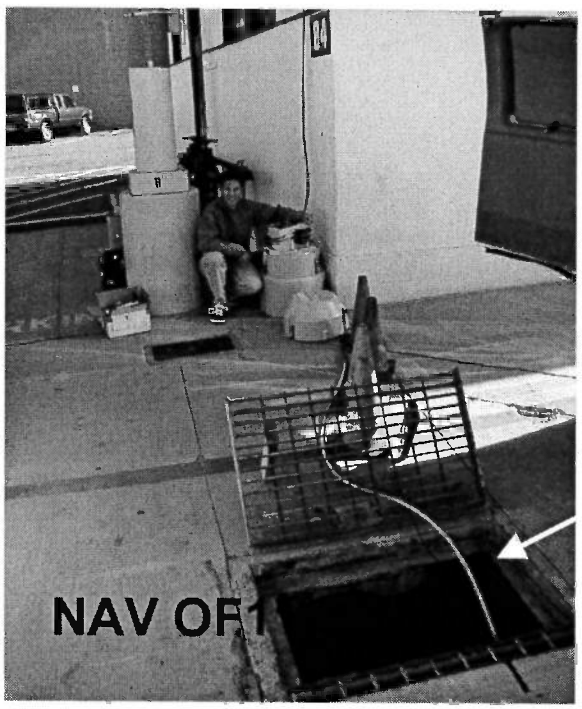


Figure 7. Naval Station San Diego storm water monitoring location for outfall 9. Automated samplers, rain gauge, power and communications systems are also shown.



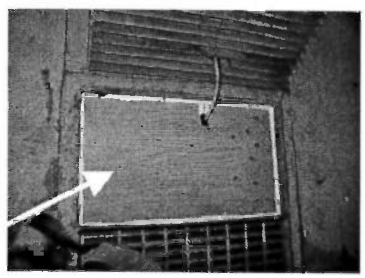


Figure 8. Naval Station San Diego storm water monitoring location for outfall 11. The rain gauge was placed on top of Building 84 in the background. The solar power panel and RF link were attached to the light pole next to the building. The short distance between the building and the grate was secured 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.

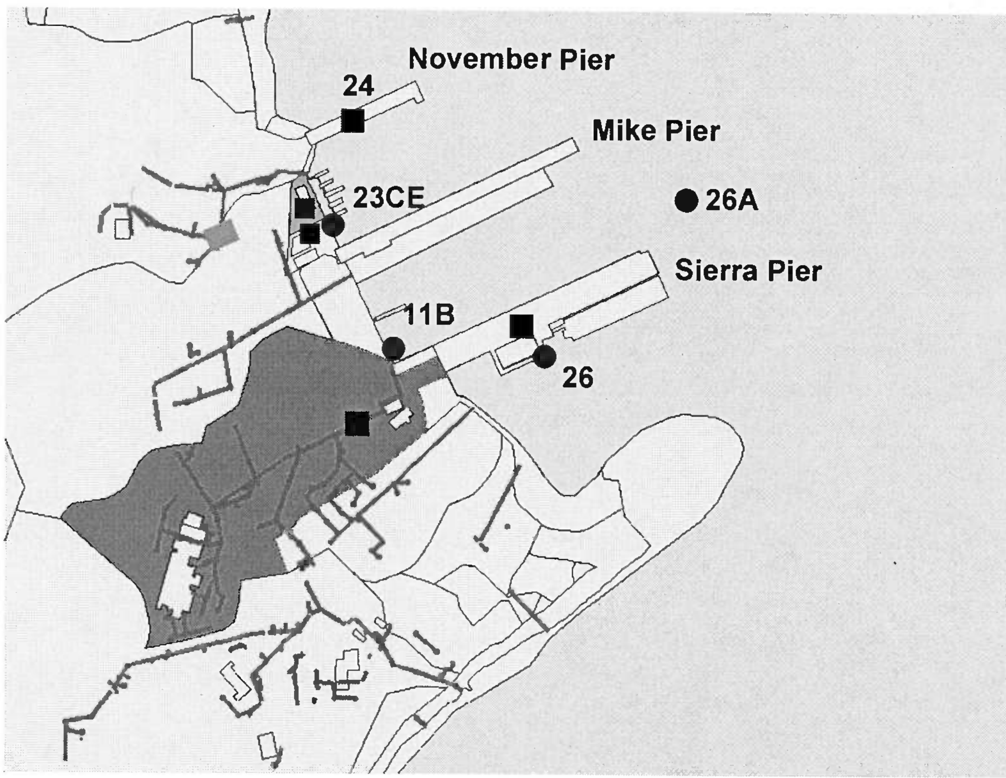


Figure 10. Detail of Naval Submarine Base San Diego drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares, though samples were also collected from multiple drains along Sierra Pier for composite samples. 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.

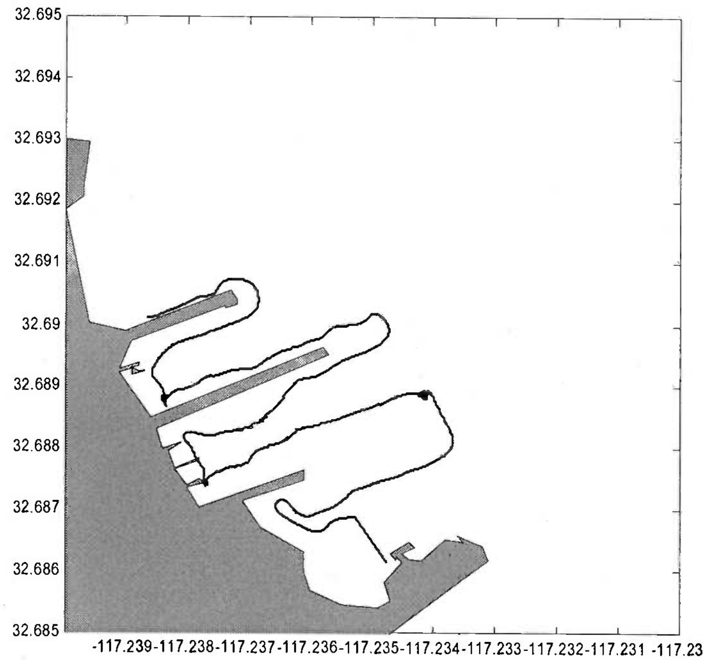


Figure 11. Example storm water plume mapping track used during storm event SDB2 at Naval Submarine Base San Diego. The track was repeated before, during, and after storm events. All plume mapping tracks are shown in Appendix G.

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.

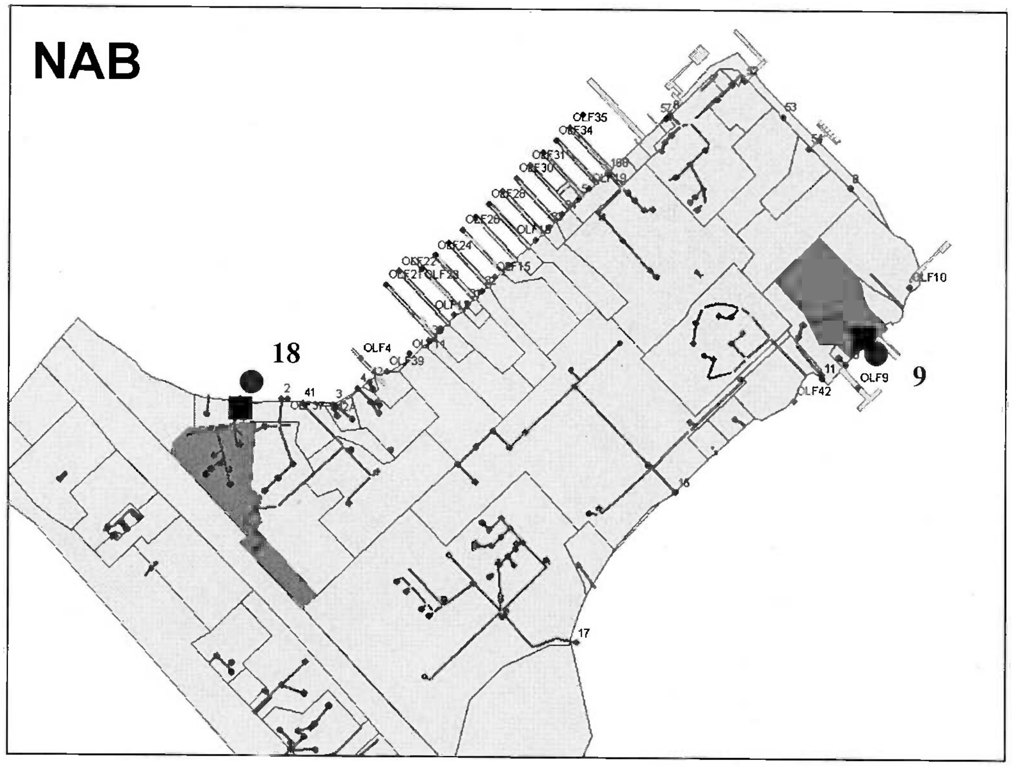


Figure 12. Detail of Naval Amphibious Base Coronado drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water sample locations are identified by the red circles and labeled with the associated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

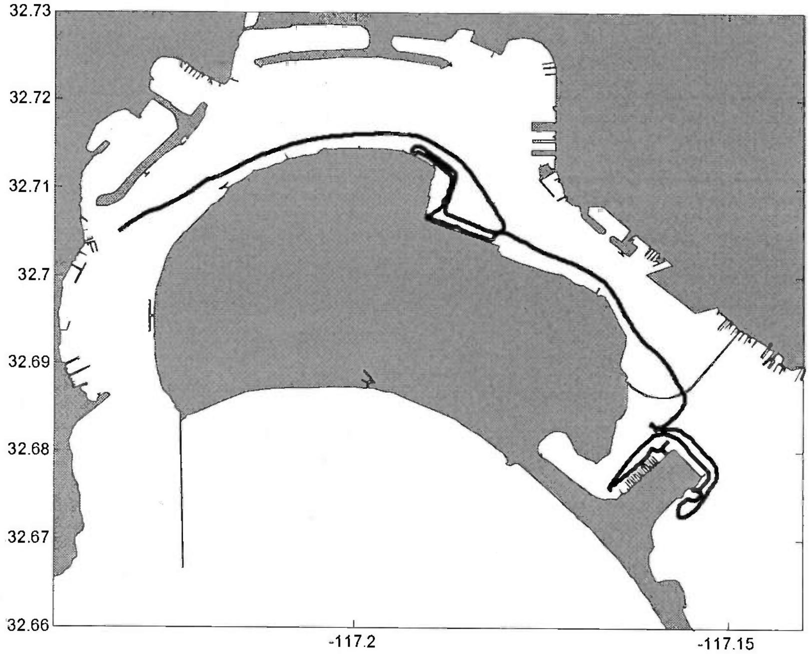


Figure 13. Example storm water plume mapping track used before storm event SDB6 for Naval Amphibious Base Coronado and Naval Air Station North Island. The track was repeated before and during storm events. All plume mapping tracks are shown in Appendix G.

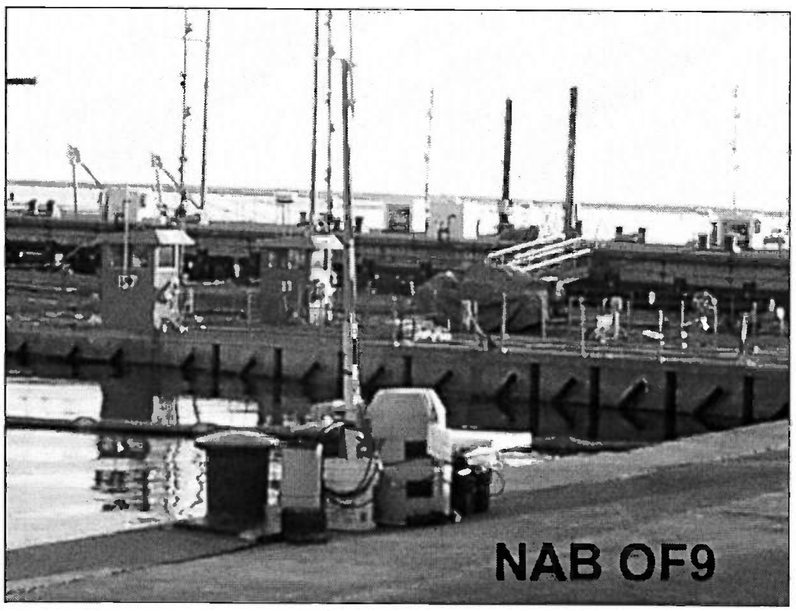


Figure 14. Naval Amphibious Base Coronado storm water monitoring location for outfall 9. The site was located in a barge maintenance area right at the quay wall.

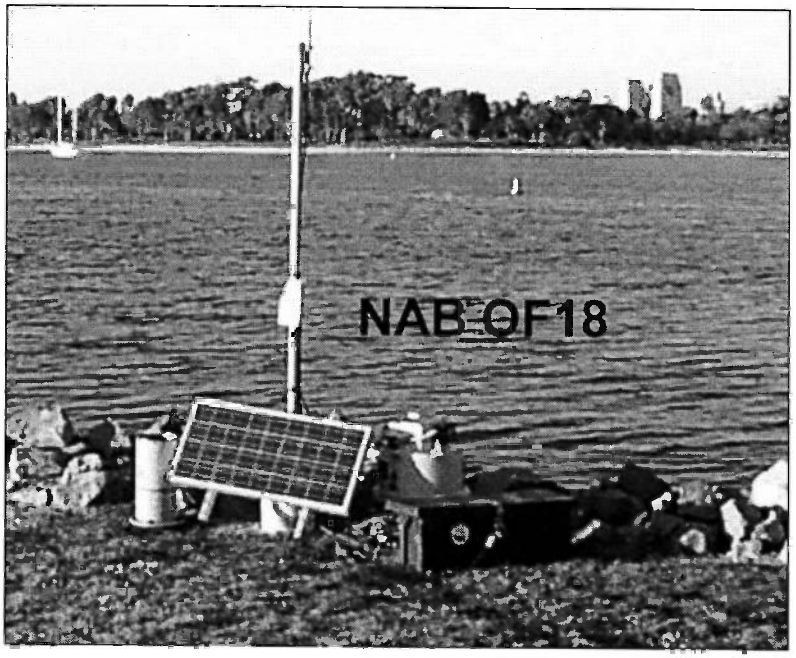


Figure 15. Naval Amphibious Base Coronado storm water monitoring location for outfall 18. The site was located within a small grassy area along a beach bordering the bay.

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.

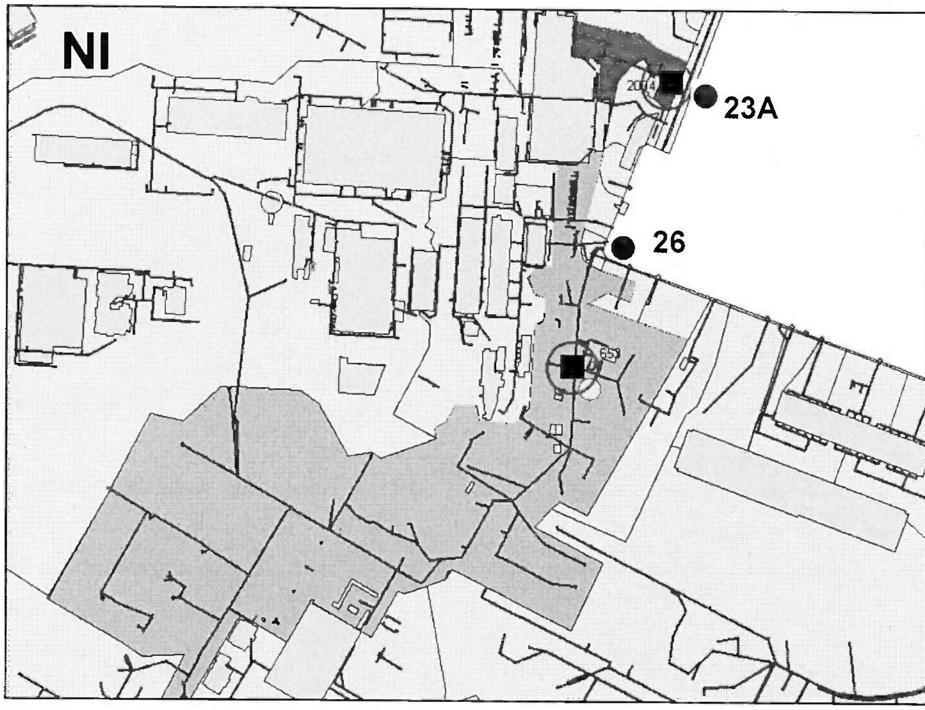


Figure 17. Detail of Naval Air Station North Island drainage areas, including storm water outfall locations and conveyance systems. Onshore storm water monitoring locations are identified by the black squares. Receiving water sample locations are identified by the red circles and labeled with the associated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

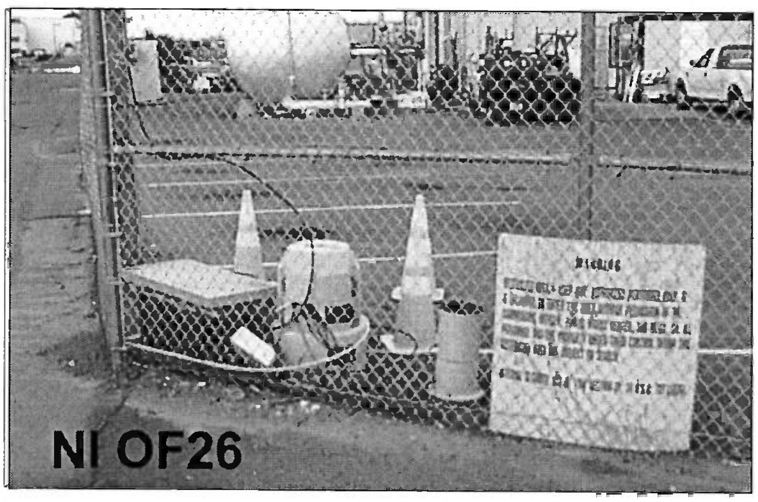


Figure 18. Naval Air Station North Island storm water monitoring location for outfall 26. The site was located along the fence surrounding a steam plant.

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.

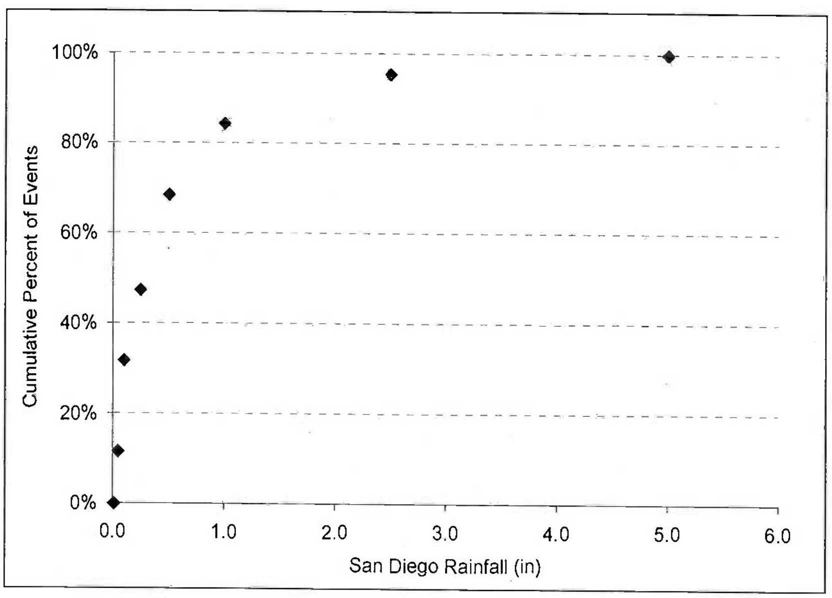


Figure 19. Cumulative frequency distribution plot of historical rainfall data for San Diego (Lindbergh Field). The plot shows rainfall totals for storm events occurring during the October–April rainy season. The plot represents percentages derived from over 15,000 records See the following website: http://www.wrh.noaa.gov/sgx/climate/san-san.htm

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.

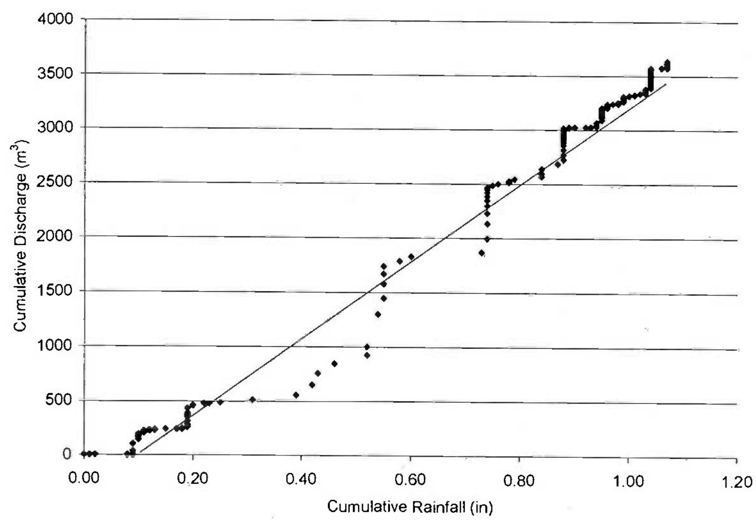


Figure 20. Relationship between rainfall and discharge volume during one storm at Naval Submarine Base San Diego outfall 11B. The good correlation validated the use of rainfall as a trigger for composite sampling for the four Navy facilities. The relationship is not expected to hold for regions with 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 10°C above ambient temperature. As mussels began to spawn, they were segregated into 200-mL beakers containing 15°C, 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 120°C) 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 90th 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 3°C. Temperature did fall slightly outside the targeted temperature range 23% of the time, but this exceedance was by less than 1°C 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 3°C, as required. Temperature did fall outside the targeted temperature range 13% of the time, but the exceedance was by less than 1°C 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 ($\geq$ 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.

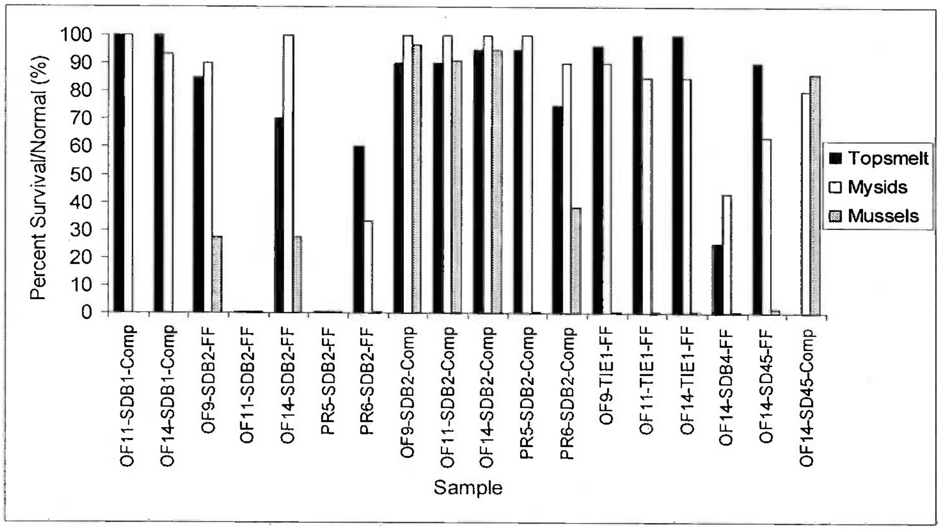


Figure 22. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Station San Diego.

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

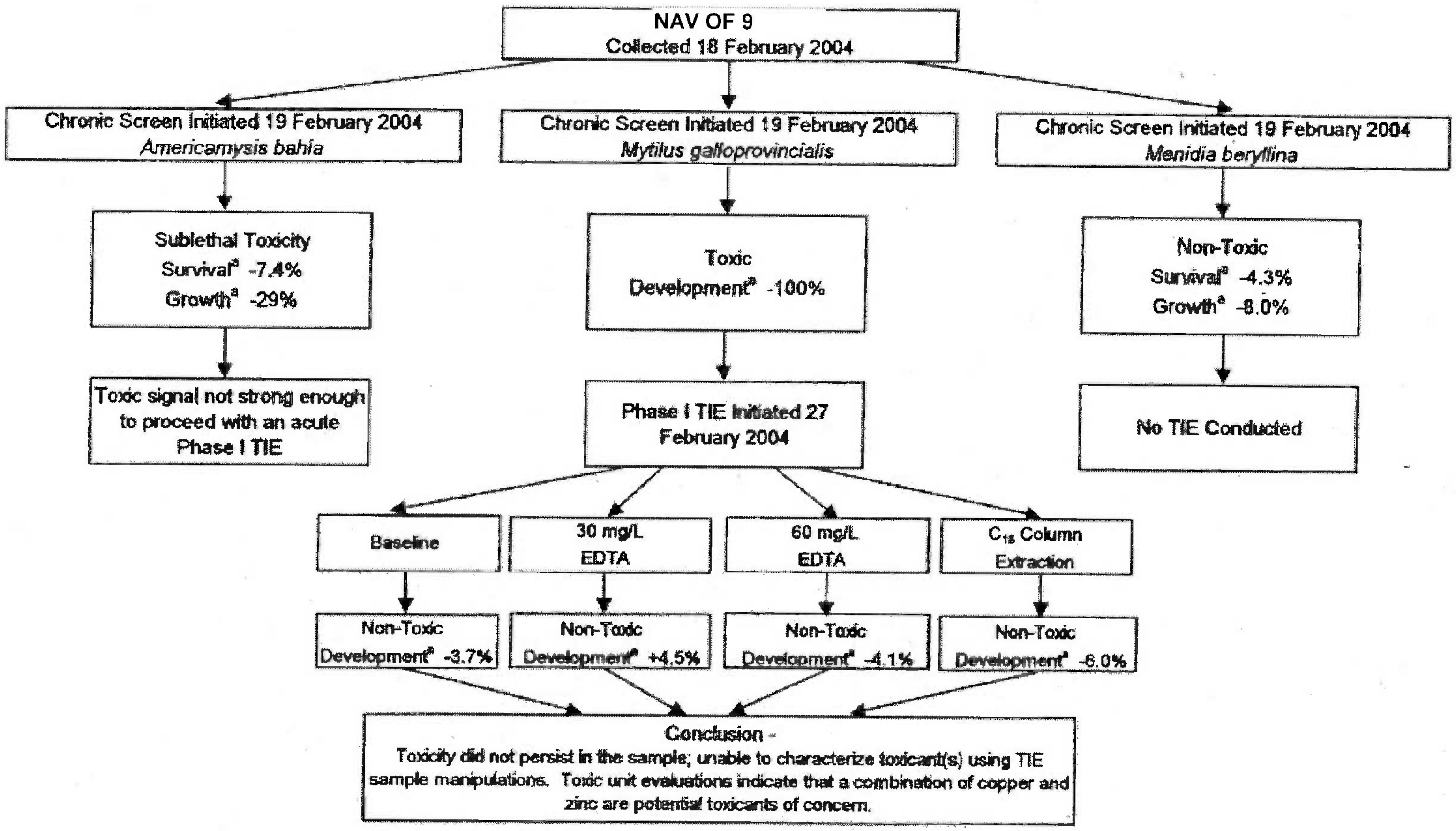
Table 13. Percent Minimum Significant Difference (PMSD) for Naval Station San Diego toxicity tests.

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

7.2.3 TIE

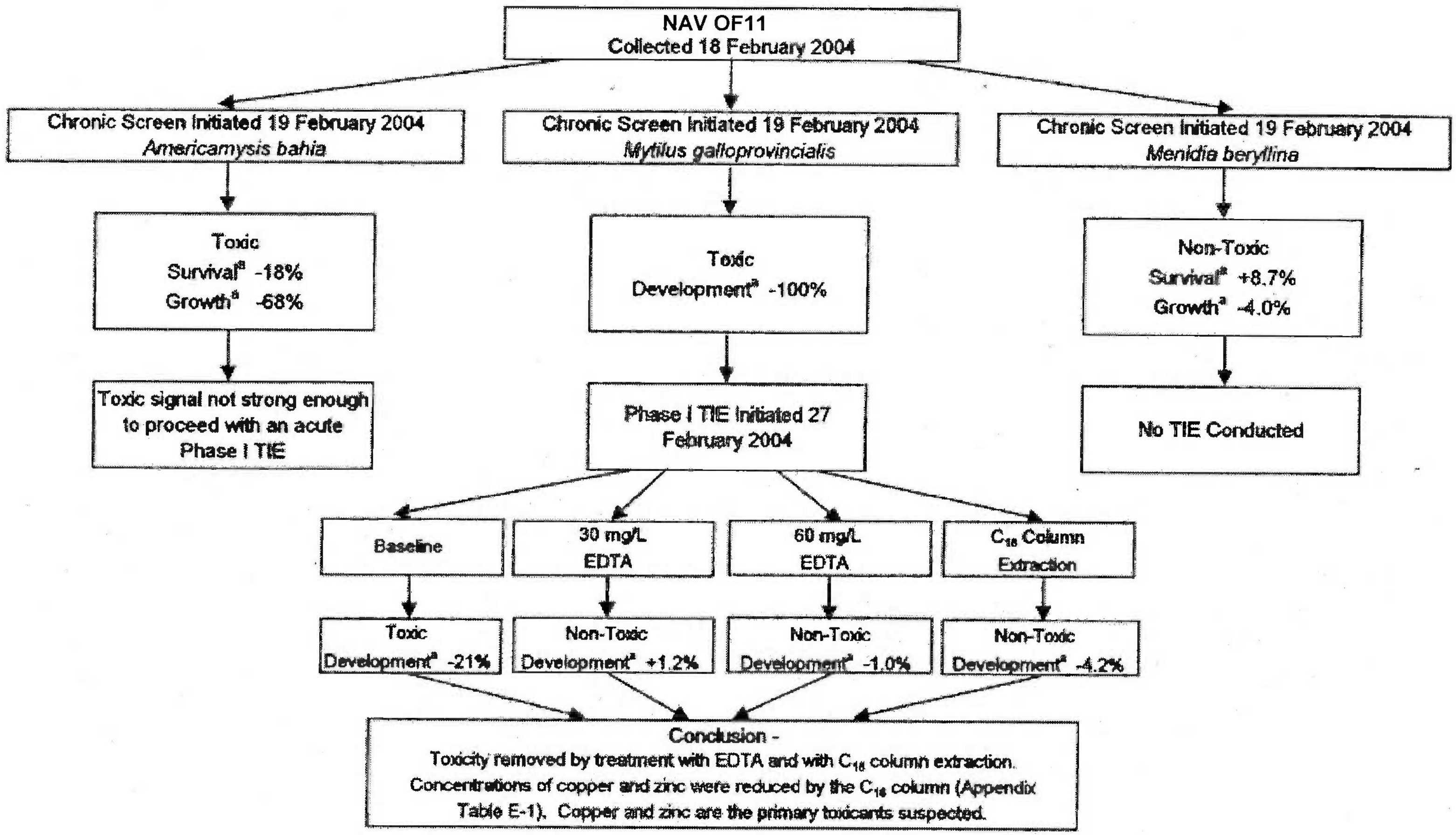
A Toxicity Identification Evaluation was performed on first-flush storm water samples collected from each of the three outfalls at Naval Station San Diego during the storm event on 18 February 2004. First-flush samples were collected at the start of a very low rainfall event in which only 0.19 inches 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.



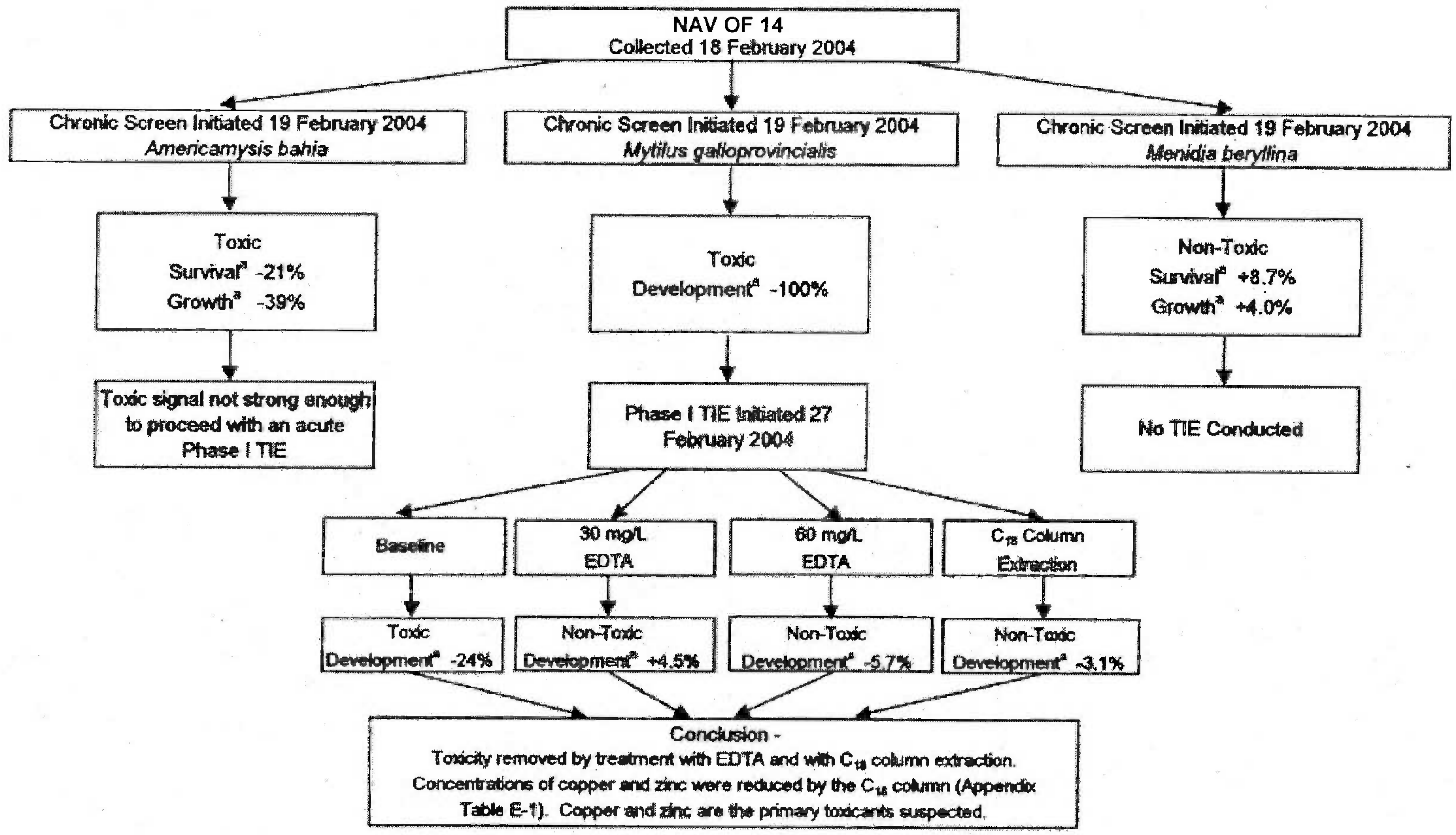
[a] Results expressed in terms of % difference from the appropriate salt or brine control in full-strength solution.

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	

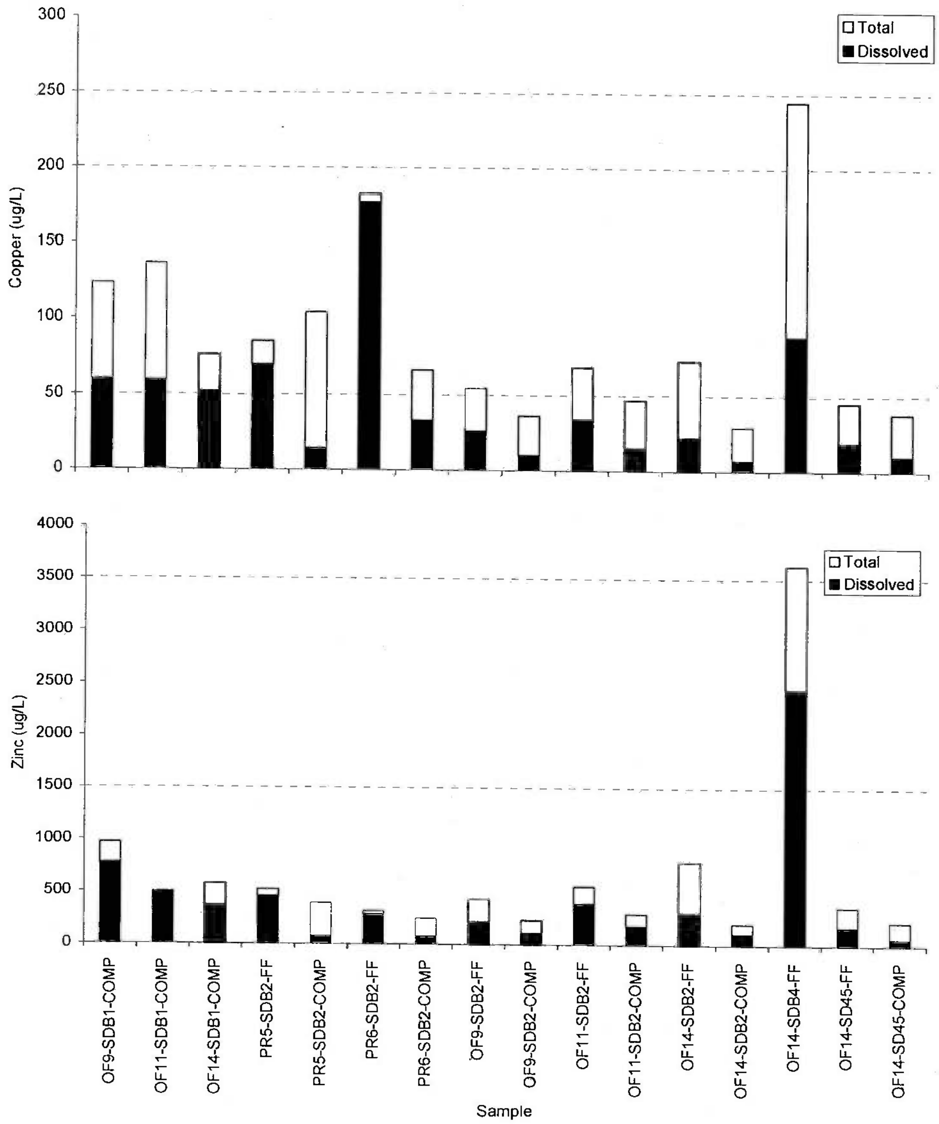


Figure 26. Total and dissolved copper and zinc concentrations measured in Naval Station San Diego first-flush (FF) and composite (Comp) outfall samples.

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%

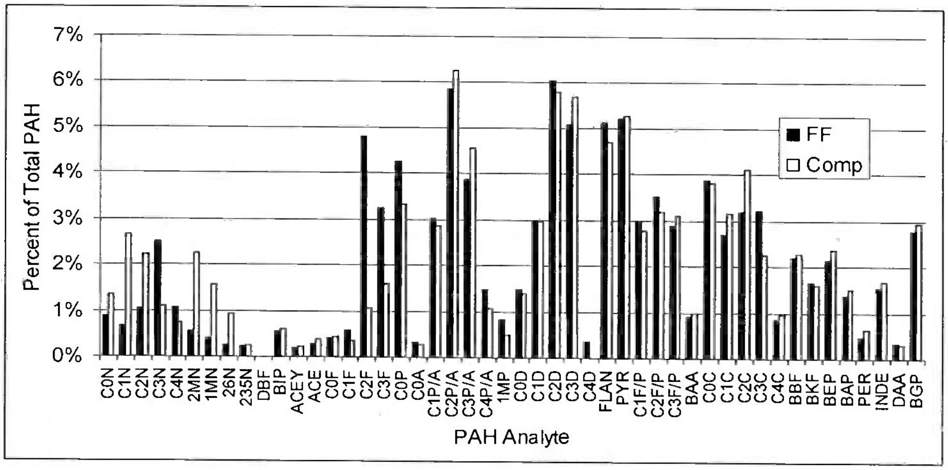


Figure 27. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Station San Diego. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

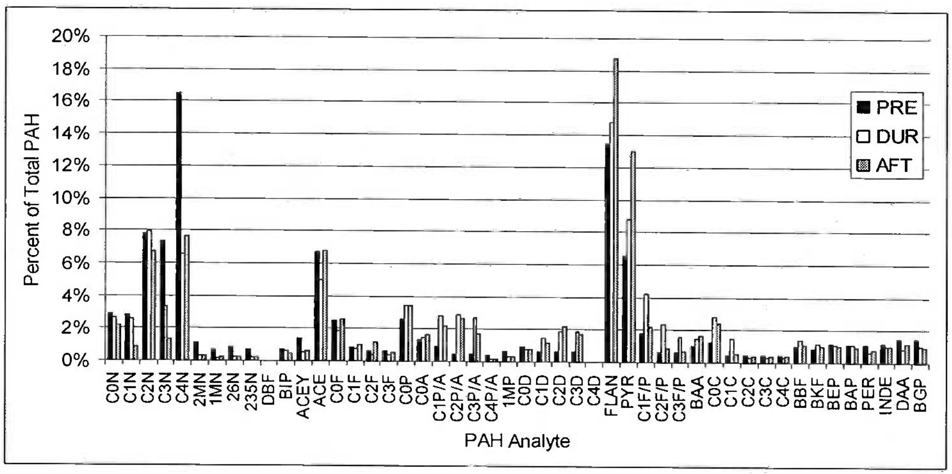


Figure 28. Average PAH composition in receiving waters before (PRE), during (DUR), and after (AFT) storm events at Naval Station San Diego. Table 6 shows analyte IDs.

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

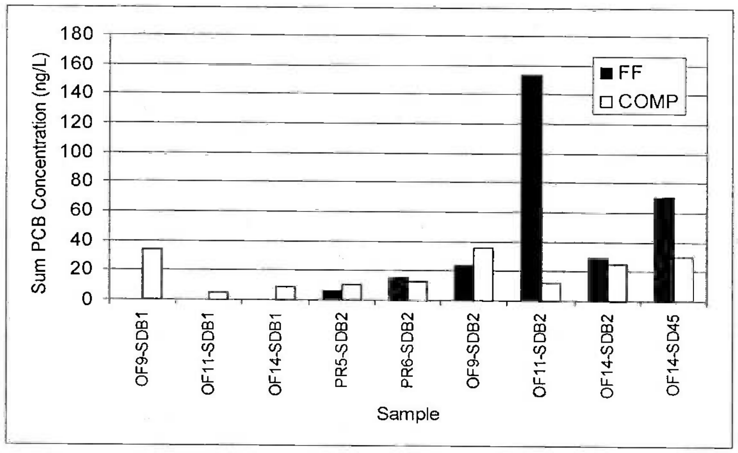


Figure 29. Summed PCB concentrations for first-flush (FF) and composite (COMP) outfall samples at Naval Station San Diego. The summation used one-half the MDL for congeners not detected in the sample.

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.

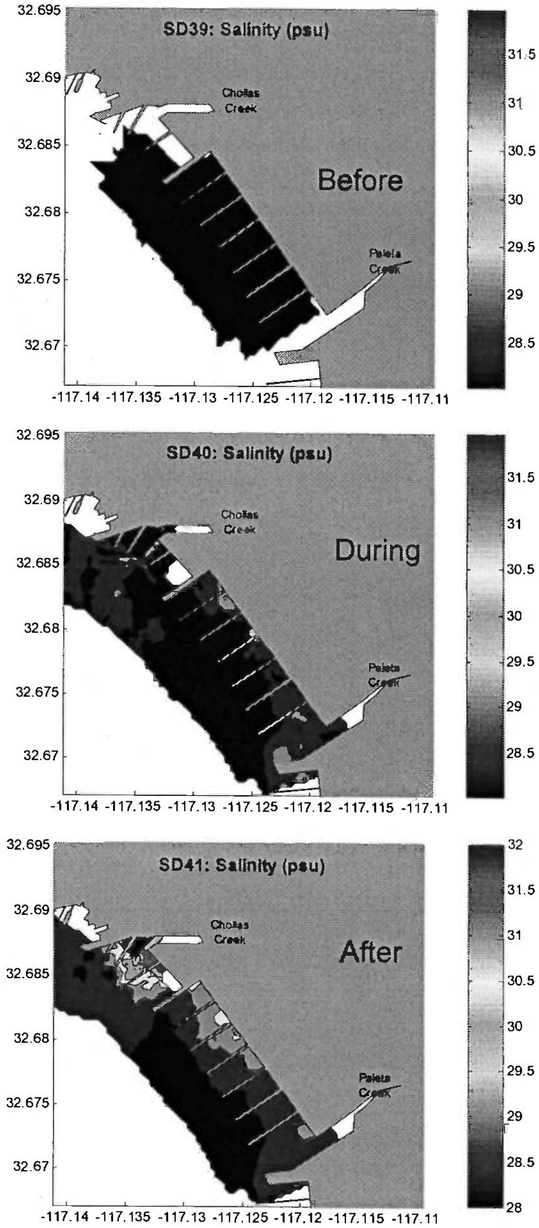


Figure 30. Surface salinity mapping before, during, and 24 hours after a storm event (SDB2) at Naval Station San Diego.

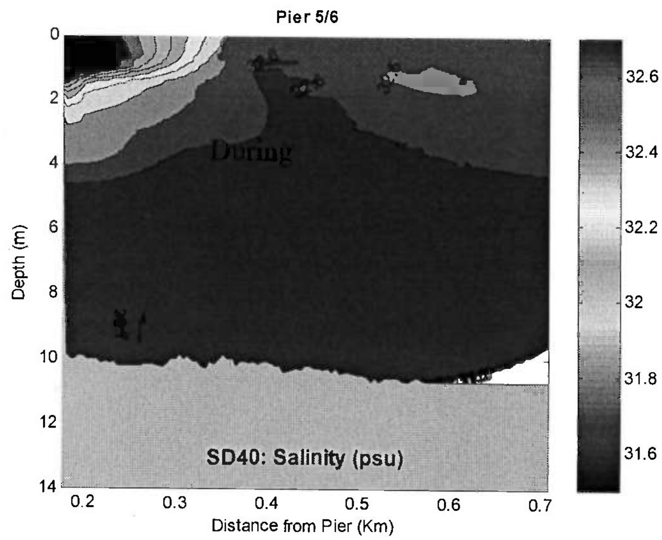


Figure 31. Vertical cross section of salinity between piers 5 and 6 (outside of outfall 9) during storm event SDB2 at Naval Station San Diego.

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.

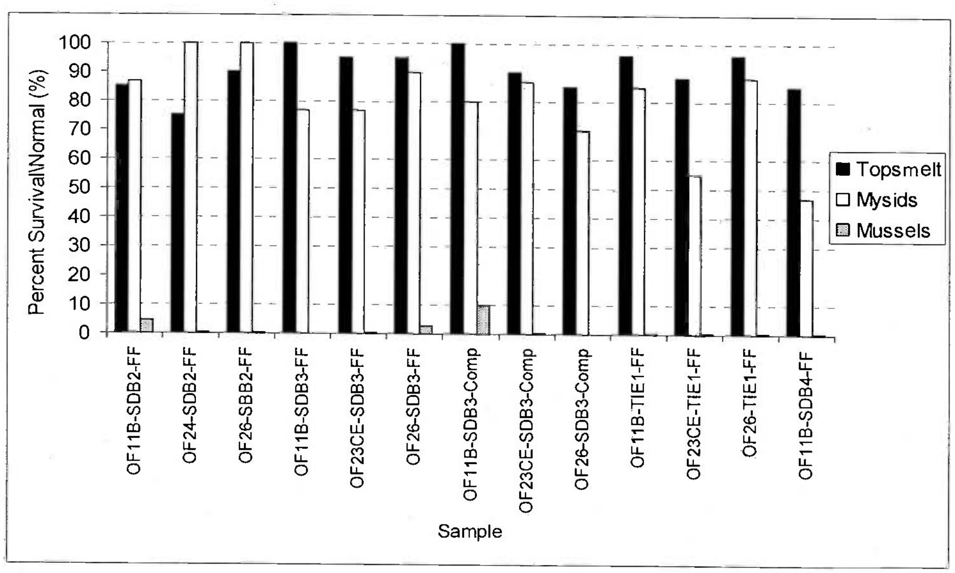


Figure 32. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Submarine Base San Diego.

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.

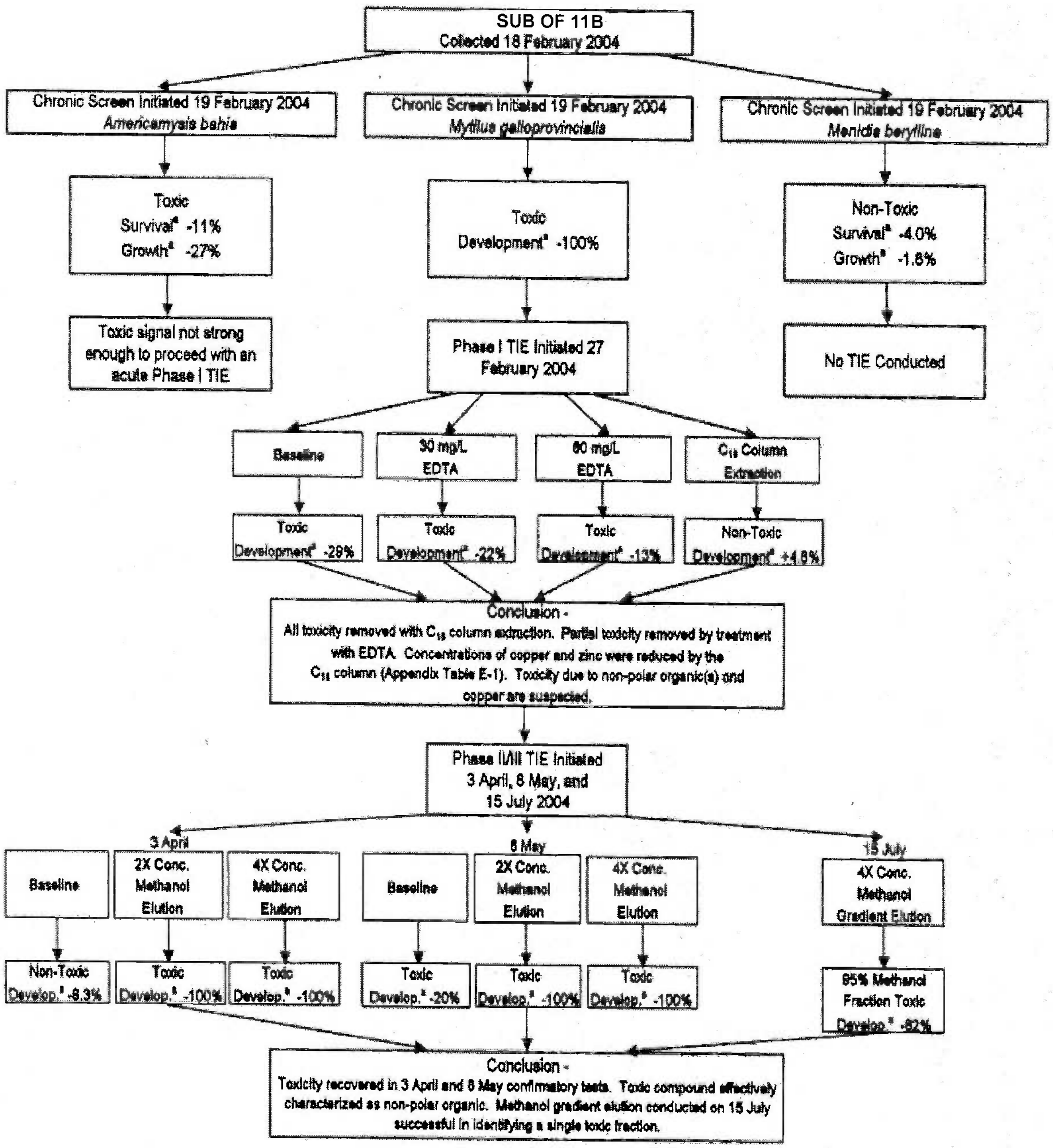
PMSD	Topsmelt	Mysids	Mussels
n	13	12	11
Min (%)	6	4	8
Mean (%)	13	9	13
Max (%)	24	13	19

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.



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

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