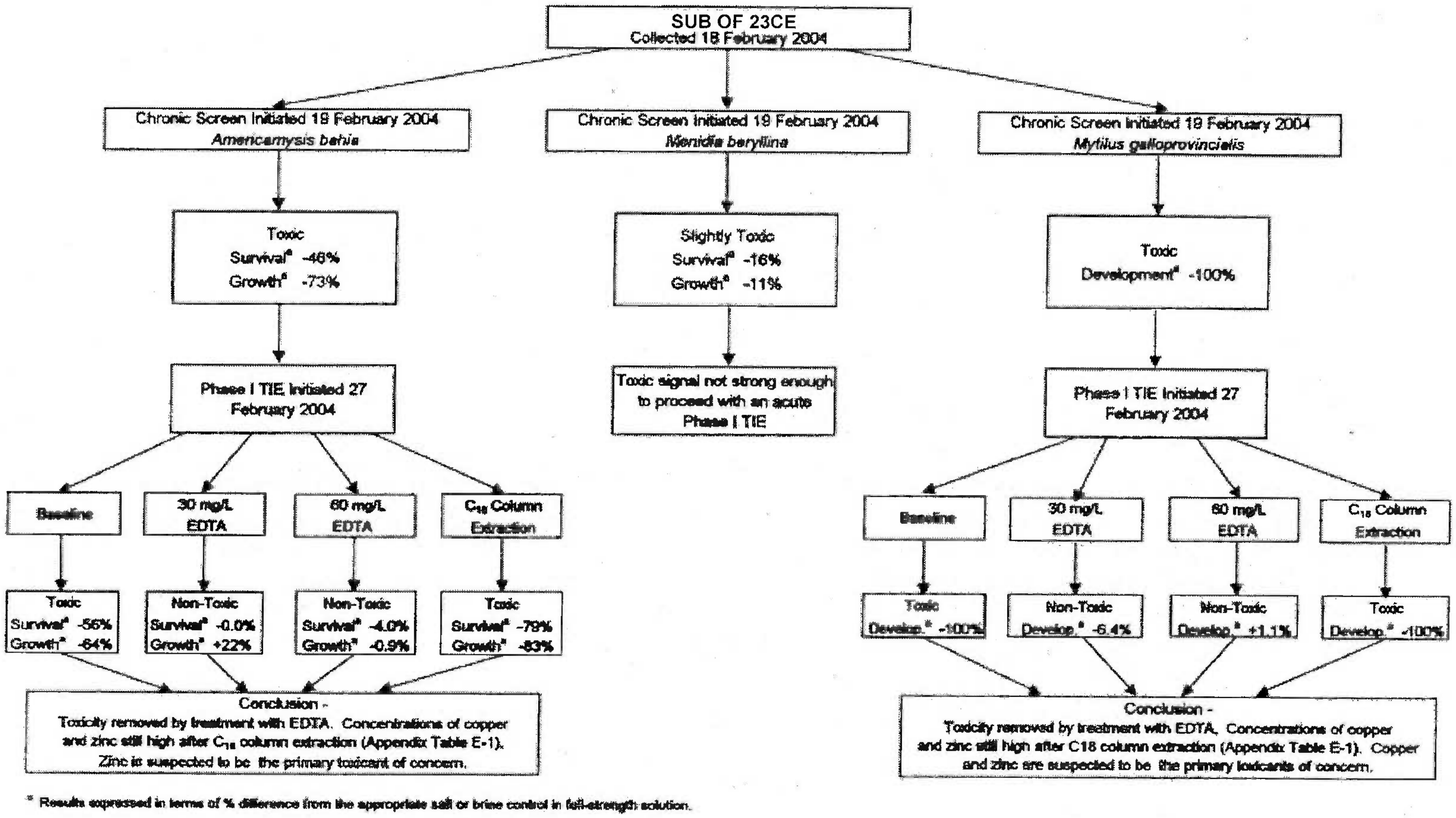
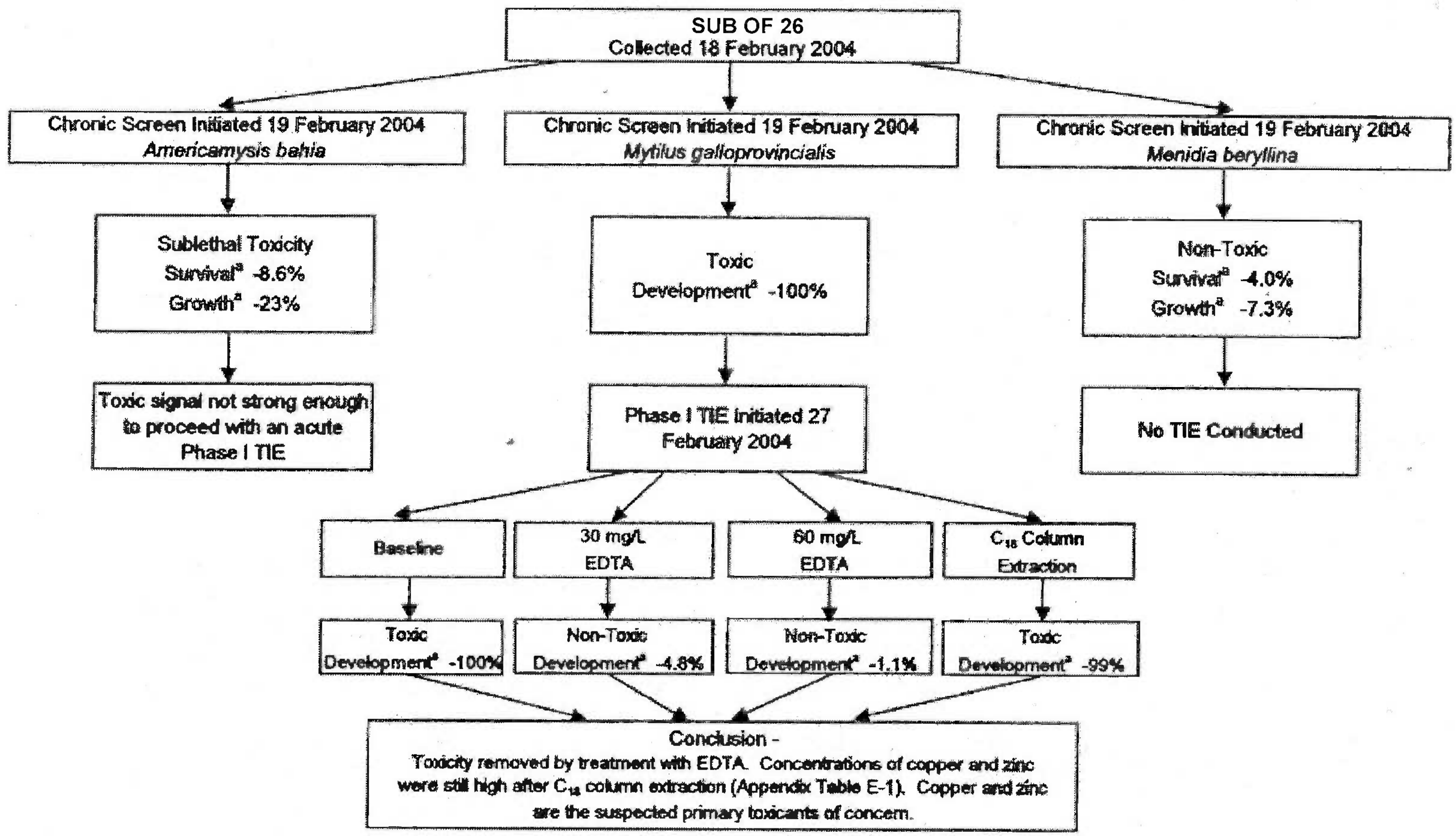


Figure 34. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Submarine Base San Diego outfall 23CE.



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

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

7.3.4 Chemistry

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

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

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

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

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

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

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

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

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

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

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

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

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

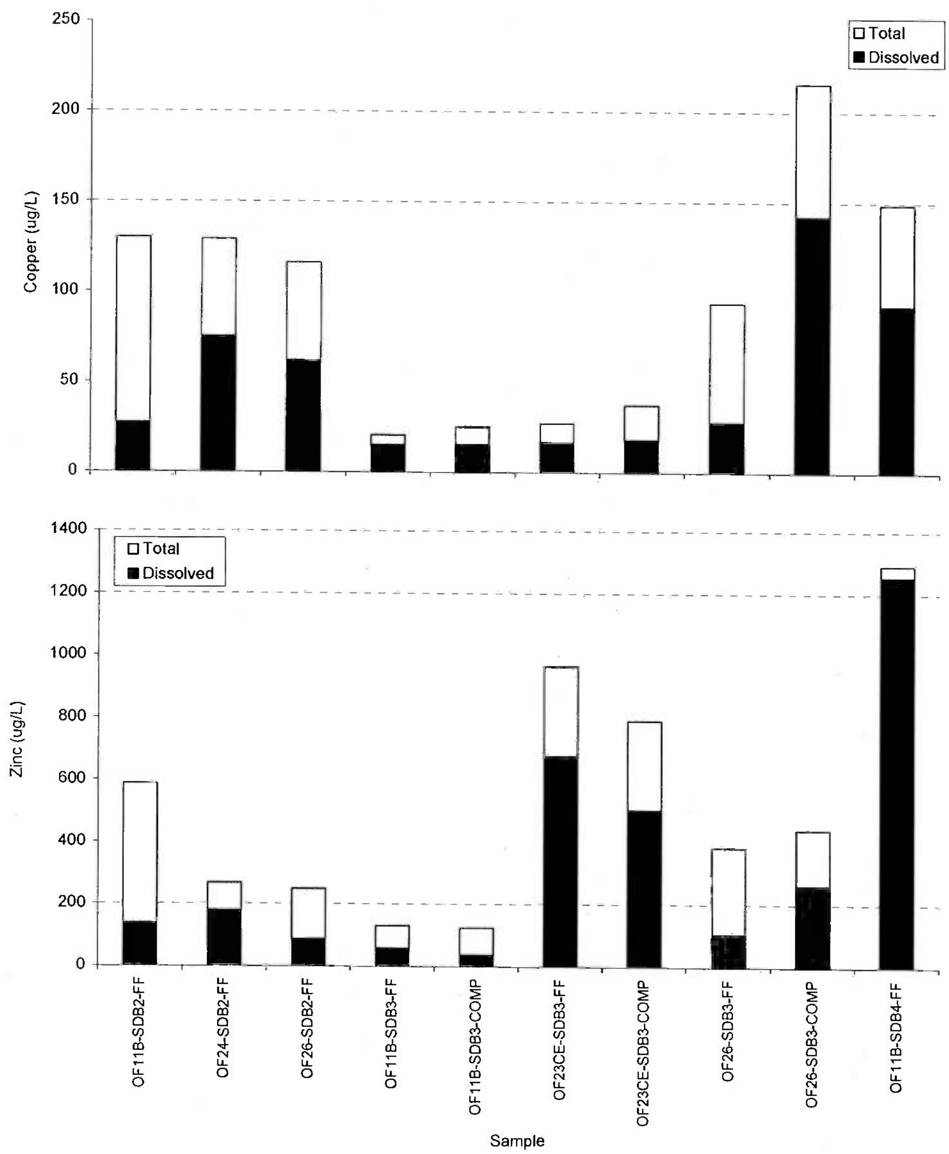


Figure 36. Total and dissolved copper and zinc concentrations measured in Naval Submarine Base San Diego first-flush (FF) and composite (Comp) outfall samples.

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

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

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

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

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

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

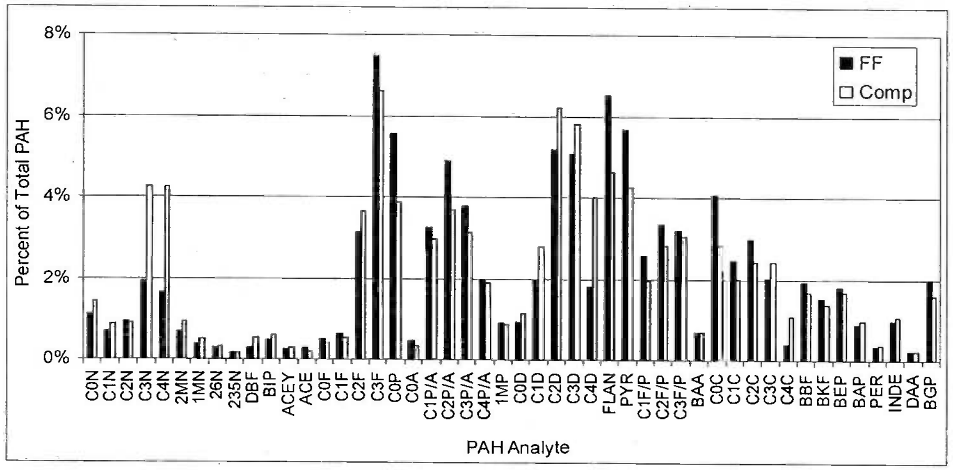


Figure 37. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Submarine Base San Diego. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

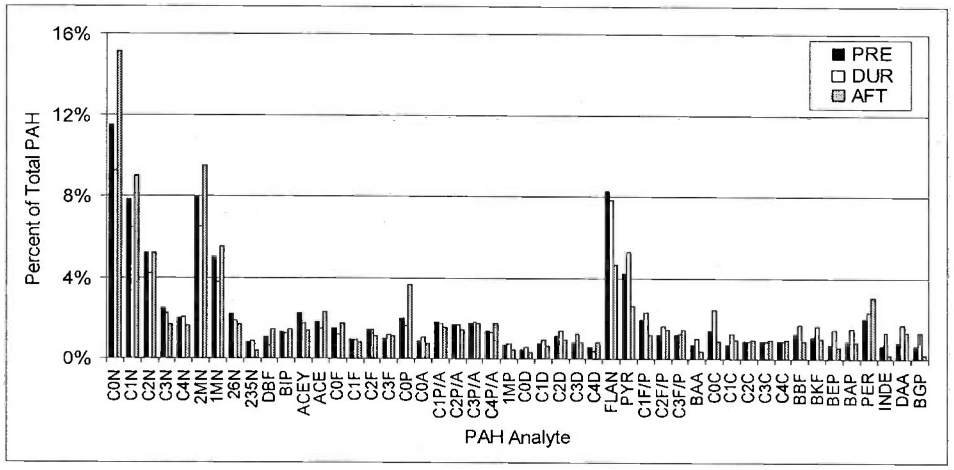


Figure 38. Average PAH composition in receiving waters before (PRE), during (DUR), and after (AFT) storm events at Naval Submarine Base San Diego. Table 6 shows analyte IDs.

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

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

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

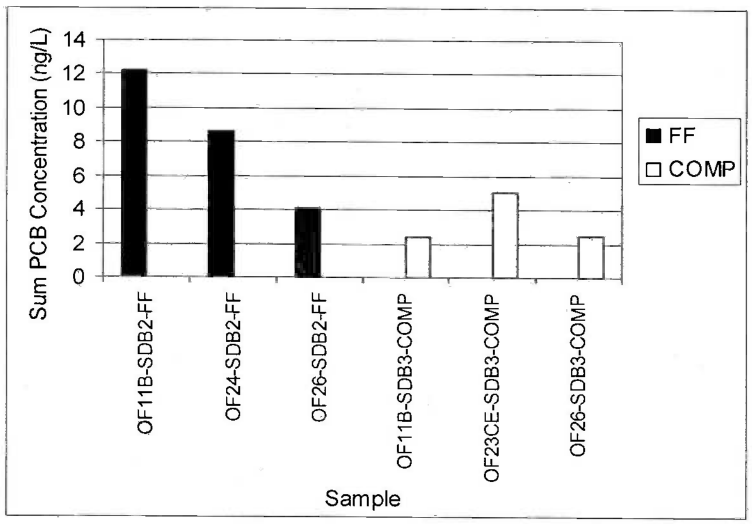


Figure 39. Summed PCB concentrations for first-flush (FF) and composite (COMP) outfall samples at Naval Submarine Base San Diego.

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

7.3.5 Plume Mapping

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

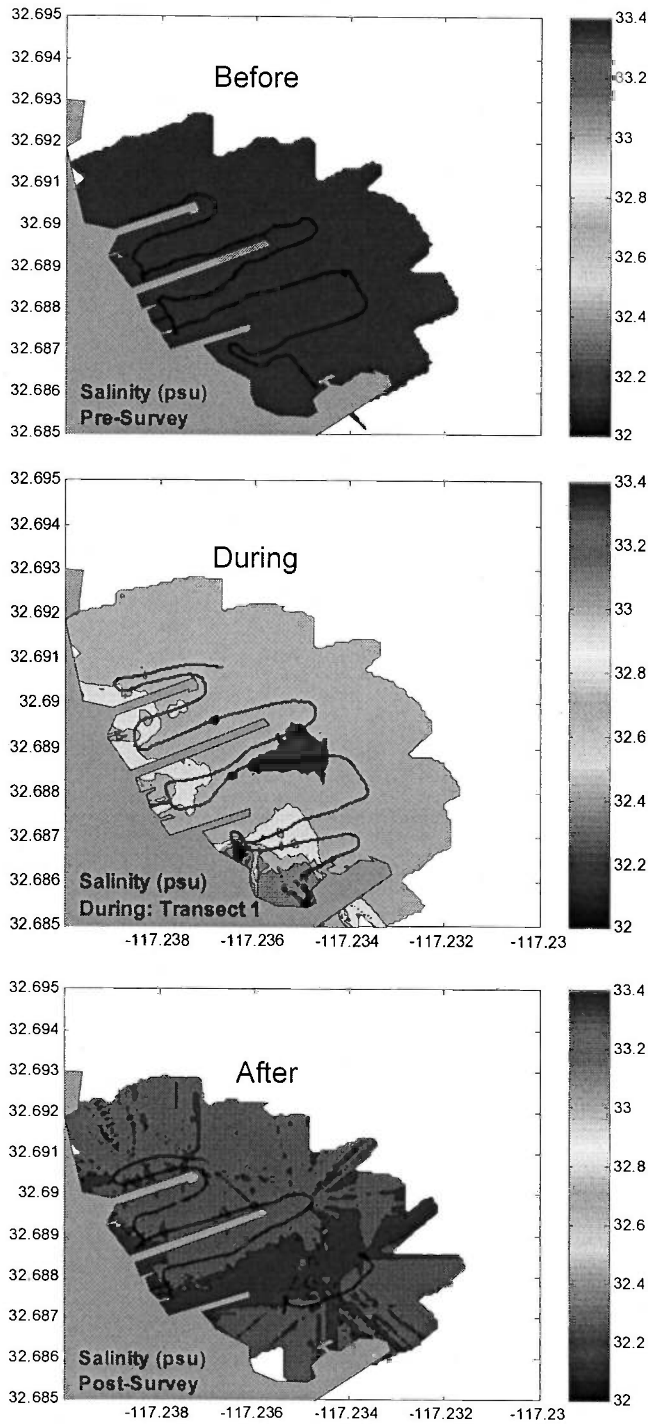


Figure 40. Surface salinity mapping before, during, and after a storm event (SDB3) at Naval Submarine Base San Diego.

7.4 NAVAL AMPHIBIOUS BASE CORONADO

7.4.1 Storm Water Toxicity

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

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

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

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

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

7.4.2 Receiving Water Toxicity

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

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

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

NA Not applicable

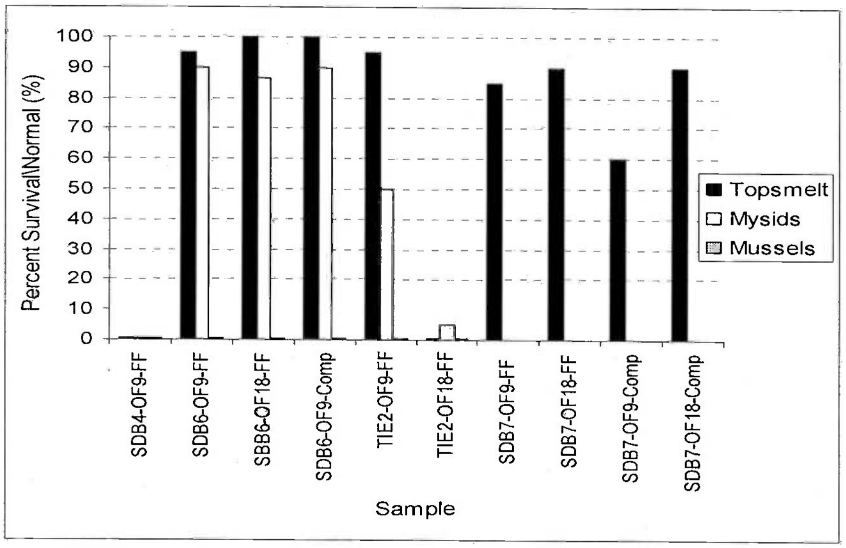


Figure 41. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Amphibious Base Coronado.

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

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

7.4.3 TIE

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

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

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

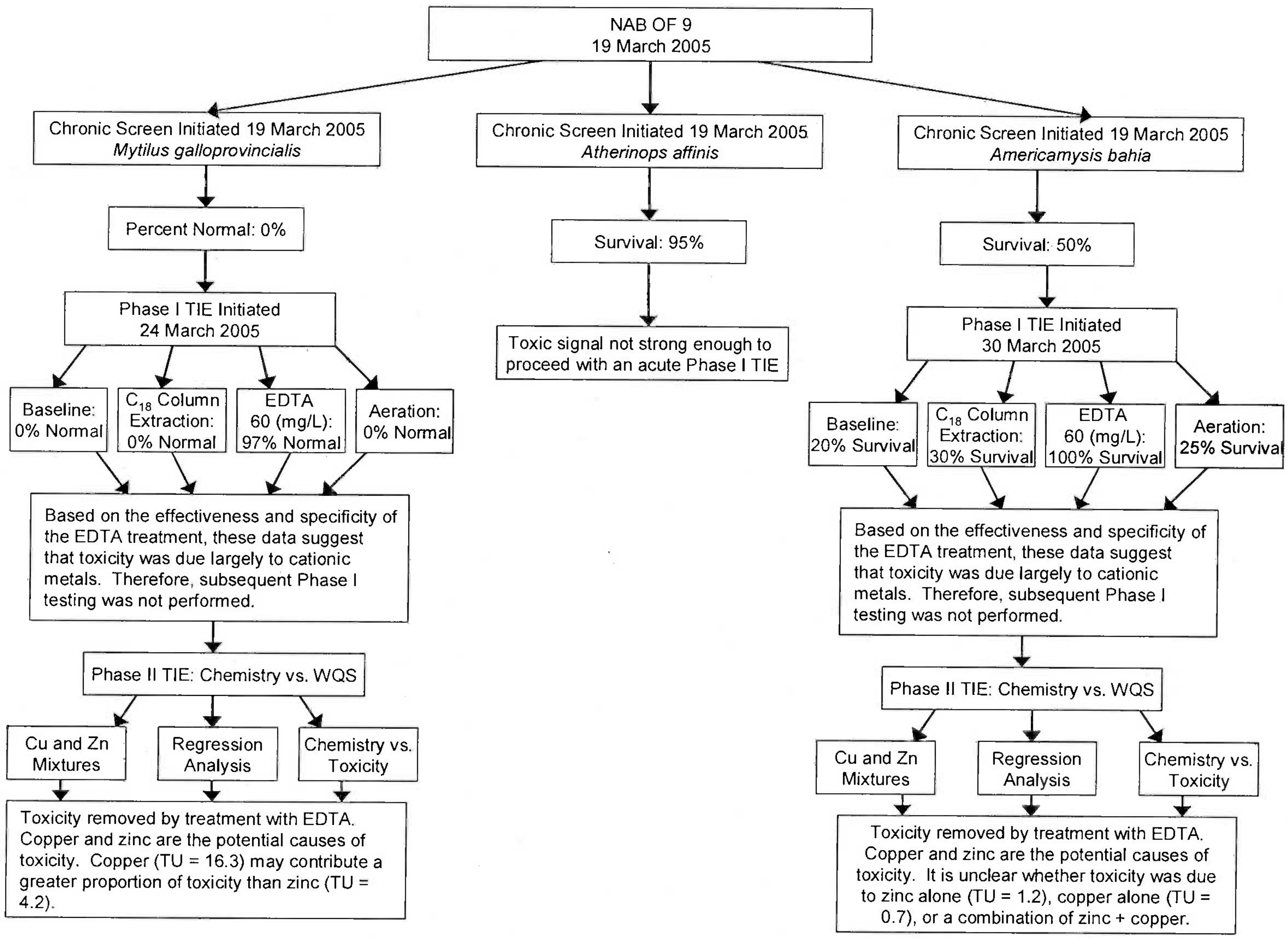


Figure 42. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Amphibious Base San Diego outfall 9.

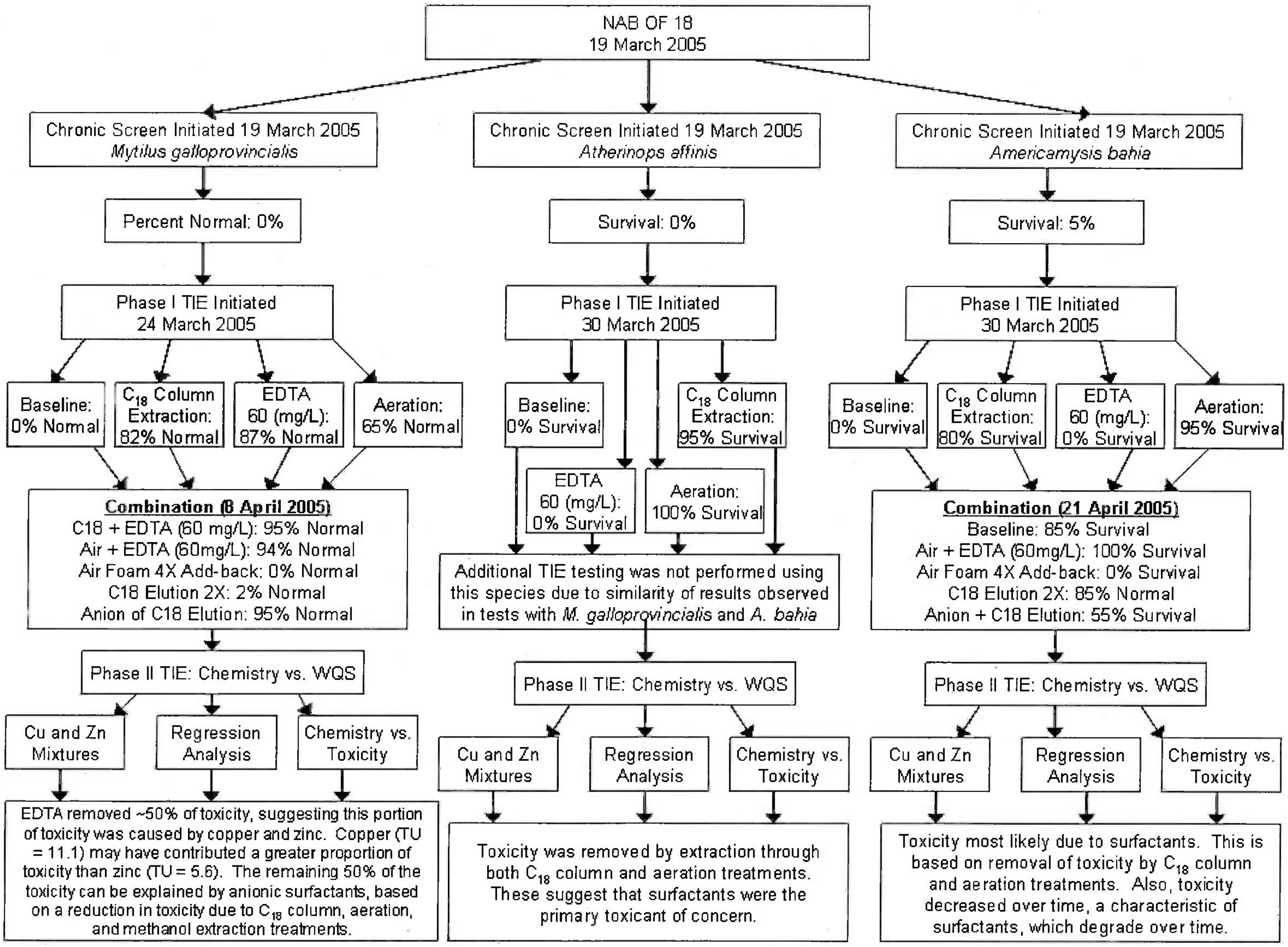


Figure 43. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Amphibious Base outfall 18.

7.4.4 Chemistry

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

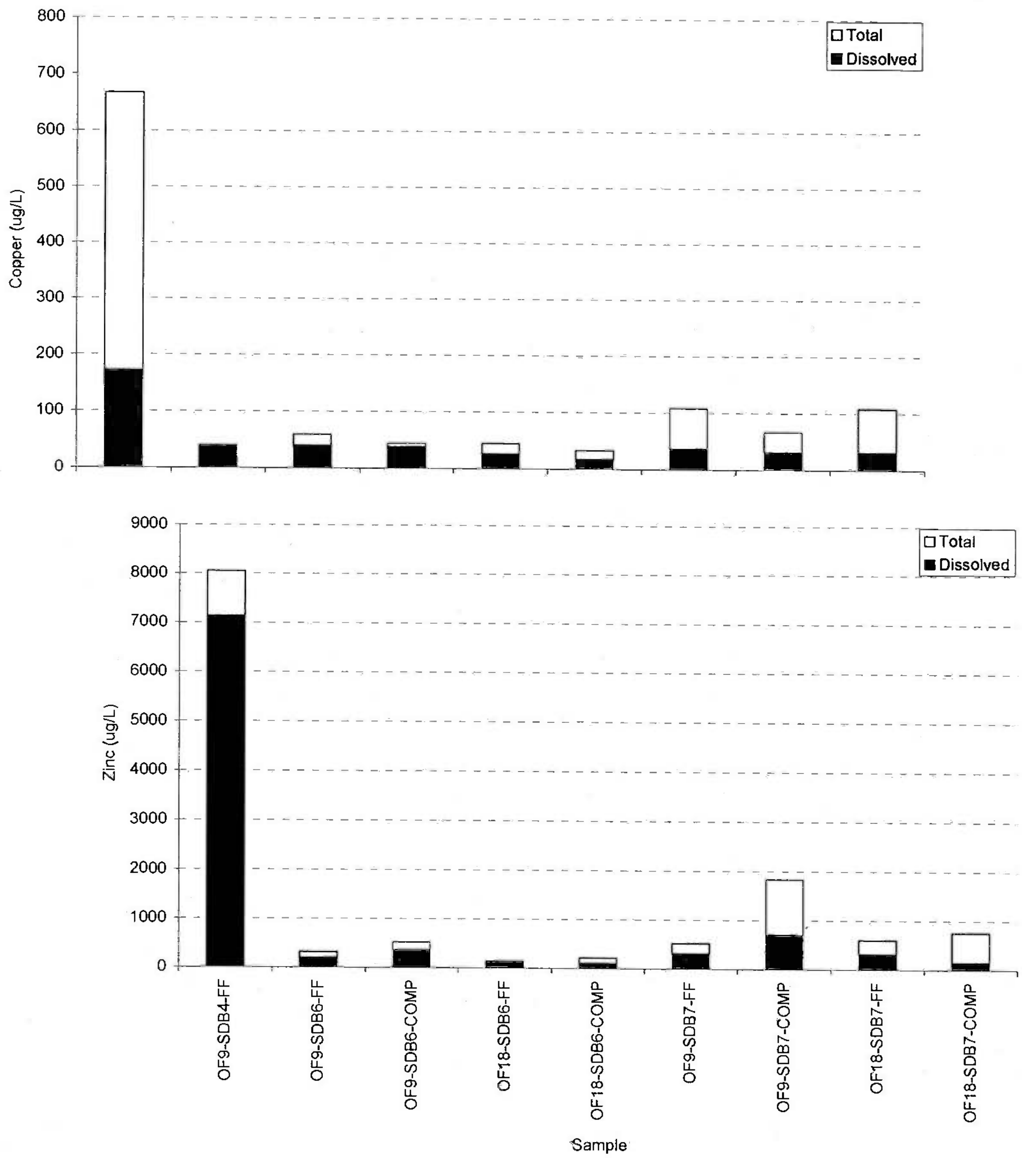


Figure 44. Total and dissolved copper and zinc concentrations measured in Naval Amphibious Base Coronado first-flush (FF) and composite (Comp) storm water outfall samples. Values for the total and the dissolved phase of the metal are shown.

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

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

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

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

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

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

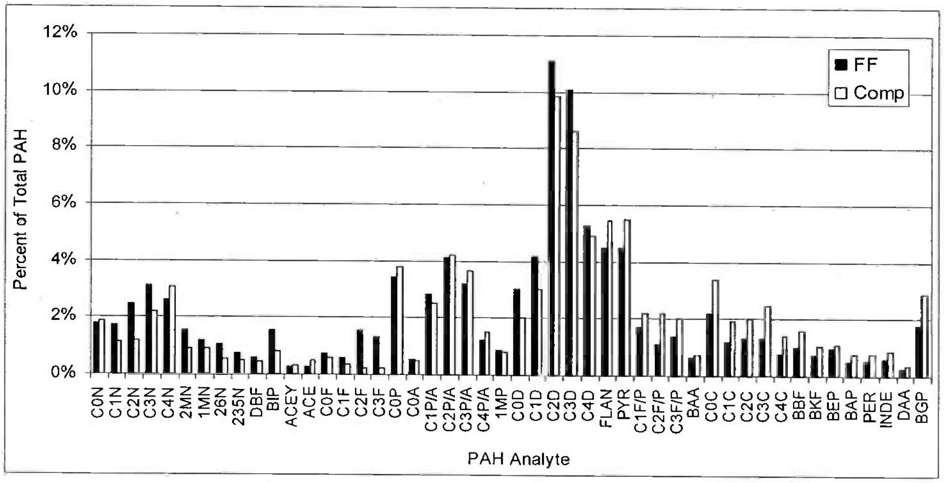


Figure 45. Average PAH composition in first-flush (FF) and composite (Comp) samples at Naval Amphibious Base Coronado. The averages were calculated by dividing each analyte by the total amount of PAH in a sample and then averaging by sample type (first-flush or composite). Table 6 shows analyte IDs.

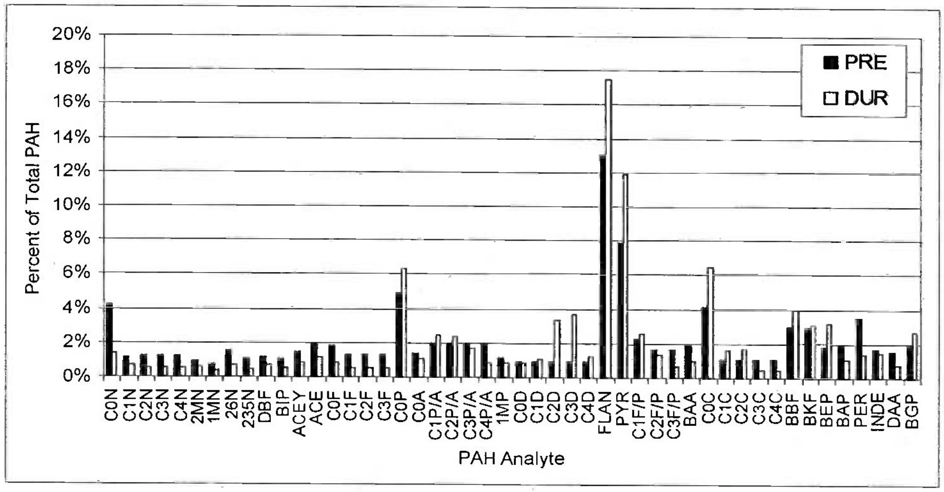


Figure 46. Average PAH composition in bay waters before (PRE) and during (DUR) storm events at Naval Amphibious Base Coronado. Table 6 shows analyte IDs.

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

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

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

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

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

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

7.4.5 Plume Mapping

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

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

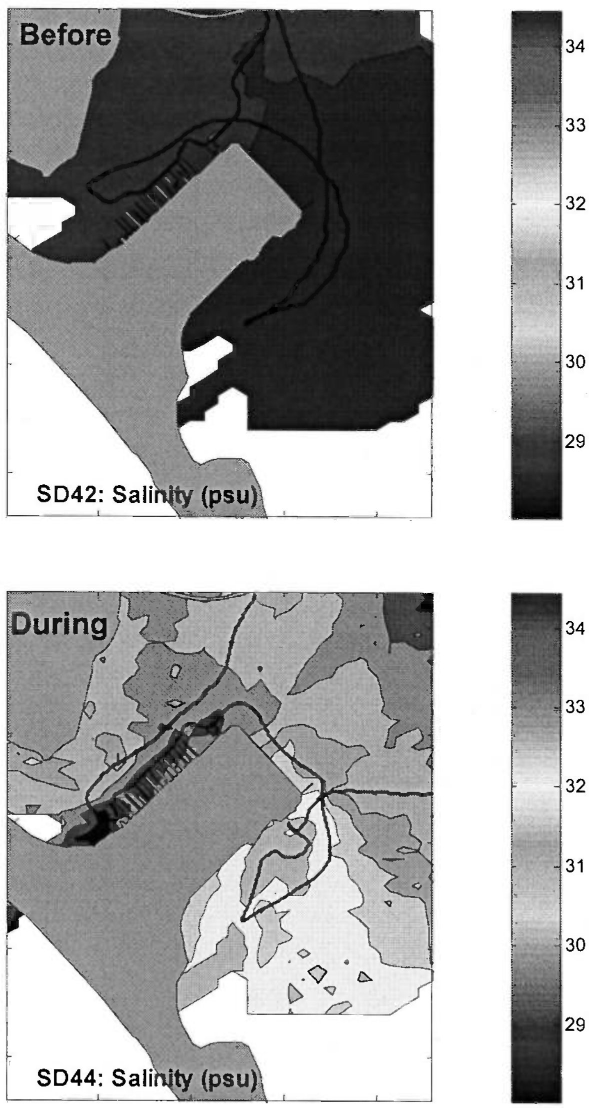


Figure 47. Surface salinity mapping before and during storm event (SDB4) at Naval Amphibious Base Coronado. There was no mapping performed after the storm.

7.5 NAVAL AIR STATION NORTH ISLAND

7.5.1 Storm Water Toxicity

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

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

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

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

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

7.5.2 Receiving Water Toxicity

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

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

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

NA Not applicable

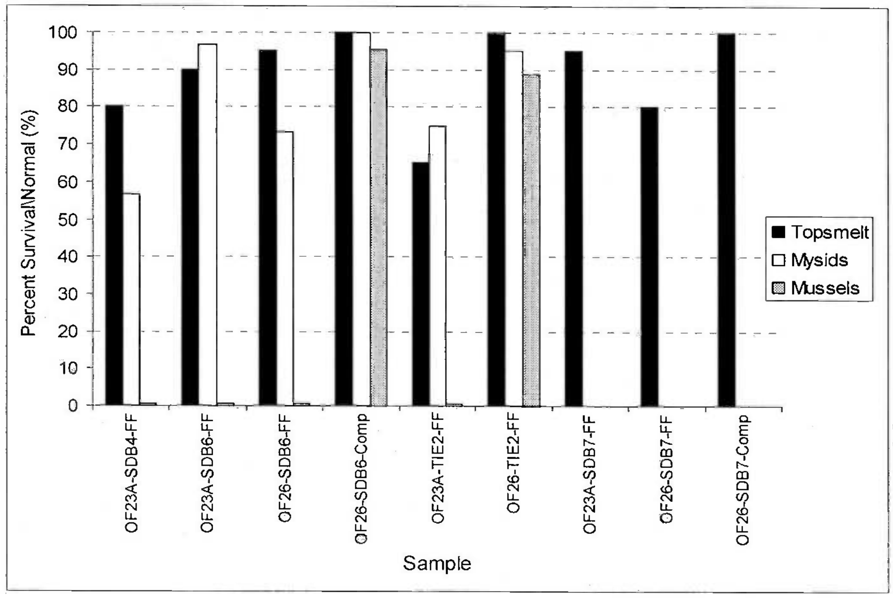


Figure 48. Topsmelt and mysid survival and normal mussel embryo-larval development in 100% storm water effluent collected from first-flush (FF) and composite (Comp) samples at Naval Air Station North Island.

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

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

7.5.3 TIE

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

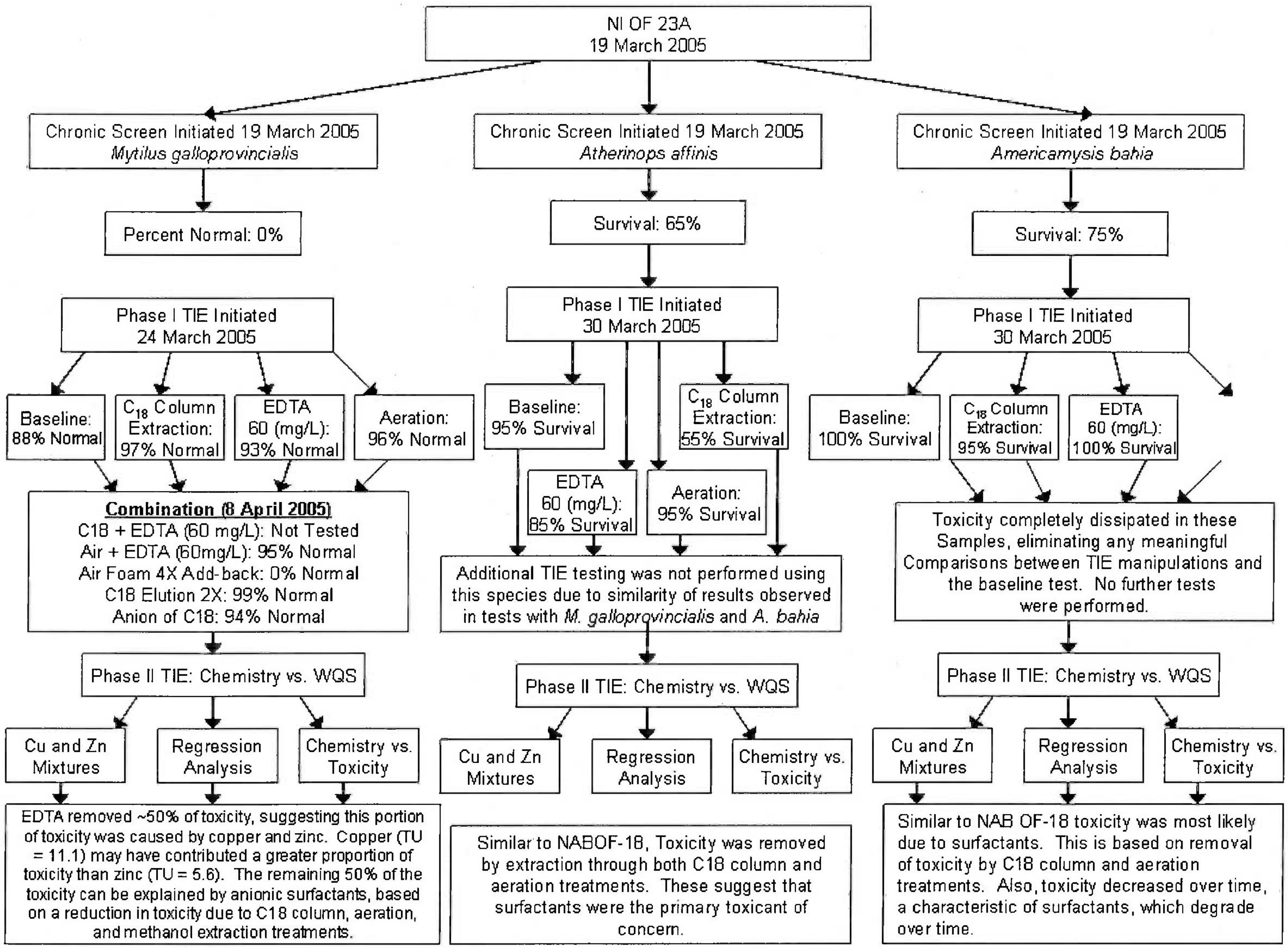


Figure 49. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Air Station North Island outfall 23A.

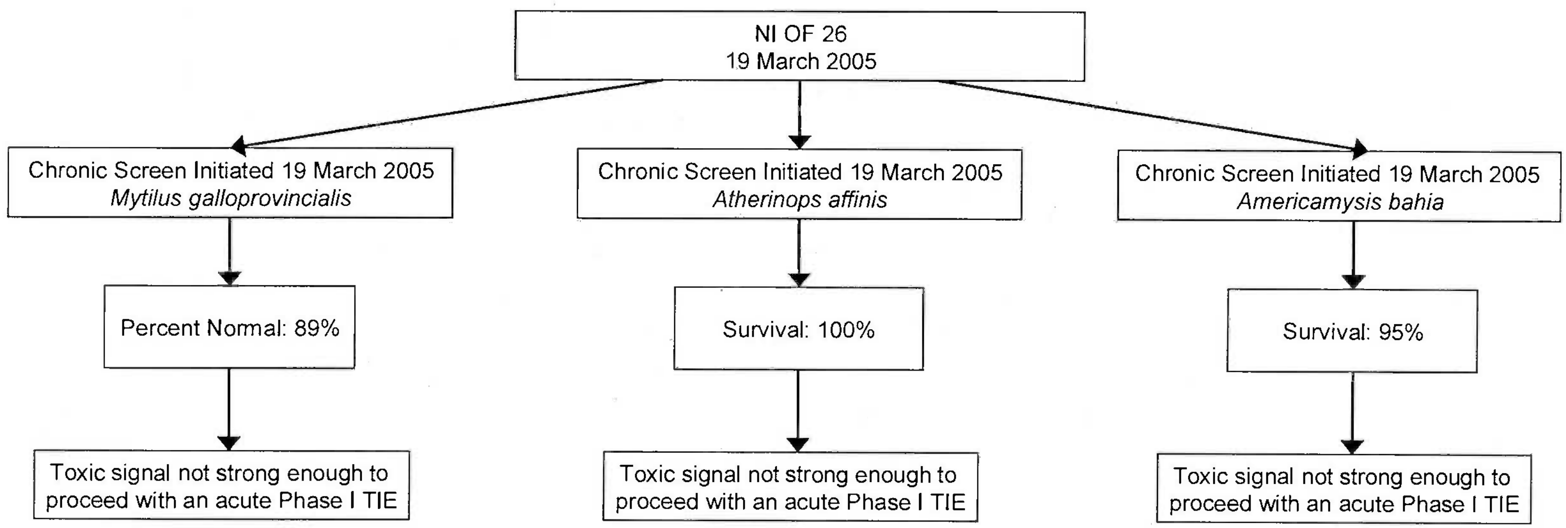


Figure 50. Flow diagram of TIE manipulations and outcome performed on first-flush sample collected from Naval Air Station North Island outfall 26.

7.5.4 Chemistry

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

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

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

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

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

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

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

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

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

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

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

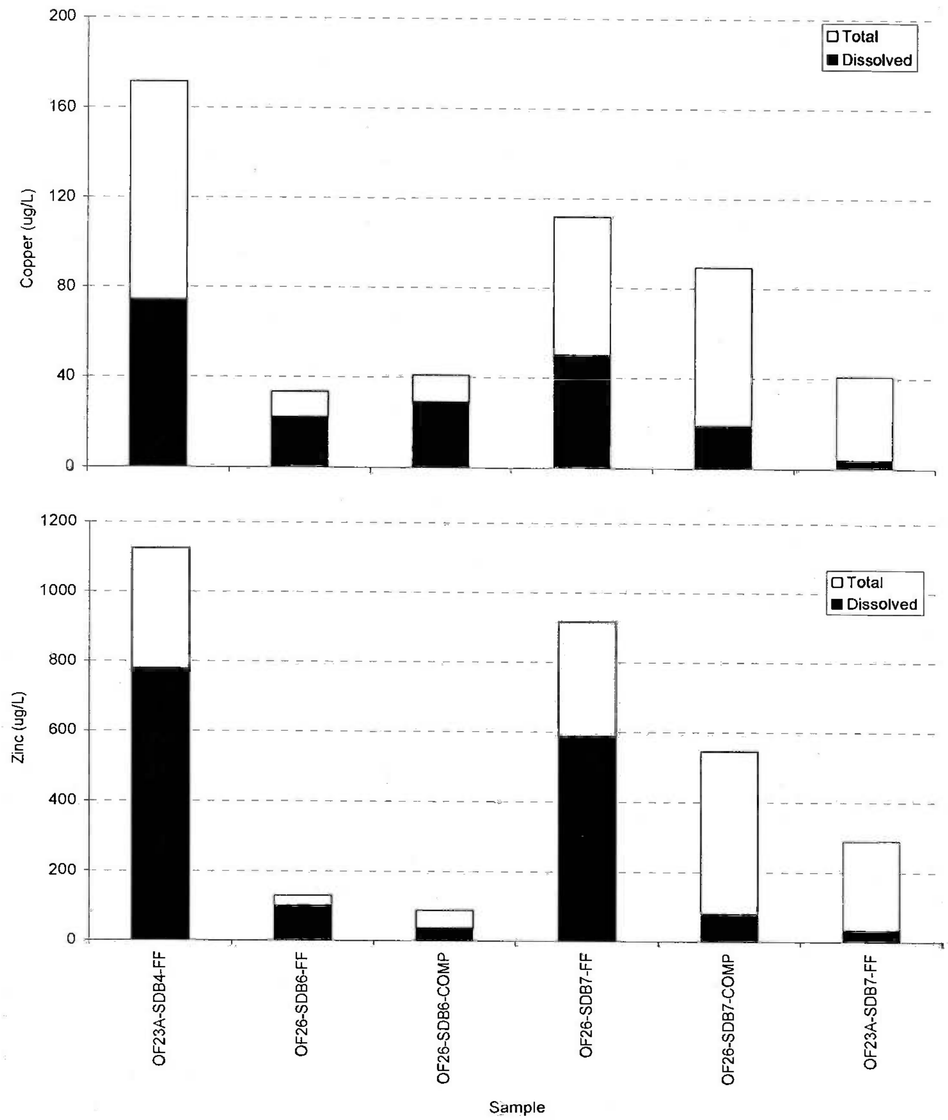


Figure 51. Total and dissolved copper and zinc concentrations measured in Naval Air Station North Island in first-flush (FF) and composite (Comp) storm water samples.

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

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

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

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

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

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

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

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

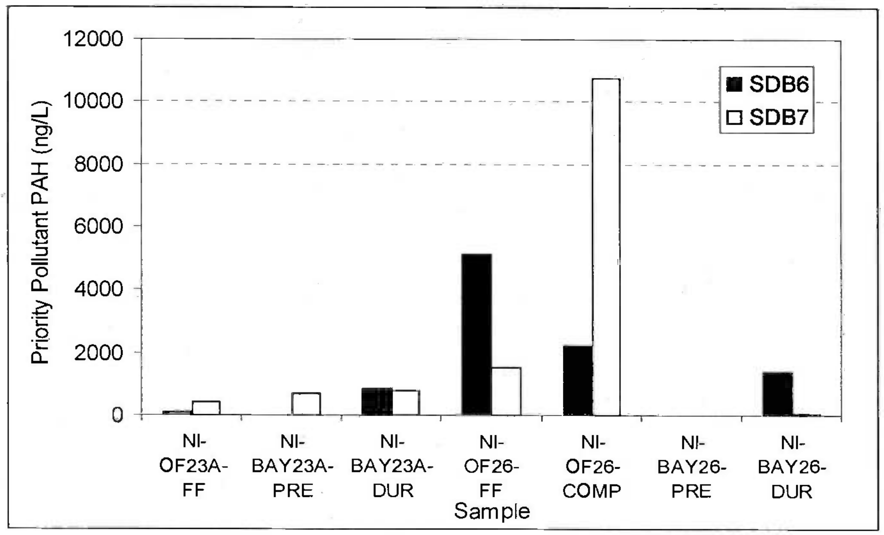


Figure 52. Summed priority pollutant PAH data for Naval Air Station North Island samples collected during storms SDB6 and SDB7. Analytes not detected were given a value equal to one-half the MDL in the summation. Sample types include first-flush (FF) and composite (COMP) outfall (OF) samples as well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

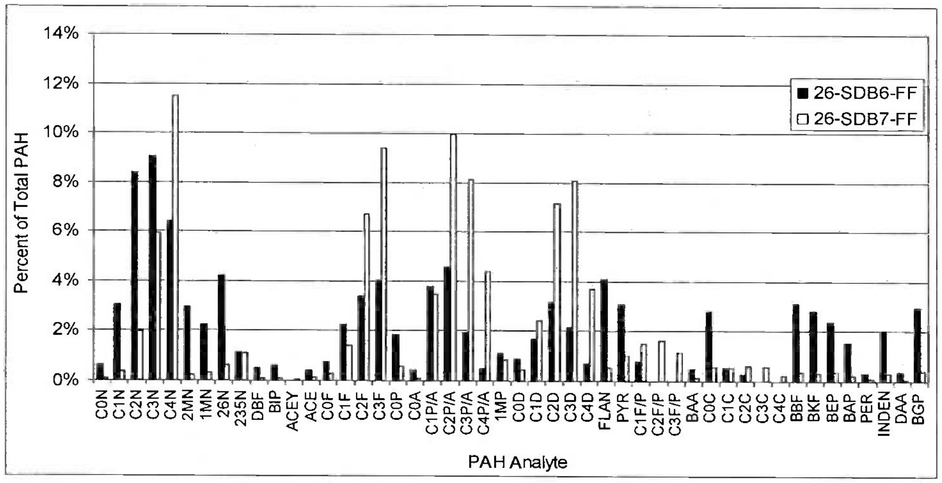


Figure 53. Relative PAH composition in first-flush samples collected from Naval Air Station North Island outfall 26 during the SDB6 and SDB7 storm events. Table 6 shows analyte IDs.

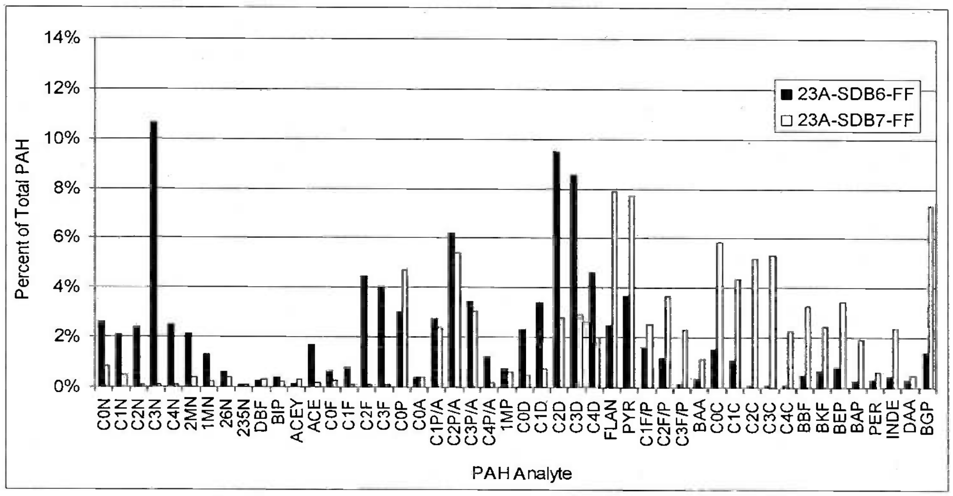


Figure 54. Relative PAH composition in first-flush samples collected from Naval Air Station North Island outfall 23A during the SDB6 and SDB7 storm events. Table 6 shows analyte IDs.

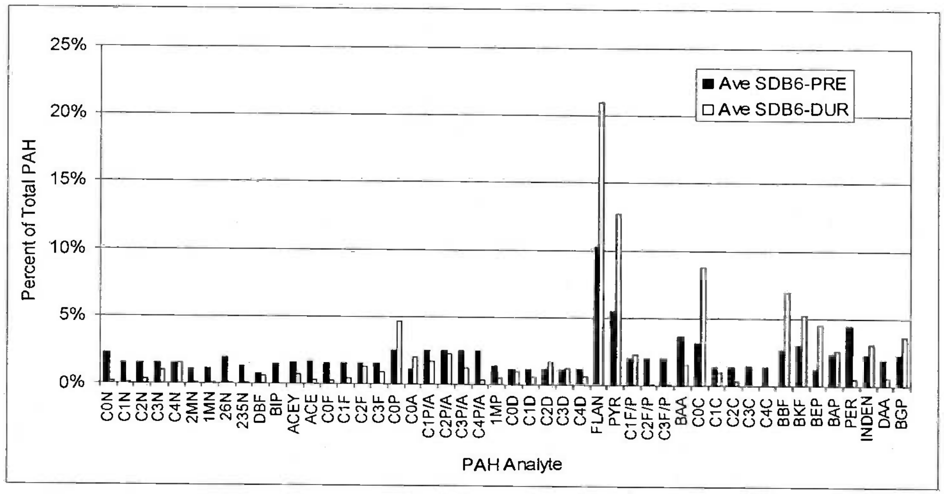


Figure 55. Average relative PAH composition in receiving water samples collected before and during the SDB6 storm event outside Naval Air Station North Island outfalls 23A and 26. Table 6 shows analyte IDs.

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

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

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

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

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

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

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

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

7.5.5 Plume Mapping

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

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

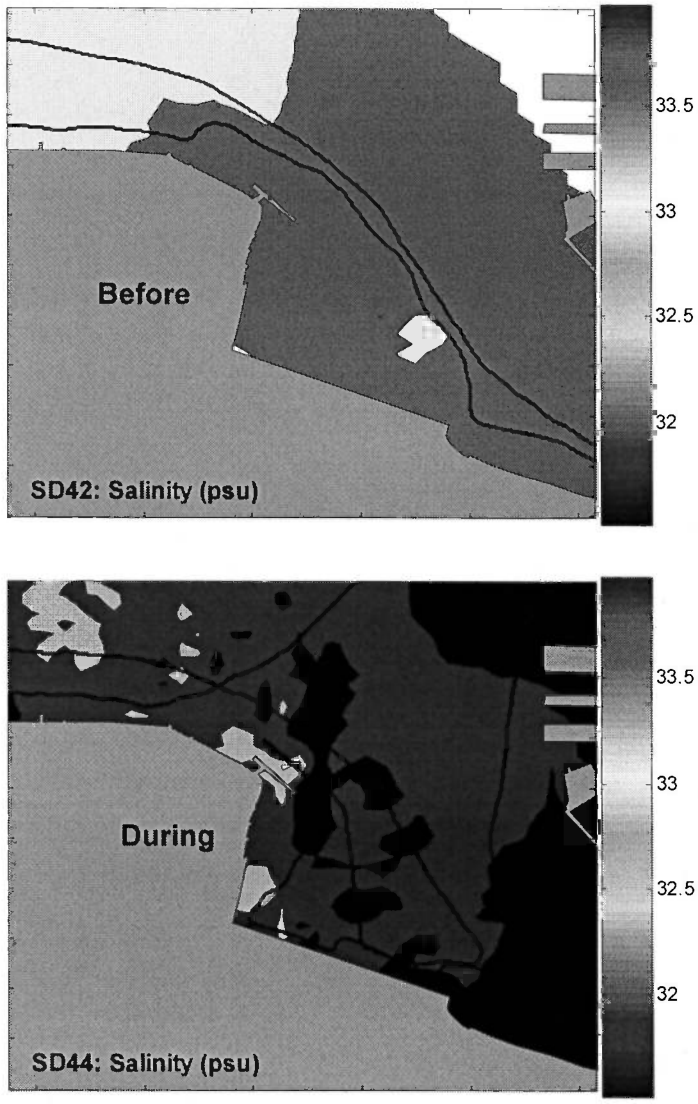


Figure 56. Surface salinity mapping before and during storm event (SDB4) at Naval Air Station North Island. There was no "after" storm mapping.

7.6 FLOATING BIOASSAY STUDY

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

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

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

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

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

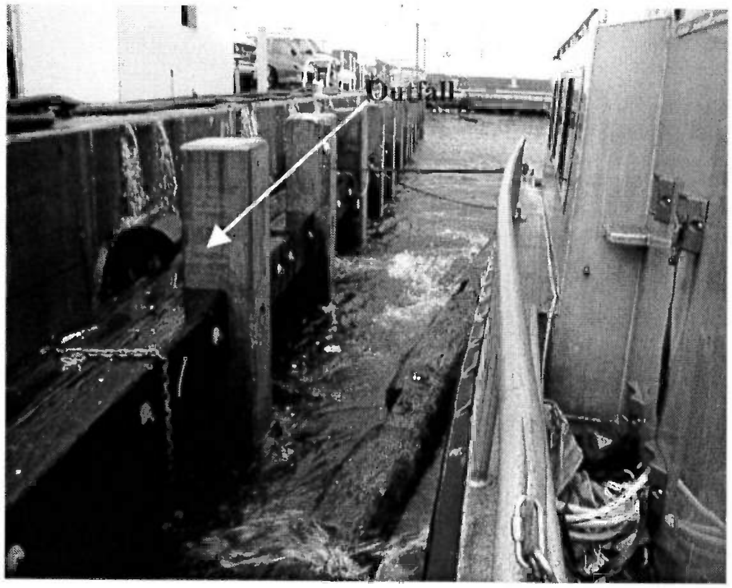


Figure 57. RV ECOS tied up along Naval Station San Diego quay wall outside outfall 14 during the special floating laboratory bioassay conducted in October 2004. The sensors and pump intake were ~ 15 feet away from the outfall. Note sheet runoff over quay wall.

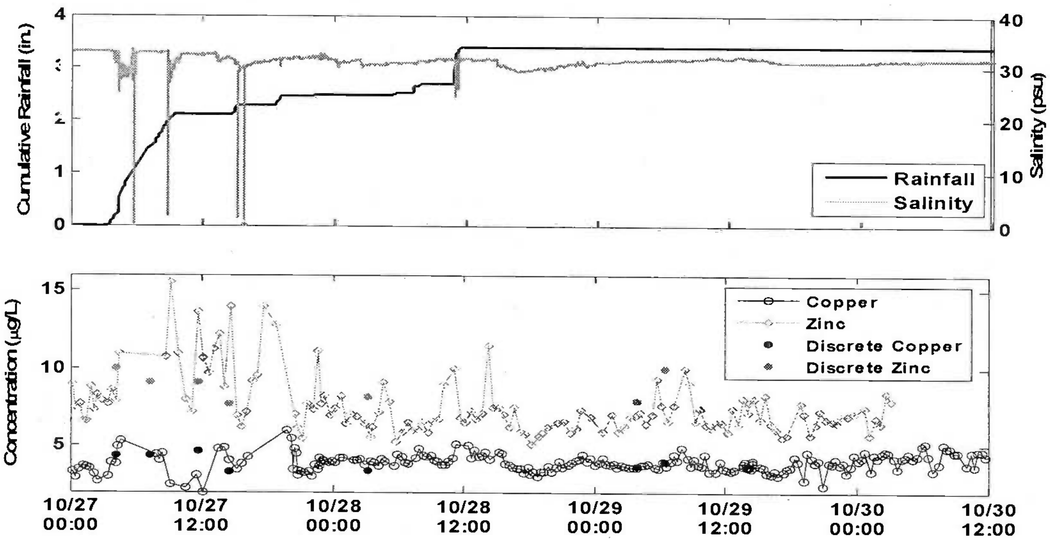


Figure 58. MESC full-storm monitoring data for receiving water salinity, cumulative rainfall (upper panel) and dissolved copper and zinc (lower panel) collected during the special floating bioassay laboratory study at Naval Station San Diego outfall 14. Dissolved copper and zinc data include results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

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

8. DISCUSSION

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

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

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

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

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

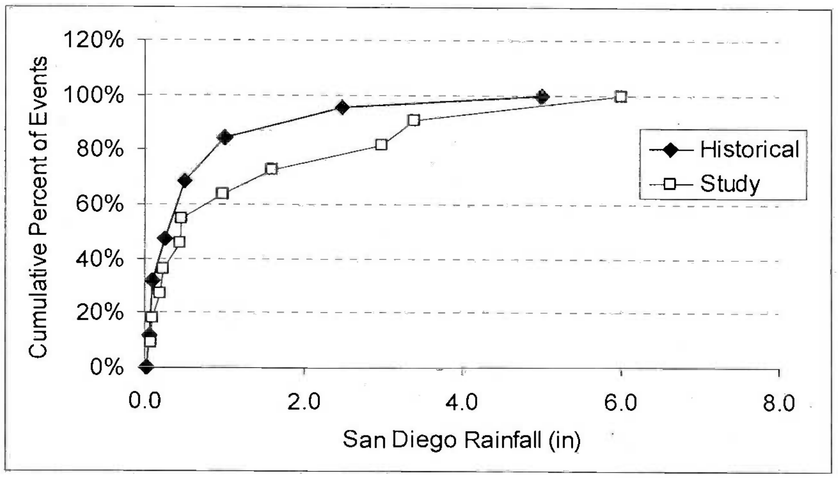


Figure 59. Historical daily rainfall data for San Diego (1948–1990) and rainfall data for storm events captured in this study.

8.1 STORM WATER TOXICITY

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

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

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

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

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

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

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

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

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

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

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

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

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

First-Flush Data (counts)

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

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

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

Composite Data (counts)

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

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

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

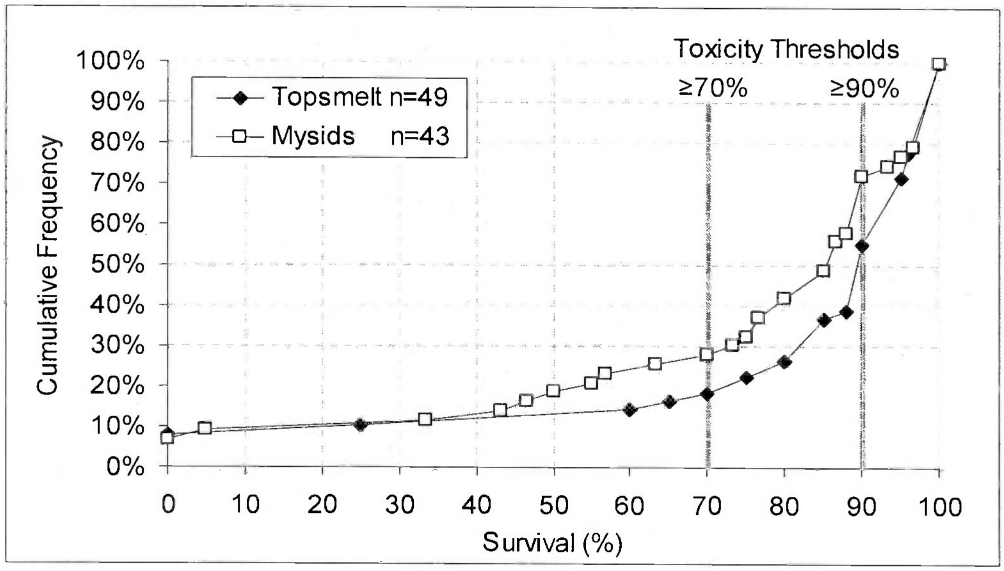


Figure 60. Mysid and topsmelt bioassay results in 100% storm water measured as percent survival in first-flush and composite storm water samples. The NPDES permit thresholds for first-flush samples are also shown.

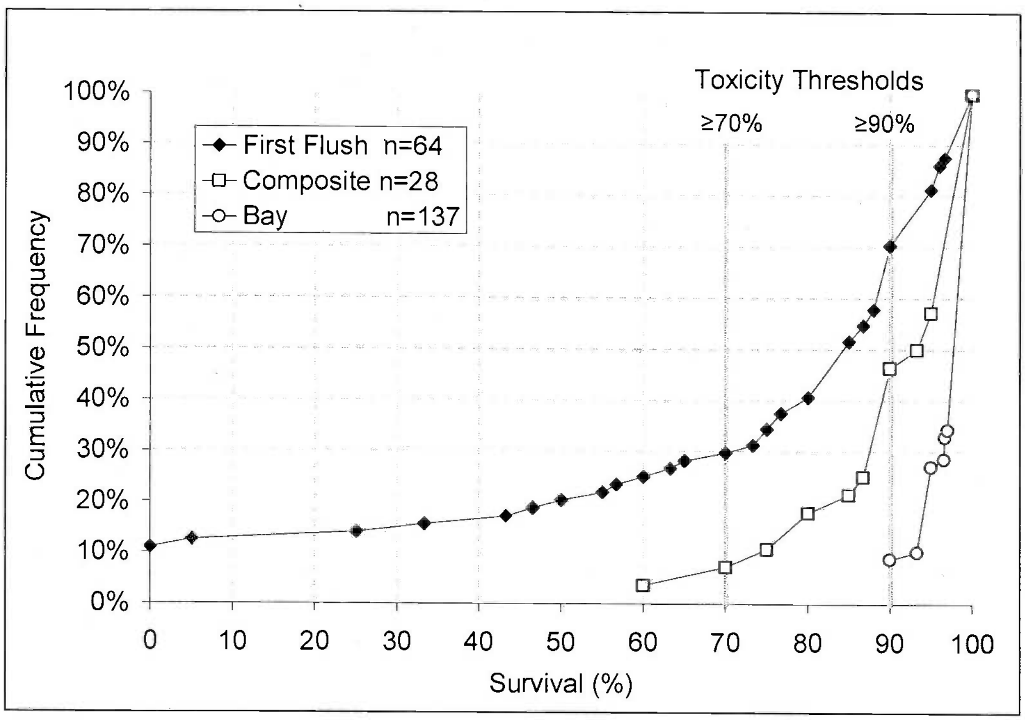


Figure 61. Combined mysid and topsmelt bioassay results in 100% storm water measured as percent survival in first-flush, composite and receiving water (Bay) samples collected from all bases. The NPDES permit thresholds for first-flush samples are also shown.

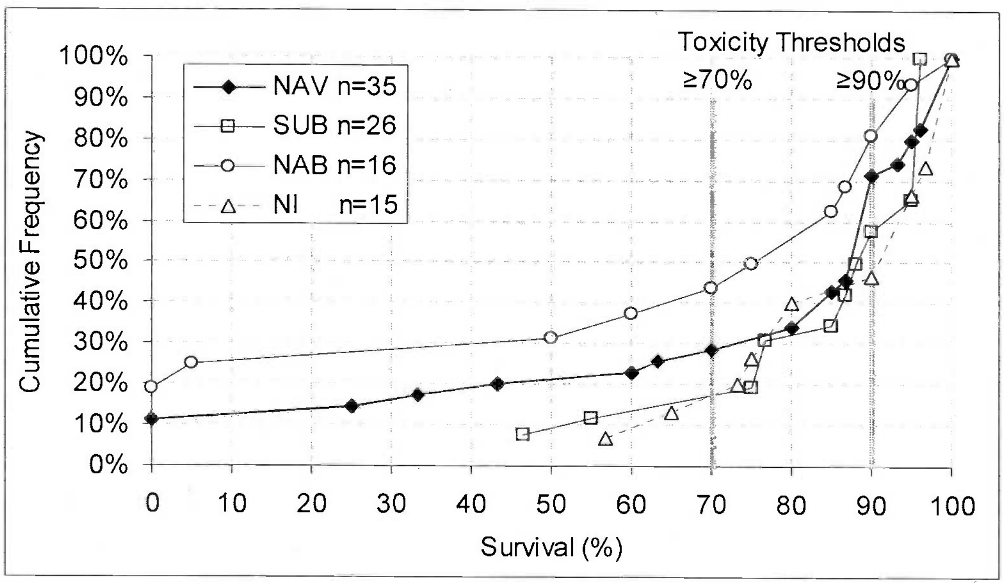


Figure 62. Combined mysid and topsmelt toxicity (as percent survival) in 100% storm water measured in first-flush and composite samples collected at the four bases Naval Station San Diego (NAV), Naval Submarine Base San Diego (SUB), Naval Amphibious Base Coronado (NAB), and Naval Air Station North Island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

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

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

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

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

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

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

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

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

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

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

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

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

* EPA values are for Inland Silversides for comparison

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

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

+ EPA values are for normal and survival endpoint

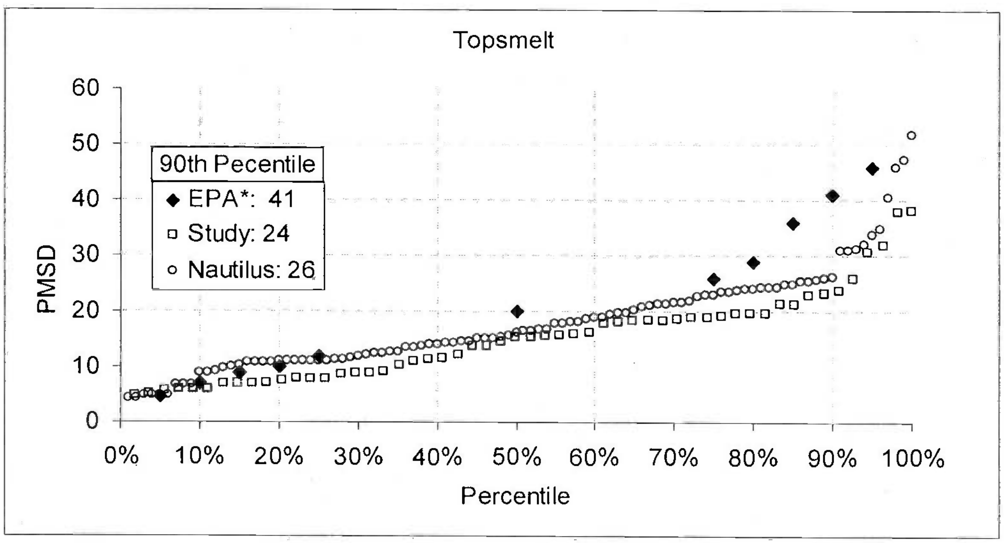


Figure 63. PMSD probability distribution for topsmelt derived from data in this study and additional data from Nautilus Environmental, LLC. EPA* data (EPA, 2000a) for inland silversides are shown for comparison.

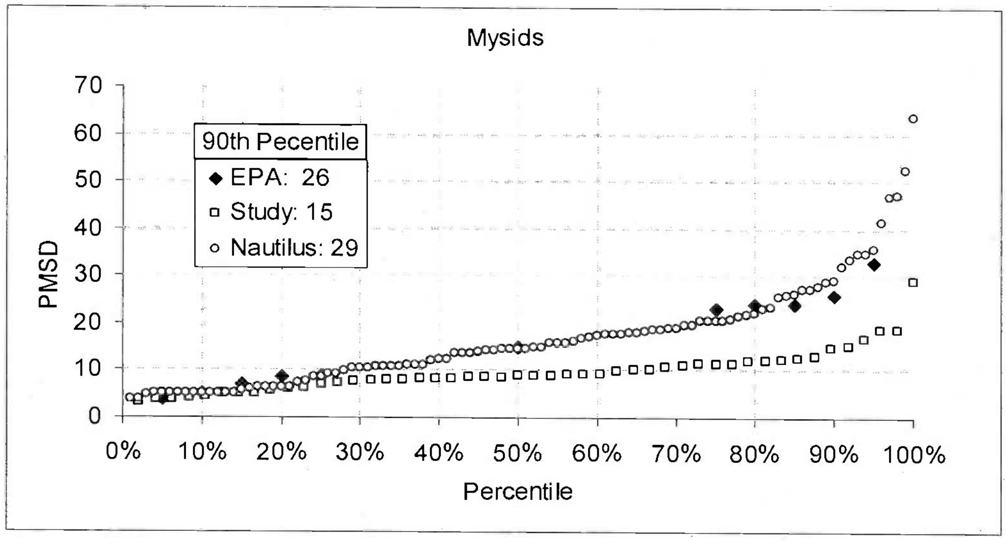


Figure 64. PMSD probability distribution for mysids derived from data in this study (EPA, 2000b) and additional data from Nautilus Environmental, LLC.

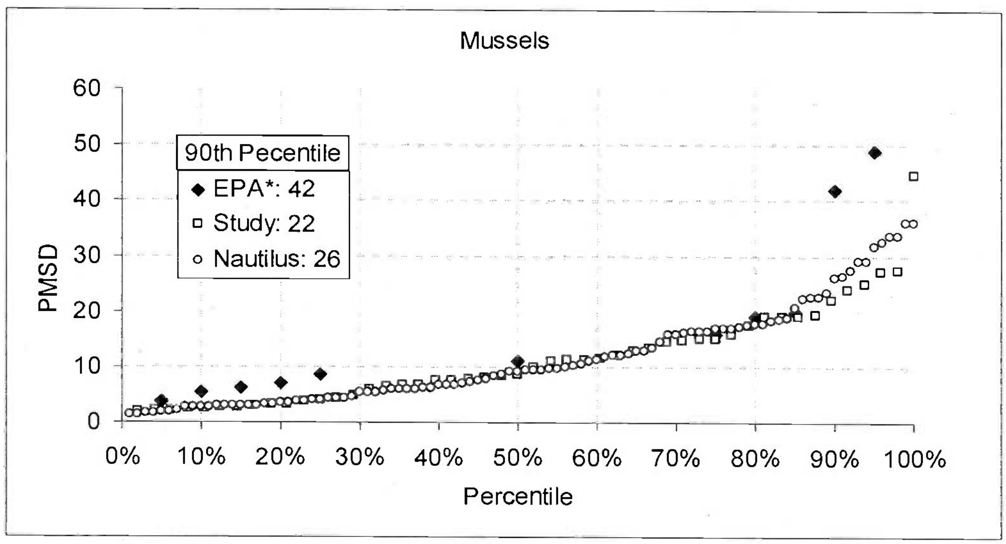


Figure 65. PMSD probability distribution for mussel embryo-larval development derived from data in this study and additional data from Nautilus Environmental, LLC. The EPA* data (EPA, 2000a) were for a survival and development endpoint which is different than just the normal development endpoint used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

8.2 CAUSES OF TOXICITY

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

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

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

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

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

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

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

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

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

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

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

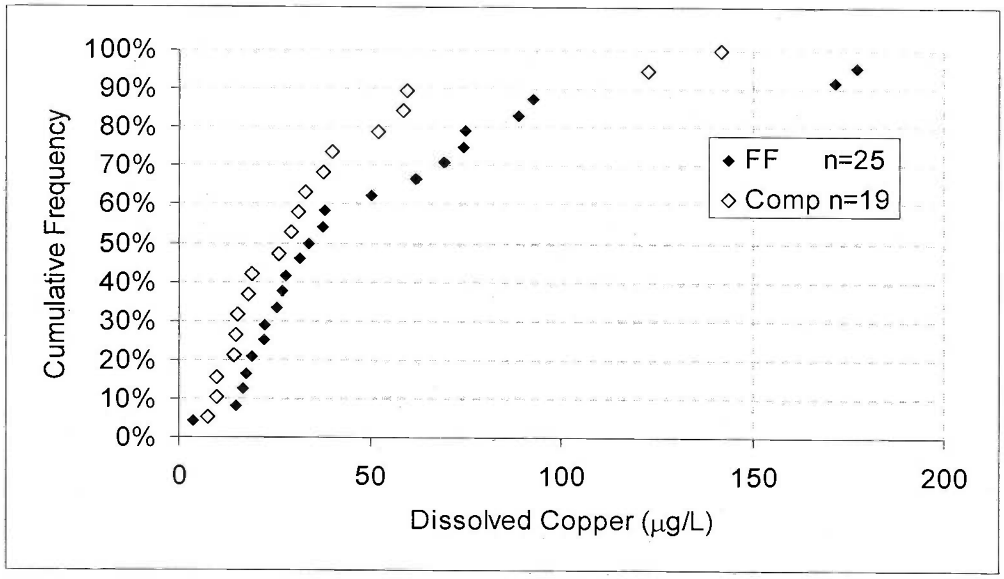


Figure 66. Cumulative frequency distribution plot of dissolved copper measured in all first-flush (FF) and composite (Comp) storm water samples.

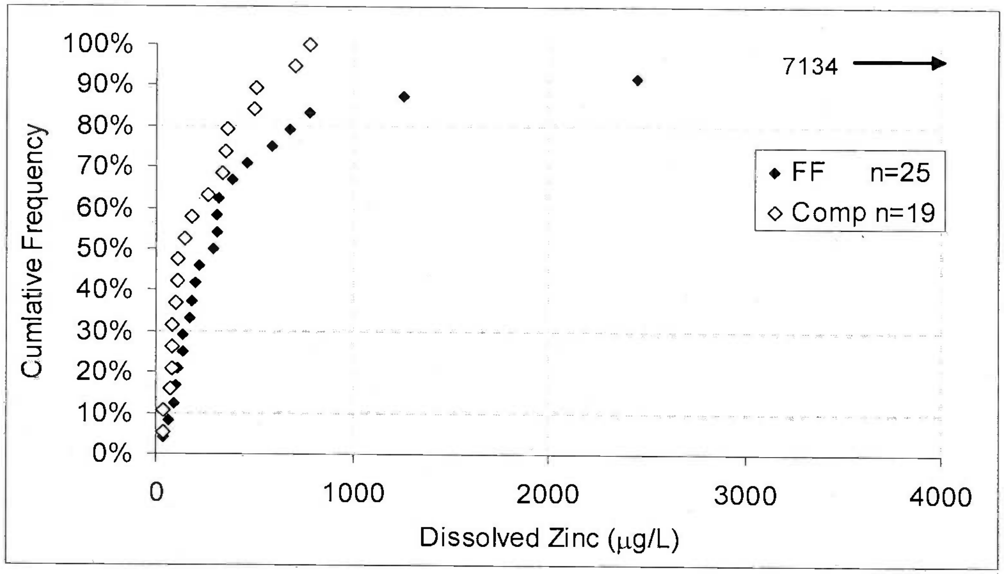


Figure 67. Cumulative frequency distribution plot of dissolved zinc measured in all first-flush (FF) and composite (Comp) storm water samples. One value was off-scale at 7134 μg/L.

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

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

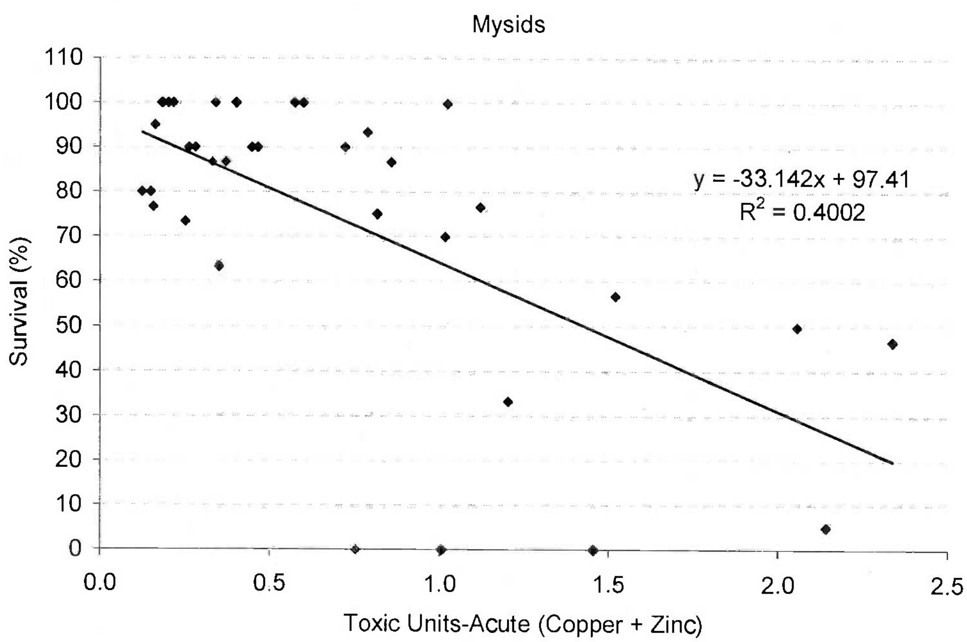


Figure 68. Mysid survival as a function of summed copper and zinc TU_A.

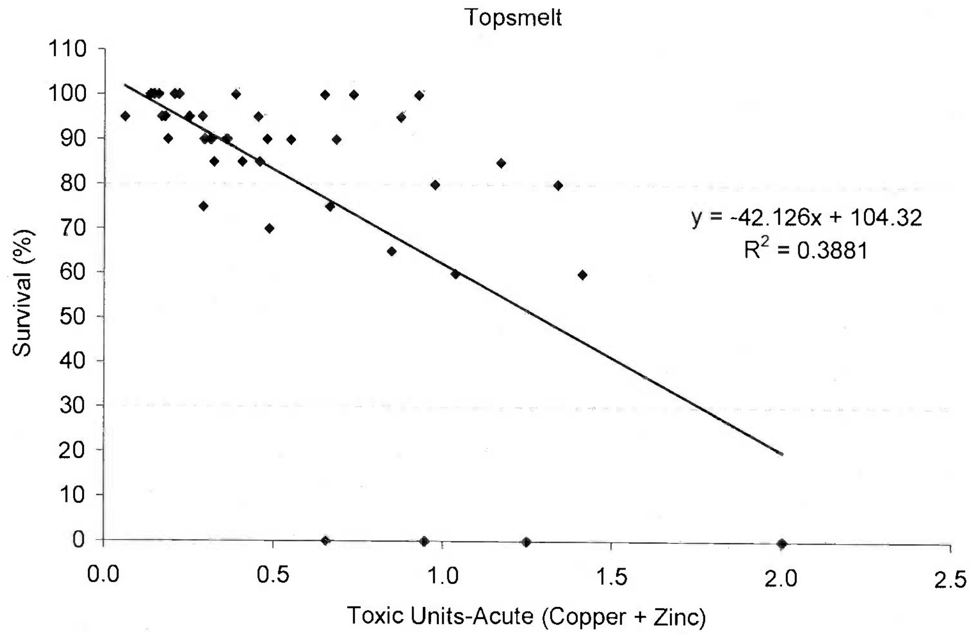


Figure 69. Topsmelt survival as a function of summed copper and zinc TU_A.

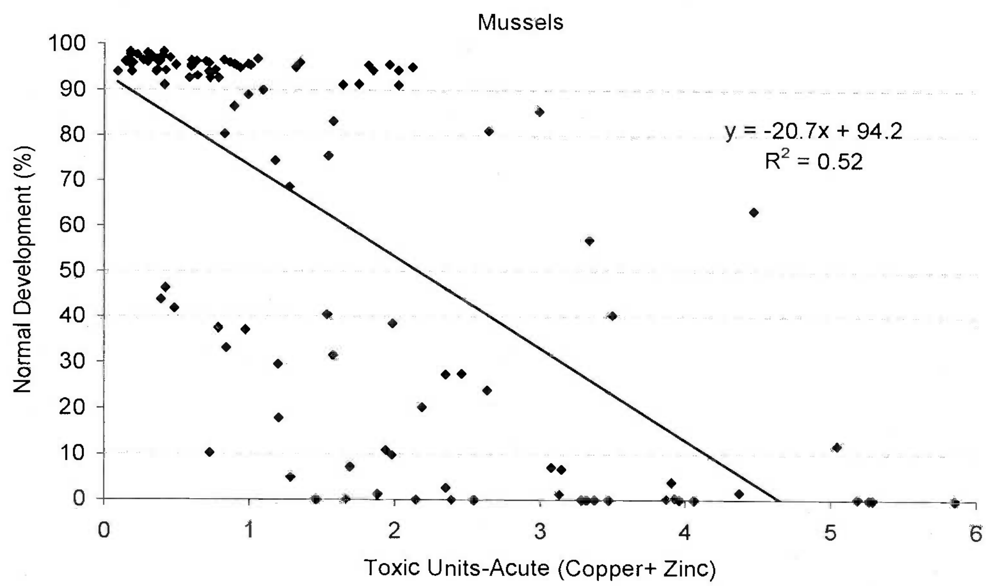


Figure 70. Normal mussel embryo-larval development as a function of summed copper and zinc TU_A. The regression was determined for data points with a $TU_A < 6.2$.

8.3 RECEIVING WATER IMPACTS

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

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

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

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

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

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

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

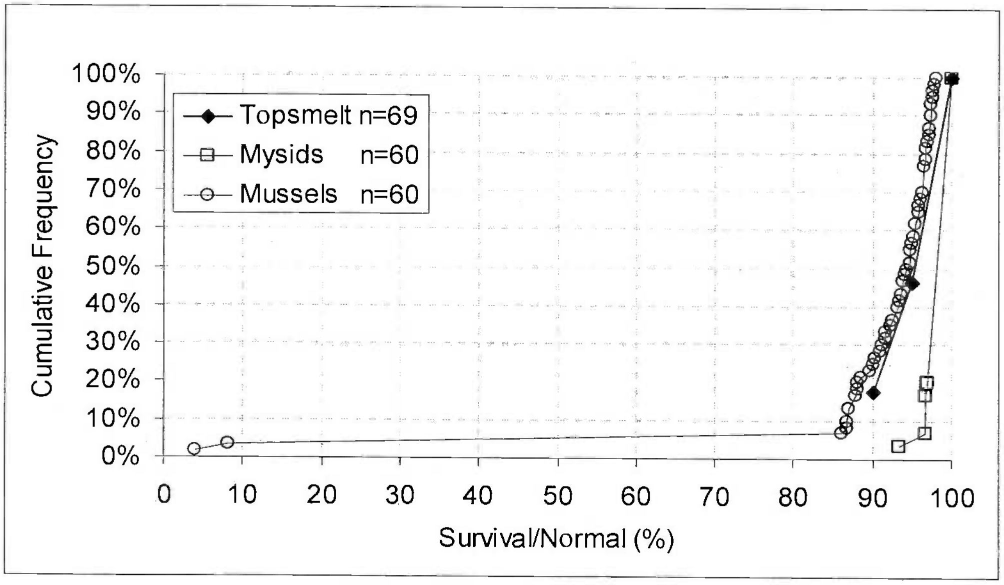


Figure 71. Topsmelt, mysid, and mussel bioassay results measured in receiving waters. The plot shows combined results for samples taken before, during, and after storm events. All results were for 100% receiving water.

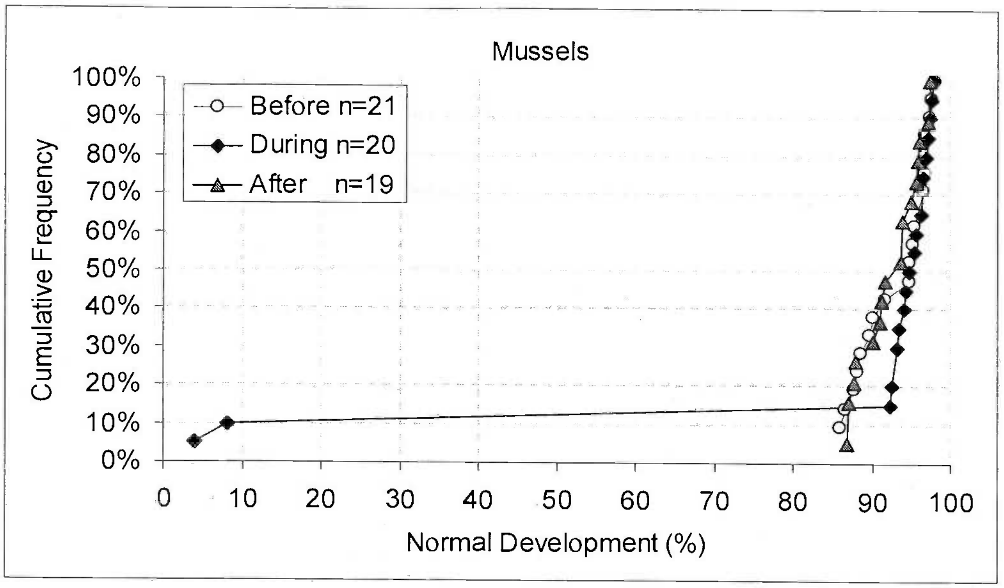


Figure 72. Mussel embryo-larval development results for receiving water samples collected before, during, and after storm water events. All results were for 100% receiving water. Two samples were significantly toxic.

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

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

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

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

9. CONCLUSIONS

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

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

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

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

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

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

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

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

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

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SPAWAR
Systems Center
San Diego

APPENDICES for

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

FINAL REPORT

May 2006

Prepared for Commander Navy Region Southwest

by

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Appendix A

Sampling Summary Table

Sample ID Naming Convention:

Base-Location-Storm Event-Sample Type

Bases:

NAV-Naval Station San Diego
SUB-Submarine Base San Diego
NAB-Naval Amphibious Base Coronado
NI-Naval Naval Air Station North Island

Locations:

OF-outfall storm water
PR-pier storm water
Bay-bay receiving water

Storm Sampling Event:

SDB1...SDB7, TIE etc.

Sample Type:

FF-first-flush storm water
COMP-composite storm water
PRE-pre-storm receiving water
DUR-during storm receiving water
AFT-after storm receiving water

Examples:

NAV-OF9-SDB1-FF:
Naval Station San Diego-Outfall 9-Storm 1-First-flush

SUB-BAY11B-SDB4-AFT:
Submarine Base San Diego-bay water outside outfall 11B-Storm 4-After

NAV

Naval Station San Diego

Sample Date	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
11/7/2002	NAV	SDB1	OF 9	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	OF 11	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	OF 14	COMP	X	X	X	X	X		X	X		
	NAV	SDB1	Bay	PRE				X			X			
	NAV	SDB1	Bay 9	PRE	X	X	X		X					
	NAV	SDB1	Bay 9	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 9	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 11	PRE	X	X	X		X					
	NAV	SDB1	Bay 11	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 11	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 14	PRE	X	X	X		X					
	NAV	SDB1	Bay 14	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 14	AFT	X	X	X	X	X		X			
	NAV	SDB1	Bay 14A	PRE	X	X	X		X					
	NAV	SDB1	Bay 14A	DUR	X	X	X	X	X		X			
	NAV	SDB1	Bay 14A	AFT	X	X	X	X	X		X			
2/24/2003	NAV	SDB2	PR 5	FF	X	X	X	X	-		X	X		
	NAV	SDB2	PR 5	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	PR 6	FF	X	X	X	X	-		X	X		
	NAV	SDB2	PR 6	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 9	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 9	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 11	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 11	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	OF 14	FF	X	X	X	X	-		X	X		
	NAV	SDB2	OF 14	COMP	X	X	X	X	-		X	X		
	NAV	SDB2	Bay 9	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 9	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 9	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 11	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 14	AFT	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	PRE	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	DUR	X	X	X	X	-		X			
	NAV	SDB2	Bay 14A	AFT	X	X	X	X	-		X			
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						
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
10/26/2004	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							

+ Collected at SSC-SD

* *in situ* toxicity

- Lost

T Analyzed by toxicity lab

SUB

Submarine Base San Diego

Sample Dates	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
2/24/2003	SUB	SDB2	OF 11B	FF	X	X	X	X	-		X	X		
	SUB	SDB2	OF 24	FF	X	X	X	X	-		X	X		
	SUB	SDB2	OF 26	FF	X	X	X	X	-		X	X		
	SUB	SDB2	Bay 11B	PRE	X		X	X	-		X			
	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
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	SUB	SDB4	OF 11B	FF	X	X	X		X					X
	SUB	SDB4	Bay 11B	DUR	X	X	X		X					X
1/10/2005	SUB	SDB5	Bay 11B	AFT	X		X							

T Analyzed by toxicity lab

NAB

Naval Amphibious Base Coronado

Sample Dates	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
10/17/2004	NAB	SDB4	OF 9	FF	X	X	X		X					X
	NAB	SDB4	Bay 9	DUR	X	X	X		X					X
1/10/2005	NAB	SDB5	Bay 9	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
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							
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

T Analyzed by toxicity lab

NI

Naval Air Station North Island

Sample Dates	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
10/17/2004	NI	SDB4	OF 23A	FF	X	X	X		X					X
	NI	SDB4	Bay 23A	DUR	X	X	X		X					X
1/10/2005	NI	SDB5	BAY 23A	AFT			X							
2/10/2005	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	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	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

T Analyzed by toxicity lab

Other

Downtown Piers

Sample Dates	Base	Storm	Outfall	Sample Type	Topsmelt	Mysid	Mussel	Metals	TSS	DOC	PAH	PCB	Pest	Cu/Zn
1/10/2005	NA	SDB5	DOWNTOWN PIER	AFT	X	X	X							

Appendix B

Toxicity Data Summary Tables

FOR ALL TABLES "-" means No Data.

NAV

OUTFALLS

TOPSMELT (*A. affinis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
Nautilus	2/24/2003	NAV	SDB2	OF11 FF	23.30	10.0	50.0	41.71	-	-	10.53	95	0
Nautilus	2/24/2003	NAV	SDB2	PR5 FF	19.68	10.0	50.0	49.46	-	-	10.53	95	0
Nautilus	2/24/2003	NAV	SDB2	PR6 FF	30.92	50.0	100.0	>100	31.12	70.33	10.53	95	60
Nautilus	2/24/2003	NAV	SDB2	OF14 FF	31.94	100.0	>100	>100	13.44	>100	12.83	90	70
Nautilus	2/24/2003	NAV	SDB2	OF9 FF	15.44	100.0	>100	>100	16.00	>100	0.00	100	85
Nautilus[a]	2/18/2004	NAV	TIE1	OF9 FF	7.00	100.0	>100	>100	>100	>100	0.00	100	96
Nautilus[a]	2/18/2004	NAV	TIE1	OF11 FF	7.00	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus[a]	2/18/2004	NAV	TIE1	OF14 FF	5.00	100.0	>100	>100	>100	>100	0.00	100	100
SSC - SD	10/17/2004	NAV	SDB4	OF14 FF	19.80	50.0	100.0	73.88	42.64	55.33	0.00	100	25
SSC - SD	10/26/2004	NAV	SD45	OF14 FF	7.89	100.0	>100	>100	>100	>100	0.00	100	90
SSC - SD	11/7/2002	NAV	SDB1	OF9 Comp.	13.68	50.0	>50	>50	-	-	11.21	90	N/A
SSC - SD	11/7/2002	NAV	SDB1	OF11 Comp.	8.98	100.0	>100	>100	-	-	0.00	100	100
SSC - SD	11/7/2002	NAV	SDB1	OF14 Comp.	10.16	100.0	>100	>100	>100	>100	9.26	95	100
Nautilus	2/24/2003	NAV	SDB2	OF9 Comp	15.71	100.0	>100	>100	>100	>100	0.00	100	90
Nautilus	2/24/2003	NAV	SDB2	OF11 Comp	15.70	100.0	>100	>100	>100	>100	0.00	100	90
Nautilus	2/24/2003	NAV	SDB2	OF14 Comp	18.24	100.0	>100	>100	>100	>100	12.83	90	95
Nautilus	2/24/2003	NAV	SDB2	PR5 Comp	19.72	100.0	>100	>100	-	-	10.53	95	95
Nautilus	2/24/2003	NAV	SDB2	PR6 Comp	19.04	100.0	>100	>100	73.80	>100	10.53	95	75

[a]Testing conducted with inland silversides (*Menidia beryllina*) due to unavailability of topsmelt

MYSIDS (*A. bahia*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
Nautilus	2/24/2003	NAV	SDB2	OF11 FF	-	-	-	30.0	14.0	20.0	0.00	100	0
Nautilus	2/24/2003	NAV	SDB2	PR5 FF	5.97	-	-	22.4	3.6	9.1	0.00	100	0
Nautilus	2/24/2003	NAV	SDB2	PR6 FF	11.50	50.0	100.0	84.0	50.0	63.9	0.00	100	33.3
Nautilus	2/24/2003	NAV	SBD2	OF9 FF	8.58	100.0	>100	>100	89.0	>100	0.00	100	90
Nautilus	2/24/2003	NAV	SBD2	OF14 FF	8.38	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/18/2004	NAV	TIE1	OF9 FF	5.00	100.0	>100	>100	>100	>100	8.60	95	90
Nautilus	2/18/2004	NAV	TIE1	OF11 FF	5.00	50.0	100.0	>100	80.00	>100	8.60	95	85
Nautilus	2/18/2004	NAV	TIE1	OF14 FF	10.00	100.0	>100	>100	75.00	>100	8.60	95	85
SSC - SD	10/17/2004	NAV	SDB4	OF14 FF	9.25	25	50	98.5	36.8	58.6	0.00	100	43.3
SSC - SD	10/26/2004	NAV	SD45	OF14 FF	4.20	50	100	>100	51.5	91.1	0.00	100	63.3
Nautilus	2/24/2003	NAV	SBD2	OF9 Comp	-	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/24/2003	NAV	SBD2	OF11 Comp	3.79	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/24/2003	NAV	SBD2	OF14 Comp	-	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/24/2003	NAV	SBD2	PR5 Comp	3.79	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/24/2003	NAV	SBD2	PR6 Comp	8.57	100.0	>100	>100	98.5	>100	0.00	100	90
SSC - SD	11/7/2002	NAV	SDB1	OF14 Comp	12.33	100.0	>100	>100	>100	>100	5.97	96.7	93.3
SSC - SD	11/7/2002	NAV	SDB1	OF11 Comp	3.09	100.0	>100	>100	>100	>100	0.00	100	100
SSC - SD	11/7/2002	NAV	SDB1	OF9 Comp	15.12	50.0	>50	>50	>50	>50	0.00	100	N/A
SSC - SD	10/26/2004	NAV	SD45	OF14 Comp	11.30	-	-	-	-	-	0.00	100	80

Mussel (*M. galloprovincialis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Dev	%Devel in 100%
Nautilus	2/24/2003	NAV	SDB2	OF9 FF	2.81	10.0	50.0	55.84	51.29	53.39	3.76	96.4	27.4
Nautilus	2/24/2003	NAV	SDB2	OF11 FF	5.82	10.0	50.0	51.55	50.09	50.78	2.59	95.4	0
Nautilus	2/24/2003	NAV	SDB2	OF14 FF	-	50.0	58.0	56.22	52.39	54.17	2.76	96.6	27.6
Nautilus	2/24/2003	NAV	SDB2	PR5 FF	10.26	10.0	50.0	25.10	-	-	6.72	88.6	0
Nautilus	2/24/2003	NAV	SDB2	PR6 FF	7.55	-	-	22.36	-	-	6.72	88.6	0
Nautilus	2/18/2004	NAV	TIE1	OF9 FF	22.00	25.0	50.0	38.43	27.69	31.72	4.13	81	0
Nautilus	2/18/2004	NAV	TIE1	OF11 FF	25.00	25.0	50.0	34.16	27.50	30.48	4.13	81	0
Nautilus	2/18/2004	NAV	TIE1	OF14 FF	15.00	25.0	50.0	27.43	23.56	25.32	4.13	81	0
SSC - SD	10/17/2004	NAV	SDB4	OF14 FF	6.40	<6.25	6.3	8.0	4.9	6.2	2.07	97.5	0
SSC - SD	10/26/2004	NAV	SD45	OF14 FF	-	25.0	50.0	49.1	43.4	46.0	4.17	92.6	1.2
Nautilus	2/24/2003	NAV	SDB2	OF14 Comp	2.93	65.0	>65	>65	>65	>65	2.75	96.6	94.8
Nautilus	2/24/2003	NAV	SDB2	OF9 Comp	-	61.0	>61	>61	>61	>61	-	96.4	96.8
Nautilus	2/24/2003	NAV	SDB2	PR6 Comp	3.84	50.0	58.0	53.5	51.5	52.4	-	96.6	0.4
Nautilus	2/24/2003	NAV	SDB2	PR5 Comp	-	50.0	58.0	56.8	-	-	-	88.6	38.6
Nautilus	2/24/2003	NAV	SDB2	OF11 Comp	4.05	65.0	>65	>65	>65	>65	-	95.4	91.2
SSC - SD	10/26/2004	NAV	SD45	OF14 Comp	4.06	50	61.4	>61.4	>61.4	>61.4	4.2	92.6	86.40

BAY SAMPLES

TOPSMELT (*A. affinis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
SSC - SD	11/7/2002	NAV	SDB1	Bay 9	None	100.0	95.0	100.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 11	None	100.0	95.0	95.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 14	None	95.0	100.0	95.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 14A	None	100.0	100.0	95.0
Nautilus	2/24/2003	NAV	SDB2	Bay 11	None	95.0	90.0	95.0
Nautilus	2/24/2003	NAV	SDB2	Bay 14	None	90.0	90.0	90.0
Nautilus	2/24/2003	NAV	SDB2	Bay 9	None	100.0	95.0	90.0
Nautilus	2/24/2003	NAV	SDB2	Bay 14A	None	95.0	90.0	100.0
SSC - SD	10/17/2004	ALL/NAV	SDB4	Bay 14	None	100.0	100.0	-
SSC - SD	10/26/2004	NAV	SD45	Bay 14	None	100.0	-	-
SSC - SD	1/10/2005	NAV	SDB5	Bay 14	None	-	-	100.0

MYSIDS (*A. bahia*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
SSC - SD	11/7/2002	NAV	SDB1	Bay 9	None	96.6	100.0	100.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 11	None	100.0	100.0	100.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 14A	None	100.0	100.0	100.0
SSC - SD	11/7/2002	NAV	SDB1	Bay 14	None	100.0	96.6	100.0
Nautilus	2/24/2003	NAV	SDB2	Bay 9	None	100.0	100.0	100.0
Nautilus	2/24/2003	NAV	SDB2	Bay 11	None	100.0	100.0	100.0
Nautilus	2/24/2003	NAV	SDB2	Bay 14	None	100.0	100.0	100.0
Nautilus	2/24/2003	NAV	SDB2	Bay 14A	None	100.0	100.0	97.0
SSC - SD	10/17/2004	All/NAV	SDB4	Bay 14	None	100.0	100.0	-
SSC - SD	10/26/2004	NAV	SD45	Bay 14	None	100.0	-	-
SSC - SD	1/10/2005	NAV	SDB5	Bay 14	None	-	-	100.0

MUSSELS (*M. galloprovincialis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Normal Development PRE	DUR	AFT
Nautilus	2/28/2003	NAV	SDB2	Bay 9	None	96.4	93.4	97.4
Nautilus	2/28/2003	NAV	SDB2	Bay 11	None	95.4	96.2	97.4
Nautilus	2/28/2003	NAV	SDB2	Bay 14	None	96.6	96.4	97.2
Nautilus	2/28/2003	NAV	SDB2	Bay 14A	None	88.6	92.6	91.2
SSC-SD	10/17/2005	ALL/NAV	SDB4	Bay 14	Dur	96.8	8.2	-
SSC-SD	10/26/2005	NAV	SDB45	Bay 14	None	92.6	-	-
SSC-SD	1/10/2005	NAV	SDB5	Bay 14	None	-	-	94.9

Note: "ALL"- Pre-sample was taken off SSC-SD pier 159 and used as control for all four bases.

SUB

OUTFALLS

TOPSMELT (*A. affinis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
Nautilus	2/24/2003	SUB	SDB2	OF11B FF	21.29	100.0	>100	>100	95.0	>100	10.53	90	85
Nautilus	2/24/2003	SUB	SDB2	OF24 FF	18.68	100.0	>100	>100	80.0	>100	12.83	90	75
Nautilus	2/24/2003	SUB	SDB2	OF26 FF	23.89	100.0	>100	>100	>100	>100	12.83	90	90
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E FF	9.19	100.0	>100	>100	>100	>100	0.00	100	95
SSC - SD	2/2/2004	SUB	SDB3	OF26 FF	18.49	100.0	>100	>100	>100	>100	22.22	90	95
SSC - SD	2/2/2004	SUB	SDB3	OF11B FF	11.02	100.0	>100	>100	>100	>100	10.53	95	100
Nautilus	2/18/2004	SUB	TIE1	OF11B FF	6.00	100.0	>100	>100	>100	>100	0.00	100	96
Nautilus	2/18/2004	SUB	TIE1	OF23 C&E FF	7.00	100.0	>100	>100	87.50	>100	0.00	100	88
Nautilus	2/18/2004	SUB	TIE1	OF26 FF	6.00	100.0	>100	>100	>100	>100	0.00	100	96
SSC - SD	10/17/2004	SUB	SDB4	OF11B FF	13.74	100.0	>100	>100	50	>100	0.00	100	85
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E Comp	5.67	50.0	100.0	>100	>100	>100	0.00	100	90
SSC - SD	2/2/2004	SUB	SDB3	OF26 Comp.	25.82	100.0	>100	>100	>100	>100	22.22	90	85
SSC - SD	2/2/2004	SUB	SDB3	OF11B Comp.	5.90	100.0	>100	>100	>100	>100	10.53	100	100

MYSIDS (*A. bahia*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
Nautilus	2/24/2003	SUB	SBD2	OF11B FF	12.13	100.0	>100	>100	84.9	>100	0.00	100	86.7
Nautilus	2/24/2003	SUB	SBD2	OF24 FF	-	100.0	>100	>100	>100	>100	0.00	100	100
Nautilus	2/24/2003	SUB	SBD2	OF26 FF	-	100.0	>100	>100	>100	>100	0.00	100	100
SSC - SD	2/2/2004	SUB	SDB3	OF11B FF	4.32	50.0	100.0	>100	71.54	>100	0.00	100	76.7
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E FF	7.46	50.0	100.0	>100	69.17	>100	5.97	96.7	76.7
SSC - SD	2/2/2004	SUB	SDB3	OF26 FF	13.04	100.0	>100	>100	>100	>100	0.00	100	90
Nautilus	2/18/2004	SUB	TIE1	OF11B FF	8.00	100.0	>100	>100	86.88	>100	9.00	95	85
Nautilus	2/18/2004	SUB	TIE1	OF23 C&E FF	11.00	50.0	100.0	>100	56.33	75.83	8.60	95	55
Nautilus	2/18/2004	SUB	TIE1	OF26 FF	7.00	100.0	>100	>100	98.33	>100	8.60	95	88
SSC - SD	10/17/2004	SUB	SDB4	OF11B FF	8.20	25	50	93.7	28.7	50.2	0.00	100	46.6
SSC - SD	2/2/2004	SUB	SDB3	OF11B Comp.	9.96	50.0	100.0	>100	57.19	>100	0.00	100	80
SSC - SD	2/2/2004	SUB	SDB3	OF26 Comp.	9.27	50.0	100.0	>100	67.49	92.34	0.00	100	70
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E Comp	12.11	100.0	>100	>100	>100	>100	5.97	96.7	86.7

MUSSELS (*M. galloprovincialis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Dev	%Devel in 100%
Nautilus	2/24/2003	SUB	SDB2	OF11B FF	9.18	50.0	58.0	53.9	-	-	-	86	0
Nautilus	2/24/2003	SUB	SDB2	OF24 FF	12.79	10.0	50.0	41.40	-	-	8.39	86	0.2
Nautilus	2/24/2003	SUB	SDB2	OF26 FF	12.09	10.0	50.0	33.01	-	-	8.39	86	0
SSC - SD	2/2/2004	SUB	SDB3	OF11B FF	8.49	33.0	66.0	47.50	36.82	41.54	3.17	94.8	4.4
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E FF	17.49	16.5	33.0	24.64	-	-	5.54	87.7	0
SSC - SD	2/2/2004	SUB	SDB3	OF26 FF	7.73	16.5	33.0	40.33	28.82	33.79	9.16	96.6	2.7
SSC - SD	10/17/2004	SUB	SDB4	OF11B FF	-	<6.25	6.3	9.8	6.2	7.7	2.07	97.5	0
Nautilus	2/18/2004	SUB	TIE1	OF11B FF	15.00	25.0	50.0	32.08	25.01	28.14	6.52	81	0
Nautilus	2/18/2004	SUB	TIE1	OF23 C&E FF	10.00	12.5	25.0	18.59	13.46	15.39	6.52	81	0
Nautilus	2/18/2004	SUB	TIE1	OF26 FF	11.00	12.5	25.0	15.96	12.99	14.32	6.52	81	0
SSC - SD	2/2/2004	SUB	SDB3	OF11B Comp.	12.17	33.0	66.0	49.08	-	-	3.17	94.8	10.2
SSC - SD	2/2/2004	SUB	SDB3	OF23 C&E Comp.	19.07	16.5	33.0	21.81	-	-	5.54	87.7	0

BAY SAMPLES

TOPSMELT (*A. affinis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
Nautilus	2/24/2003	SUB	SDB2	Bay 11B	None	90.0	-	100.0
Nautilus	2/24/2003	SUB	SDB2	Bay 24	None	-	-	100.0
Nautilus	2/24/2003	SUB	SDB2	Bay 26	None	-	-	95.0
SSC - SD	12/11/2003	SUB	SDB2A	Bay 23CE	None	90.0	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 11B	None	100.0	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 26	None	95.0	-	-
SSC - SD	2/2/2004	SUB	SDB3	Bay 23 C&E	None	100.0	95.0	95.0
SSC - SD	2/2/2004	SUB	SDB3	Bay 26	None	90.0	100.0	100.0
SSC - SD	2/2/2004	SUB	SDB3	Bay 26A	None	100.0	100.0	100.0
SSC - SD	2/2/2004	SUB	SDB3	Bay 11B	None	95.0	100.0	100.0
SSC - SD	10/17/2004	SUB	SDB4	Bay 11B	None	-	90.0	-
SSC - SD	1/10/2005	SUB	SDB5	Bay 11B	None	-	-	100.0

MYSIDS (*A. bahia*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
Nautilus	2/24/2003	SUB	SDB2	Bay 11B	None	100.0	-	97.0
Nautilus	2/24/2003	SUB	SDB2	Bay 24	None	-	-	100.0
Nautilus	2/24/2003	SUB	SDB2	Bay 26	None	-	-	100.0
SSC - SD	12/11/2003	SUB	SDB2A	Bay 23CE	None	96.7	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 11B	None	93.3	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 26	None	100.0	-	-
SSC - SD	2/2/2004	SUB	SDB3	Bay 11B	None	100.0	100.0	96.7
SSC - SD	2/2/2004	SUB	SDB3	Bay 26	None	100.0	100.0	96.7
SSC - SD	2/2/2004	SUB	SDB3	Bay 26A	None	100.0	100.0	100.0
SSC - SD	2/2/2004	SUB	SDB3	Bay 23 C&E	None	96.7	100.0	100.0
SSC - SD	10/17/2004	SUB	SDB4	Bay 11B	None	-	100.0	-

MUSSELS (*M. galloprovincialis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Normal Development PRE	DUR	AFT
Nautilus	2/24/2003	SUB	SDB2	Bay 11B	None	86.0	-	86.8
Nautilus	2/24/2003	SUB	SDB2	Bay 24	None	-	-	87.8
Nautilus	2/24/2003	SUB	SDB2	Bay 26	None	-	-	91.0
SSC - SD	12/11/2003	SUB	SDB2A	Bay 23CE	None	88.1	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 11B	None	86.0	-	-
SSC - SD	12/11/2003	SUB	SDB2A	Bay 26	None	86.7	-	-
SSC - SD	2/2/2004	SUB	SDB3	Bay 11B	None	94.8	94.3	96.1
SSC - SD	2/2/2004	SUB	SDB3	Bay 23 C&E	None	87.8	94.8	95.7
SSC - SD	2/2/2004	SUB	SDB3	Bay 26A	None	95.1	94.0	93.9
SSC - SD	2/2/2004	SUB	SDB3	Bay 26	None	89.7	97.3	95.9
Nautilus	2/26/2004	SUB	TIE-Add	Bay 11B	None			87.0
Nautilus	2/26/2004	SUB	TIE-Add	Bay 23 C&E	None			88.0
Nautilus	2/26/2004	SUB	TIE-Add	Bay 26	None			87.0
SSC - SD	10/17/2004	SUB	SDB4	Bay 11B	None	-	96.9	-
SSC - SD	1/10/2005	SUB	SDB5	Bay 11B	None	-	-	91.7

NAB

OUTFALLS

TOPSMELT (*A. affinis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
SSC - SD	10/17/2004	NAB	SDB4	OF9 FF	18.30	12.5	25.0	22.1	13.1	16.8	0.00	100	0
SSC - SD	2/10/2005	NAB	SDB6	OF9 FF	-	100	>100	>100	>100	>100	0.00	100	95
SSC - SD	2/10/2005	NAB	SDB6	OF18 FF	-	100	>100	>100	>100	>100	0.00	100	100
Nautilus	3/19/2005	NAB	TIE2	OF9 FF	12.50	100	>100	>100	-	>100	0.00	100	95
Nautilus	3/19/2005	NAB	TIE2	OF18 FF	12.50	25	50.0	38.2	-	32.1	0.00	100	0
SSC - SD	4/27/2005	NAB	SDB7	OF9 FF	15.50	100	>100	>100	96.8	>100	10.53	95	85
SSC - SD	4/27/2005	NAB	SDB7	OF18 FF	11.47	100.0	>100	>100	10.7	>100	0.00	100	90
SSC - SD	2/10/2005	NAB	SDB6	OF9 Comp	-	100	>100	>100	>100	>100	0.00	100	100
SSC - SD	4/27/2005	NAB	SDB7	OF9 Comp	18.44	50	100.0	>100	36.8	73.0	10.53	95	60
SSC - SD	4/27/2005	NAB	SDB7	OF18 Comp	8.69	100.0	>100	>100	>100	>100	0.00	100	90

MYSIDS (*A. bahia*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
SSC - SD	10/17/2004	NAB	SDB4	OF9 FF	29.00	12.5	25	19.3	11.9	15.0	0.00	100	0
SSC - SD	2/10/2005	NAB	SDB6	OF9 FF	8.93	100	>100	>100	>100	>100	0.00	100	90
SSC - SD	2/10/2005	NAB	SDB6	OF18 FF	6.38	50	100	>100	83.3	>100	0.00	100	86.7
Nautilus	3/19/2005	NAB	TIE2	OF9 FF	28.90	50	100	>100	-	73.4	10.50	95	50
Nautilus	3/19/2005	NAB	TIE2	OF18 FF	14.80	25	50	42.4	-	32.7	10.50	95	5
SSC - SD	2/10/2005	NAB	SDB6	OF9 Comp	8.58	100	>100	>100	>100	>100	0.00	100	90

MUSSELS (*M. galloprovincialis*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Dev	%Devel in 100%
SSC - SD	10/17/2004	NAB	SDB4	OF9 FF	2.59	<6.25	6.3	1.7	0.6	1.0	2.07	97.5	0
SSC - SD	2/10/2005	NAB	SDB6	OF9 FF	6.82	12.4	24.8	32.1	16.6	23.1	1.20	96.4	0
SSC - SD	2/10/2005	NAB	SDB6	OF18 FF	3.24	12.4	24.8	22.4	17.2	19.5	1.55	97.3	0
Nautilus	3/19/2005	NAB	TIE2	OF9FF	4.67	<12.5	12.5	12.5	-	11.3	4.29	95	0
Nautilus	3/19/2005	NAB	TIE2	OF18 FF	3.04	<12.5	12.5	13.7	-	12.6	4.29	95	0
SSC - SD	2/10/2005	NAB	SDB6	OF9 Comp	3.68	12.9	25.7	37.7	26.7	30.8	1.20	96.4	0

BAY SAMPLES

TOPSMELT (*A. affinis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
SSC-SD	10/19/2004	NAB	SDB4	Bay 9	None	-	95.0	-
SSC-SD	1/10/2005	NAB	SDB5	Bay 9	None	-	-	100.0
SSC-SD	2/10/2005	NAB	SDB6	Bay 9	None	100.0	90.0	-
SSC-SD	2/10/2005	NAB	SDB6	Bay 18	None	100.0	100.0	-
Nautilus	3/19/2005	NAB	TIE2	Bay 9	None	-	100.0	-
Nautilus	3/19/2005	NAB	TIE2	Bay 18	None	-	95.0	-
SSC-SD	4/27/2005	NAB	SDB7	Bay 9	None	95.0	100.0	-
SSC-SD	4/27/2005	NAB	SDB7	Bay 18	None	100.0	95.0	-

MYSIDS (*A. bahia*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	DUR	AFT
SSC-SD	10/17/2005	NAB	SDB4	Bay 9	None	-	100.0	-
SSC-SD	1/10/2005	NAB	SDB5	Bay 9	None	-	-	96.7
SSC-SD	2/10/2005	NAB	SDB6	Bay 9	None	100.0	100.0	-
SSC-SD	2/10/2005	NAB	SDB6	Bay 18	None	100.0	96.7	-
Nautilus	3/19/2005	NAB	TIE2	Bay 9	None	-	100.0	
Nautilus	3/19/2005	NAB	TIE2	Bay 18	None	-	100.0	

MUSSELS (*M. galloprovincialis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Normal Development PRE	DUR	AFT
SSC-SD	10/17/2005	NAB	SDB4	Bay 9	Dur	-	4.0	-
SSC-SD	1/10/2005	NAB	SDB5	Bay 9	None	-	-	90.2
SSC-SD	2/10/2005	NAB	SDB6	Bay 9	None	96.4	97.7	-
SSC-SD	2/10/2005	NAB	SDB6	Bay 18	None	97.3	95.4	-
Nautilus	3/19/2005	NAB	TIE2	Bay 9	None	-	96.0	-
Nautilus	3/19/2005	NAB	TIE2	Bay 18	None	-	96.0	-
SSC-SD	4/27/2005	NAB	SDB7	Bay 9	None	94.6	93.2	-
SSC-SD	4/27/2005	NAB	SDB7	Bay 18	None	91.6	93.2	-

NI

OUTFALLS

TOPSMELT (*A. affinis*)

Laboratory	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
SSC - SD	10/17/2004	NI	SDB4	OF23A FF	15.88	100.0	>100	>100	22.5	>100	0.00	100	80
SSC - SD	2/10/2005	NI	SDB6	OF23A FF	-	100	>100	>100	>100	>100	0.00	100	90
SSC - SD	2/10/2005	NI	SDB6	OF26 FF	-	100	>100	>100	>100	>100	10.53	95	95
Nautilus	3/19/2005	NI	TIE2	OF23a FF	12.2	50	100	>100	-	86	0	100	65
Nautilus	3/19/2005	NI	TIE2	OF26 FF	10.00	100	>100	>100	-	>100	0.00	100	100
SSC - SD	4/27/2005	NI	SDB7	OF23A FF	7.93	100	>100	>100	>100	>100	0.00	100	95
SSC - SD	4/27/2005	NI	SDB7	OF26 FF	16.25	100	>100	>100	79.0	>100	12.83	90	80
SSC - SD	2/10/2005	NI	SDB6	OF26Comp	-	100	>100	>100	>100	>100	10.53	95	100
SSC - SD	4/27/2005	NI	SDB7	OF26 Comp	19.10	100	>100	>100	>100	>100	12.83	90	100

MYSIDS (*A. bahia*)

Lab	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Survival	%Survival in 100%
SSC - SD	10/17/2004	NI	SDB4	OF23A FF	10.80	25	50	>100	30.2	57.9	0.00	100	56.7
SSC - SD	2/10/2005	NI	SDB6	OF23A FF	5.20	100	>100	>100	>100	>100	0.00	100	96.7
SSC - SD	2/10/2005	NI	SDB6	OF26 FF	7.82	50	100	>100	61.5	96.2	0.00	100	73.3
Nautilus	3/19/2005	NI	TIE2	OF23a FF	12.00	100	>100	>100	-	>100	10.50	95	75
Nautilus	3/19/2005	NI	TIE2	OF26 FF	14.80	100	>100	>100	>100	>100	10.50	95	95
SSC - SD	2/10/2005	NI	SDB6	OF26 Comp	8.29	100	>100	>100	>100	>100	0.00	100	100

MUSSELS (*M. galloprovincialis*)

Laboratory	Sample Date	Sample Location	Survey	Sample ID	PMSD	NOEC	LOEC	LC50/ EC50	LC10/ EC10	LC25/ EC25	Control CV%	% Control Dev	% Devel in 100%
SSC - SD	10/17/2004	NI	SDB4	OF23A FF	4.90	6.3	12.5	17.0	11.9	14.1	2.07	97.5	0
SSC - SD	2/10/2005	NI	SDB6	OF23A FF	2.02	12.4	24.8	19.3	15.0	16.9	0.85	98.2	0
SSC - SD	2/10/2005	NI	SDB6	OF26 FF	1.89	12.4	24.8	31.9	26.3	28.8	1.35	97.5	0
Nautilus	3/19/2005	NI	TIE2	OF23a FF	4.19	12.5	25	22.1	-	19.4	4.29	95	0
Nautilus	3/19/2005	NI	TIE2	OF26 FF	4.28	69	>69	>69	-	>69	4.29	93	89
SSC - SD	2/10/2005	NI	SDB6	OF26 Comp	2.64	55.7	>55.7	>55.7	>55.7	>55.7	1.35	97.5	95.5

BAY SAMPLES

TOPSMELT (*A. affinis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	% Survival DUR	% Survival AFT
SSC-SD	10/17/2005	NI	SDB4	Bay 23A	None	-	95.0	-
SSC-SD	1/10/2005	NI	SDB5	Downtown Pier	None	-	-	100.0
SSC-SD	2/10/2005	NI	SDB6	Bay 23A	None	100.0	100.0	-
SSC-SD	2/10/2005	NI	SDB6	Bay 26	None	95.0	100.0	-
Nautilus	3/19/2005	NI	TIE2	Bay 23A	None	-	95.0	-
Nautilus	3/19/2005	NI	TIE2	Bay 26	None	-	100.0	-
SSC-SD	4/27/2005	NI	SDB7	Bay 23A	None	100.0	100.0	-
SSC-SD	4/27/2005	NI	SDB7	Bay 26	None	90.0	100.0	-

MYSIDS (*A. bahia*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Survival PRE	% Survival DUR	% Survival AFT
SSC-SD	10/17/2005	NI	SDB4	Bay 23A	None	-	100.0	-
SSC-SD	1/10/2005	NI	SDB5	Downtown Pier	None	-	-	93.3
SSC-SD	2/10/2005	NI	SDB6	Bay 23A	None	100.0	100.0	-
SSC-SD	2/10/2005	NI	SDB6	Bay 26	None	100.0	100.0	-
Nautilus	3/19/2005	NI	TIE2	Bay 23A	None	-	100.0	-
Nautilus	3/19/2005	NI	TIE2	Bay 26	None	-	95.0	-

MUSSELS (*M. galloprovincialis*)

Laboratory	Sample Date	Location	Survey	Sample ID	Significant	% Normal Development PRE	% Normal Development DUR	% Normal Development AFT
SSC-SD	10/17/2005	NI	SDB4	Bay 23A	None	-	97.6	-
SSC-SD	1/10/2005	NI	SDB5	Bay 23A	None	-	-	93.9
SSC-SD	1/10/2005	NI	SDB5	Downtown Pier	None	-	-	93.6
SSC-SD	2/10/2005	NI	SDB6	Bay 23A	None	98.0	97.1	-
SSC-SD	2/10/2005	NI	SDB6	Bay 26	None	97.5	96.4	-
Nautilus	3/19/2005	NI	TIE2	Bay 23A	None	-	96.0	-
Nautilus	3/19/2005	NI	TIE2	Bay 26	None	-	95.0	-
SSC-SD	4/27/2005	NI	SDB7	Bay 23A	None	90.0	92.3	-
SSC-SD	4/27/2005	NI	SDB7	Bay 26	None	96.8	95.7	-

Appendix C

Toxicity Data

Note regarding the organization of the tables

The following tables contain toxicity and water quality data from the laboratory toxicity tests conducted over the course of this study for both storm water effluent (Outfalls) and in the receiving environment (Bay Samples) immediately adjacent to the outfalls prior to (PRE), during (DUR), and after (AFT) each storm event. Except where otherwise noted, the PRE water samples, which were collected approximately 24 hours prior to the storm event, served as the negative control for the dilution series tests using the Outfall samples. To prevent redundancy, the PRE sample data have been grouped with the Bay Sample tables, and not the Outfall tables. Therefore, to identify the relevant negative control associated with a particular sample, it is advised that the reader refer to the Bay Sample tables. For instance, the control for outfall sample NAV-OF9-SDB1-COMP is the Bay sample NAV-Bay9-SDB1-PRE.

Appendix C1

NAV

SDB1- 11/7/2002
SDB2- 2/24/2003
TIE1- 2/18/2004
SDB4- 10/17/2004
SDB45- 10/26/2004
SDB5- 01/10/2005

SDB1 – 11/7/2002

OUTFALLS

TOPSMELT (*A. affinis*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[1]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-OF9-SDB1-COMP	12.5	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	50	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-OF11-SDB1-COMP	6.25	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
	12.5	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
	25	a	5	100.0	90.0	11.5	90.0	0.091	No
		b	4	80.0					
		c	4	80.0					
		d	5	100.0					
	50	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					
	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-OF14-SDB1-COMP	6.25	a	5	100.0	100.0	0.0	105.3	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
	12.5	a	5	100.0	95.0	10.0	100.0	0.196	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	25	a	5	100.0	95.0	10.0	100.0	0.196	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
	50	a	5	100.0	100.0	0.0	105.3	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
	100	a	5	100.0	100.0	0.0	105.3	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					

MYSIDS (*A. bahia*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[1]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-OF9-SDB1-COMP	12.5	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
	50	a	10	100.0	90.0	17.3	93.1	0.291	No
		b	7	70.0					
		c	10	100.0					
NAV-OF11-SDB1-COMP	6.25	a	9	90.0	96.7	5.8	96.7	0.211	No
		b	10	100.0					
		c	11	100.0					
	12.5	a	10	100.0	100.0	0.0	100.0	n/a	No
		b	10	100.0					
		c	10	100.0					
	25	a	10	100.0	100.0	0.0	100.0	n/a	No
		b	10	100.0					
		c	12	100.0					
	100	a	10	100.0	100.0	0.0	100.0	n/a	No
		b	10	100.0					
		c	10	100.0					
NAV-OF14-SDB1-COMP	6.25	a	10	100.0	100.0	0.0	100.0	n/a	No
		b	10	100.0					
		c	10	100.0					
	12.5	a	10	100.0	96.7	5.8	96.7	0.211	No
		b	9	90.0					
		c	10	100.0					
	25	a	9	90.0	90.0	10.0	90.0	0.113	No
		b	8	80.0					
		c	10	100.0					
	50	a	10	100.0	96.7	5.8	96.7	0.211	No
		b	10	100.0					
		c	9	90.0					
	100	a	9	90.0	93.3	5.8	93.3	0.092	No
		b	10	100.0					
		c	9	90.0					

MUSSELS (*M. galloprovincialis*)

SAMPLE ID	CONC (%)	REP.	NORM DEVEL (%)	MEAN NORM DEV (%)	STD DEV	% of CONTROL[1]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-OF9-SDB1-COMP	4.4	a	38.0	41.7	3.3	106.8	0.248	No
		b	42.8					
		c	44.4					
	8.8	a	36.4	36.9	3.0	94.5	0.286	No
		b	40.1					
		c	34.2					
	17.5	a	12.3	10.9	2.9	27.9	0.001	**Yes**
		b	12.8					
		c	7.5					
	35.0	a	0.0	0.2	0.3	0.5	0.003	**Yes**
		b	0.0					
		c	0.5					
	70	a	0.0	0.0	0.0	0.0	0.003	**Yes**
		b	0.0					
		c	0.0					
NAV-OF11-SDB1-COMP	4.6	a	53.5	46.3	6.7	102.8	0.398	No
		b	40.1					
		c	45.5					
	9.1	a	32.1	33.2	3.3	73.5	0.008	**Yes**
		b	36.9					
		c	30.5					
	18.3	a	6.4	7.1	1.2	15.8	0.001	**Yes**
		b	8.6					
		c	6.4					
	36.5	a	0.0	0.0	0.0	0.0	0.001	**Yes**
		b	0.0					
		c	0.0					

MUSSELS (*M. galloprovincialis*)

SAMPLE ID	CONC (%)	REP.	NORM DEVEL (%)	MEAN NORM DEV (%)	STD DEV	% of CONTROL[1]	P-VALUE[b]	SIG DIFF FROM CONTROL?
	73	a	0.0	0.0	0.0	0.0	0.001	Yes
		b	0.0					
		c	0.0					
NAV-OF14-SDB1-COMP	5.1	a	42.8	43.7	0.8	89.4	0.063	No
		b	43.9					
		c	44.4					
	10.2	a	41.2	37.4	6.5	76.6	0.036	Yes
		b	41.2					
		c	30.0					
	20.4	a	32.1	31.6	1.9	64.6	0.003	Yes
		b	33.2					
		c	29.4					
	40.7	a	0.5	1.2	0.6	2.5	0.001	Yes
		b	1.6					
		c	1.6					
	81.4	a	0.0	0.0	0.0	0.0	0.001	Yes
		b	0.0					
		c	0.0					

[a]Controls (QA/QC) correspond to all samples from SDB1
[b]Student's t-test with a one tailed distribution and two sample unequal variance
[c] p-value is significant because treatment had a significantly greater proportion normal compared to the control
n/a - t-test not used since control and treatment have same percentage survival
[1]Controls were the Bay water samples taken prior to storm (PRE) with comparable sample ID
[2]Controls were Scripps filtered seawater

BAY SAMPLES

TOPSMELT (*A. affinis*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[2]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-BAY9-SDB1-PRE	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY9-SDB1-DUR	100	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY9-SDB1-AFT	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY11-SDB1-PRE	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY11-SDB1-DUR	100	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					
NAV-BAY11-SDB1-AFT	100	a	4	80.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY14-SDB1-PRE	100	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY14-SDB1-DUR	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY14-SDB1-AFT	100	a	4	80.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					

TOPSMELT (*A. affinis*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[a]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-BAY14A-SDB1-PRE	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY14A-SDB1-DUR	100	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
NAV-BAY14A-SDB1-AFT	100	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					

MYSIDS (*A. bahia*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[a]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-BAY9-SDB1-PRE	100	a	9	90.0	96.7	5.8	100.0	0.500	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY9-SDB1-DUR	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY9-SDB1-AFT	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY11-SDB1-PRE	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY11-SDB1-DUR	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY11-SDB1-AFT	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY14-SDB1-PRE	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY14-SDB1-DUR	100	a	10	100.0	96.7	5.8	100.0	0.500	No
		b	9	90.0					
		c	10	100.0					
NAV-BAY14-SDB1-AFT	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY14A-SDB1-PRE	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY14A-SDB1-DUR	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
NAV-BAY14A-SDB1-AFT	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					

MUSSELS (*M. galloprovincialis*)

SAMPLE ID	CONC (%)	REP.	NORM DEVEL (%)	MEAN NORM DEV (%)	STD DEV	% of CONTROL[a]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-BAY9-SDB1-PRE	100	a	34.2	39.0	5.1	85.9	0.081	No
		b	38.5					
		c	44.4					
NAV-BAY9-SDB1-DUR	100	a	41.7	47.1	9.3	103.5	0.401	No
		b	41.7					
		c	57.8					

MUSSELS (*M. galloprovincialis*)

SAMPLE ID	CONC (%)	REP.	NORM DEVEL (%)	MEAN NORM DEV (%)	STD DEV	% of CONTROL[a]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-BAY9-SDB1-AFT	100	a	41.2	39.6	8.9	87.1	0.189	No
		b	47.6					
		c	29.9					
NAV-BAY11-SDB1-PRE	100	a	44.4	45.1	3.8	99.2	0.457	No
		b	41.7					
		c	49.2					
NAV-BAY11-SDB1-DUR	100	a	45.5	41.7	4.4	91.8	0.165	No
		b	42.8					
		c	36.9					
NAV-BAY11-SDB1-AFT	100	a	43.9	45.6	1.6	100.4	0.473	No
		b	47.1					
		c	46.0					
NAV-BAY14-SDB1-PRE	100	a	46.0	48.8	3.6	107.5	0.165	No
		b	47.6					
		c	52.9					
NAV-BAY14-SDB1-DUR	100	a	42.2	41.5	1.7	91.4	0.107	No
		b	42.8					
		c	39.6					
NAV-BAY14-SDB1-AFT	100	a	31.6	33.9	3.6	74.5	0.009	**Yes**
		b	32.1					
		c	38.0					
NAV-BAY14A-SDB1-PRE	100	a	42.8	47.1	4.6	103.5	0.333	No
		b	46.5					
		c	51.9					
NAV-BAY14A-SDB1-DUR	100	a	49.7	44.4	5.6	97.6	0.401	No
		b	38.5					
		c	44.9					
NAV-BAY14A-SDB1-AFT	100	a	49.2	46.2	3.9	101.6	0.417	No
		b	41.7					
		c	47.6					

QA/QC SAMPLES[a]

TOPSMELT (*A. affinis*)

SAMPLE ID	CONC (% or µg/l Cu)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[a]	P-VALUE[b]	SIG DIFF FROM CONTROL?
Scripps Control	n/a	a	5	100.0	100.0	0.0	n/a	n/a	n/a
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
Salt Control 1	n/a	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
Copper Ref. Tox.	50	a	5	100.0	100.0	0.0	100.0	n/a	No
		b	5	100.0					
		c	5	100.0					
		d	5	100.0					
	100	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
	200	a	3	60.0	65.0	10.0	65.0	0.003	**Yes**
		b	3	60.0					
		c	4	80.0					
		d	3	60.0					
	400	a	1	20.0	20.0	16.3	20.0	0.001	**Yes**
		b	0	0.0					
		c	2	40.0					
		d	1	20.0					

MYSIDS (*A. bahia*)

SAMPLE ID	CONC (% or µg/l Cu)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[2]	P-VALUE[b]	SIG DIFF FROM CONTROL?
Scripps Control	n/a	a	10	100.0	96.7	5.8	n/a	n/a	n/a
		b	9	90.0					
		c	10	100.0					
Salt Control 1	n/a	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
Copper Ref. Tox.	25	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
	50	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
	100	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
	200	a	10	100.0	100.0	0.0	103.4	0.211	No
		b	10	100.0					
		c	10	100.0					
	400	a	3	30.0	33.3	5.8	34.5	0.000	Yes
		b	4	40.0					
		c	3	30.0					

MUSSELS (*M. galloprovincialis*)

SAMPLE ID	CONC (% or µg/l Cu)	REP.	NORM DEVEL (%)	MEAN NORM DEV (%)	STD DEV	% of CONTROL[2]	P-VALUE[b]	SIG DIFF FROM CONTROL?
Scripps Control	n/a	a	49.7	45.5	3.9	n/a	n/a	n/a
		b	44.4					
		c	42.2					
Brine Control	n/a	a	42.8	42.1	3.8	92.5	0.170	No
		b	38.0					
		c	45.5					
Salt Control	n/a	a	36.4	37.4	6.0	82.4	0.067	No
		b	32.1					
		c	43.9					
Copper Ref. Tox.	1.5	a	50.3	53.3	2.6	117.3	0.025	Yes[c]
		b	55.1					
		c	54.5					
	3.0	a	47.1	49.2	2.1	108.2	0.117	No
		b	49.2					
		c	51.3					
	6.0	a	20.3	19.8	1.9	43.5	0.001	Yes
		b	21.4					
		c	17.6					
	9.0	a	1.1	1.2	0.3	2.7	0.001	Yes
		b	1.6					
		c	1.1					
	12.0	a	0.0	0.0	0.0	0.0	0.001	Yes
		b	0.0					
		c	0.0					

REFERENCE TOXICANT RESULTS- QA/QC

COPPER REFERENCE TOXICANT TEST

SPECIES	NOEC (µg/l)	LOEC (µg/l)	EC50 (µg/l)	95% C.L. (µg/l)
TOPSMELT	100.0	200.0	248.4	184.7-333.9
MYSIDS	200.0	400.0	336.4	294.1-384.7
MUSSELS	3.0	6.0	5.7	5.4-5.9

[a]Controls (QA/QC) correspond to all samples from SDB1

[b]Student's t-test with a one tailed distribution and two sample unequal variance

[c] p-value is significant because treatment had a significantly greater proportion normal compared to the control

n/a - t-test not used since control and treatment have same percentage survival

[1]Controls were the Bay water samples taken prior to storm (PRE) with comparable sample ID

[2]Controls were Scripps filtered seawater

WATER QUALITY

TOPSMELT (*A. affinis*)

Sample ID	Effluent Concentration (% or µg/l Cu)	pH (SU)					Dissolved Oxygen (mg/l)					Temperature (°C)					Salinity (‰)				
		0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96
NAV-OF9-SDB1-COMP	12.5%	ND	7.8	7.8	7.8	7.8	ND	6.4	6.1	7.2	6.2	ND	19.5	19.9	18.9	19.2	ND	33.0	ND	34.0	ND
	50%	ND	7.9	7.8	7.8	7.8	ND	6.0	6.0	6.9	6.2	ND	20.2	19.9	19.3	19.4	ND	32.0	33.0	34.0	ND
NAV-OF11-SDB1-COMP	6.25%	ND	7.9	7.8	7.8	7.8	ND	6.4	6.2	6.9	6.3	ND	19.9	19.5	19.0	19.3	ND	ND	ND	34.0	ND
	12.5%	ND	7.9	7.8	7.8	7.8	ND	6.2	6.0	7.1	6.2	ND	19.9	19.3	19.1	19.1	ND	ND	ND	33.0	ND
	25%	ND	7.9	7.8	7.8	7.8	ND	6.3	6.0	6.9	6.2	ND	20.0	19.6	19.2	18.9	ND	ND	ND	34.0	ND
	50%	ND	7.9	7.8	7.8	7.8	ND	6.2	6.0	6.9	6.0	ND	20.0	19.5	19.1	19.0	ND	ND	ND	33.0	ND
	100%	ND	7.9	7.8	7.8	7.7	ND	5.6	5.7	6.7	6.0	ND	20.0	19.8	19.3	19.0	ND	32.0	32.0	32.0	ND
NAV-OF14-SDB1-COMP	6.25%	ND	7.9	7.8	7.8	7.8	ND	6.3	6.0	7.0	6.3	ND	20.1	19.4	19.0	19.2	ND	ND	ND	34.0	ND
	12.5%	ND	7.9	7.8	7.8	7.8	ND	6.2	5.9	6.9	6.1	ND	19.9	19.3	19.1	19.1	ND	ND	ND	34.0	ND
	25%	ND	7.9	7.8	7.8	7.7	ND	5.8	5.9	6.7	6.1	ND	20.2	19.3	19.0	19.2	ND	ND	ND	34.0	ND
	50%	ND	7.9	7.8	7.8	7.7	ND	6.0	6.0	6.5	6.0	ND	20.2	19.3	19.1	19.1	ND	ND	ND	34.0	ND
	100%	ND	7.9	7.8	7.8	7.7	ND	5.0	5.4	6.3	5.8	ND	20.2	19.3	19.3	19.3	ND	ND	32.0	34.0	ND
NAV-BAY9-SDB1-PRE	100%	7.9	7.9	7.9	7.8	7.8	7.3	6.5	6.9	6.9	6.3	19.9	19.4	18.3	19.0	19.3	35.0	ND	34.0	34.0	ND
NAV-BAY11-SDB1-PRE	100%	7.9	7.9	7.8	7.8	7.8	7.3	6.4	6.9	7.2	6.3	19.8	19.4	18.0	18.9	19.0	35.0	33.0	33.0	33.0	ND
NAV-BAY14-SDB1-PRE	100%	7.9	7.9	7.8	7.8	7.8	7.2	6.4	6.7	7.2	6.2	19.8	19.4	18.3	18.8	19.0	35.0	ND	ND	33.0	ND
NAV-BAY14A-SDB1-PRE	100%	7.9	7.9	7.8	7.8	7.8	7.3	6.4	7.0	7.1	6.0	19.8	19.4	18.1	18.9	19.3	35.0	ND	ND	34.0	ND
NAV-BAY9-SDB1-DUR	100%	7.9	7.8	7.9	7.8	7.8	7.2	6.4	6.8	7.2	6.4	20.0	19.4	18.8	18.7	18.9	32.0	ND	33.0	34.0	ND
NAV-BAY11-SDB1-DUR	100%	7.9	7.8	7.8	7.8	7.8	7.5	6.4	6.7	7.2	6.6	19.8	19.8	18.8	18.8	18.9	32.0	ND	ND	33.0	ND
NAV-BAY14-SDB1-DUR	100%	7.9	7.8	7.8	7.8	7.8	7.3	6.4	6.7	7.0	6.6	19.8	19.4	18.8	18.9	18.8	32.0	ND	ND	33.0	ND
NAV-BAY14A-SDB1-DUR	100%	7.9	7.8	7.8	7.8	7.8	7.3	6.5	6.7	7.3	6.6	19.8	19.3	18.8	18.8	18.9	32.0	ND	33.0	33.0	ND
NAV-BAY9-SDB1-AFT	100%	7.9	7.8	7.8	7.8	7.8	7.3	6.4	6.6	7.1	6.2	19.9	19.9	18.4	19.0	19.3	35.0	ND	ND	33.0	ND
NAV-BAY11-SDB1-AFT	100%	7.9	7.8	7.8	7.8	7.8	7.2	6.4	6.7	7.2	6.2	19.8	19.3	18.1	18.7	18.8	35.0	ND	33.0	33.0	ND
NAV-BAY14-SDB1-AFT	100%	7.9	7.8	7.8	7.8	7.8	7.2	6.4	6.7	7.3	6.4	19.8	19.4	18.3	18.8	18.8	35.0	ND	32.0	33.0	ND
NAV-BAY14A-SDB1-AFT	100%	7.9	7.8	7.8	7.8	7.8	7.2	6.4	6.7	7.2	6.2	20.2	19.4	18.3	18.8	18.8	35.0	ND	32.0	32.0	ND
Natural Seawater Control	100%	ND	ND	7.8	7.8	7.8	ND	ND	7.0	7.1	6.3	ND	ND	19.8	19.2	19.3	ND	ND	ND	33.0	ND
Salt Control	100%	ND	7.9	7.9	7.8	7.8	ND	5.8	6.7	6.8	6.3	ND	19.9	18.6	19.1	19.3	ND	32.0	33.0	33.0	ND

MYSIDS (*A. bahia*)

Sample ID	Effluent Concentration (% or µg/l Cu)	pH (SU)					Dissolved Oxygen (mg/l)					Temperature (°C)					Salinity (‰)				
		0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96
NAV-OF9-SDB1-COMP	12.5%	ND	ND	7.8	7.7	7.7	ND	ND	5.5	6.4	5.7	ND	ND	19.8	19.6	19.6	ND	ND	ND	33.0	33.0
	50%	ND	ND	7.7	7.5	7.5	ND	ND	5.3	4.7	4.8	ND	ND	19.9	19.6	19.7	ND	ND	33.0	34.0	ND
NAV-OF11-SDB1-COMP	6.25%	ND	ND	7.7	7.7	7.7	ND	ND	5.7	6.0	5.6	ND	ND	19.5	19.8	19.8	ND	ND	ND	33.0	33.0
	12.5%	ND	ND	7.7	7.6	7.7	ND	ND	5.5	5.4	5.7	ND	ND	19.5	19.7	19.6	ND	ND	ND	33.0	33.0
	25%	ND	ND	7.7	7.7	7.7	ND	ND	5.7	5.9	5.5	ND	ND	19.6	19.8	19.7	ND	ND	ND	33.0	33.0
	50%	ND	ND	7.7	7.7	7.7	ND	ND	5.7	5.8	5.4	ND	ND	19.6	19.9	19.8	ND	ND	ND	32.0	33.0
	100%	ND	ND	7.7	7.7	7.7	ND	ND	4.8	5.8	5.3	ND	ND	19.8	20.0	20.0	ND	ND	32.0	32.0	32.0
NAV-OF14-SDB1-COMP	6.25%	ND	ND	7.8	7.7	7.7	ND	ND	5.7	6.4	6.1	ND	ND	19.2	19.8	19.5	ND	ND	ND	34.0	ND
	12.5%	ND	ND	7.7	7.7	7.7	ND	ND	5.8	6.2	6.1	ND	ND	19.3	19.8	19.8	ND	ND	ND	34.0	ND
	25%	ND	ND	7.8	7.7	7.7	ND	ND	5.7	6.1	5.8	ND	ND	19.3	19.8	19.5	ND	ND	ND	34.0	ND
	50%	ND	ND	7.8	7.7	7.7	ND	ND	5.7	5.8	5.7	ND	ND	19.4	19.8	19.5	ND	ND	ND	33.0	34.0
	100%	ND	ND	7.7	7.7	7.7	ND	ND	4.8	5.2	5.2	ND	ND	19.7	19.9	19.6	ND	ND	33.0	34.0	34.0
NAV-BAY9-SDB1-PRE	100%	7.9	ND	7.8	7.5	7.4	7.3	ND	6.0	4.4	4.6	19.9	ND	19.3	20.0	19.6	35.0	ND	34.0	33.0	ND
NAV-BAY11-SDB1-PRE	100%	7.9	ND	7.6	7.7	7.6	7.3	ND	5.7	6.5	5.7	19.8	ND	19.1	19.9	19.5	35.0	ND	ND	34.0	ND
NAV-BAY14-SDB1-PRE	100%	7.9	ND	7.7	7.7	7.7	7.2	ND	5.8	6.5	5.9	19.8	ND	19.7	19.5	19.4	35.0	ND	ND	34.0	ND
NAV-BAY14A-SDB1-PRE	100%	7.9	ND	7.7	7.7	7.7	7.3	ND	6.1	6.6	6.0	19.8	ND	19.2	19.6	19.4	35.0	ND	ND	34.0	ND
NAV-BAY9-SDB1-DUR	100%	7.9	ND	7.7	7.7	7.7	7.2	ND	5.9	6.4	6.0	20.0	ND	21.1	19.4	19.3	35.0	ND	33.0	34.0	ND
NAV-BAY11-SDB1-DUR	100%	7.9	ND	7.7	7.7	7.7	7.5	ND	5.6	6.5	5.9	19.7	ND	19.9	19.4	19.5	35.0	ND	33.0	33.0	ND
NAV-BAY14-SDB1-DUR	100%	7.9	ND	7.6	7.7	7.7	7.3	ND	5.7	6.3	6.1	19.8	ND	19.7	19.3	19.5	35.0	ND	ND	33.0	33.0
NAV-BAY14A-SDB1-DUR	100%	7.9	ND	7.7	7.7	7.7	7.3	ND	5.8	6.6	5.9	19.8	ND	19.3	19.5	19.3	35.0	ND	ND	34.0	33.0
NAV-BAY9-SDB1-AFT	100%	7.9	ND	7.7	7.7	7.7	7.3	ND	5.7	6.5	6.0	19.9	ND	19.3	19.4	19.4	35.0	ND	ND	33.0	33.0
NAV-BAY11-SDB1-AFT	100%	7.9	ND	7.6	7.7	7.7	7.2	ND	5.7	5.9	5.7	19.8	ND	19.8	19.6	19.5	35.0	ND	ND	33.0	34.0
NAV-BAY14-SDB1-AFT	100%	7.9	ND	7.8	7.5	7.5	7.2	ND	6.0	4.4	4.8	19.8	ND	19.5	19.6	19.6	35.0	ND	ND	33.0	33.0
NAV-BAY14A-SDB1-AFT	100%	7.9	ND	7.7	7.6	7.6	7.2	ND	6.0	4.9	5.1	20.2	ND	19.3	19.6	19.6	35.0	ND	ND	33.0	33.0
Natural Seawater Control	100%	ND	ND	7.8	7.7	7.7	ND	ND	6.4	6.4	6.0	ND	ND	19.8	20.0	19.9	ND	ND	ND	32.0	33.0
Salt Control	100%	ND	ND	7.9	7.8	7.8	ND	ND	6.0	5.9	5.9	ND	ND	19.3	19.9	19.9	ND	ND	33.0	33.0	33.0

ND - water quality not recorded

SDB2 – 02/24/2003

OUTFALLS

TOPSMELT (*A. affinis*)

SAMPLE ID	CONC (%)	REP	SURVIVAL (#)	SURVIVAL (%)	MEAN SURVIVAL (%)	STD DEV	% of CONTROL[1,3]	P-VALUE[b]	SIG DIFF FROM CONTROL?
NAV-PR5-SDB2-FF	10	a	5	100.0	90.0	20.0	94.7	0.338	No
		b	3	60.0					
		c	5	100.0					
		d	5	100.0					
	50	a	3	60.0	65.0	10.0	68.4	0.003	Yes
		b	3	60.0					
		c	4	80.0					
		d	3	60.0					
	100	a	0	0.0	0.0	0.0	0.0	0.000	Yes
		b	0	0.0					
		c	0	0.0					
		d	0	0.0					
NAV-PR5-SDB2-COMP	10	a	3	60.0	85.0	19.1	89.5	0.201	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	50	a	5	100.0	90.0	11.5	94.7	0.269	No
		b	4	80.0					
		c	4	80.0					
		d	5	100.0					
	100	a	5	100.0	95.0	10.0	100.0	0.500	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					
NAV-PR6-SDB2-FF	10	a	4	80.0	90.0	11.5	94.7	0.269	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					
	50	a	3	60.0	80.0	23.1	84.2	0.149	No
		b	3	60.0					
		c	5	100.0					
		d	5	100.0					
	100	a	2	40.0	60.0	28.3	63.2	0.042	Yes
		b	3	60.0					
		c	2	40.0					
		d	5	100.0					
NAV-PR6-SDB2-COMP	10	a	5	100.0	95.0	10.0	100.0	0.500	No
		b	4	80.0					
		c	5	100.0					
		d	5	100.0					
	50	a	5	100.0	95.0	10.0	100.0	0.500	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	100	a	3	60.0	75.0	19.1	78.9	0.065	No
		b	4	80.0					
		c	3	60.0					
		d	5	100.0					
NAV-OF9-SDB2-FF	10	a	4	80.0	90.0	11.5	90.0	0.091	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	50	a	5	100.0	95.0	10.0	95.0	0.196	No
		b	5	100.0					
		c	4	80.0					
		d	5	100.0					
	100	a	3	60.0	85.0	19.1	85.0	0.108	No
		b	5	100.0					
		c	5	100.0					
		d	4	80.0					