WASHINGTON STATE DEPARTMENT OF ECOLOGY

Stormwater Quality Survey of Western Washington Log Yards

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Stormwater Quality Survey of Western Washington Log Yards

by
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Abstract

Stormwater discharged from six log yard facilities in western Washington was sampled by the Washington State Department of Ecology during December 2003 to March 2004. The samples were analyzed for a suite of general chemistry parameters, metals, TPH, and PAH as well as toxicity from *Daphnia pulex* acute bioassays. Results were found to vary considerably.

Sampling events were limited in number because of only a few days with qualifying conditions of rainfall 0.1 inches or greater per day, following at least 24 hours of no significant precipitation. An analysis of historic rainfall patterns showed that, although the 2003-2004 sampling season had lower than average rainfall, the number of qualifying days for sampling would not be considerably greater during other, more typical years.

Sampling was conducted to evaluate typical concentrations of pollutants and differences between sites. The presence of stormwater retention ponds was associated with relatively low concentrations of pollutants and toxicity. Even sites with small retention capacity showed lower pollutant concentrations during the first hour of collection than in subsequent samples.

Acknowledgements

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- The operators of the six log yard facilities included in this study for their cooperation and assistance.
- Staff from the Department of Ecology's Environmental Assessment Program:
  - Dale Norton for reviewing the project plan and final report.
  - Art Johnson for reviewing the final report.
  - Joan LeTourneau for formatting and editing the final report.

Introduction

Effective April 2003, under the Industrial Stormwater General Permit (ISGP), permittees were required for the first time to report self-monitoring data. Self-monitoring is to take place four times per year, once per quarter. Permit coverage is required for industrial facilities that have specific Standard Industrial Classification (SIC) codes if they have a discharge of stormwater from their industrial areas to a receiving water of the state or to storm drains that discharge to a receiving water.

Self-monitoring parameters for all industrial facilities include turbidity, pH, zinc, and oil & grease. Log yards are required, in addition, to monitor BOD_5. Other parameters, depending on the industrial group, include ammonia, phosphorus, copper, lead, and hardness. Facilities discharging to 303(d) listed waters are required to monitor for the 303(d) listed parameters. Landfills also are required to sample for specific additional parameters.

Other than the limited set of parameters required to be monitored by the ISGP, little data are available to characterize the quality of stormwater discharged from western Washington log yards. One requirement of self-monitoring is that stormwater discharge samples be collected during the first hour of discharge. However, information has not been available to characterize stormwater discharge quality as a function of time.

The purpose of this study is to characterize the concentrations of various pollutants in log yard stormwater discharges and to evaluate the current data collection requirements of the ISGP. The data developed through this study serve to evaluate self-reported parameters as well as the timing of sampling. This study, conducted by the Washington State Department of Ecology (Ecology) during the 2003-2004 wet season, provides information on a broad range of constituents in stormwater from western Washington log yards.

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Methods

Study Design

Six permitted facilities with log yards were selected for a thorough evaluation of their stormwater discharge quality. Logistical limitations and resources required that this study include only the western portion of the state and be limited to six facility sites within 100 roadway miles of Olympia. To provide anonymity for the log yards, site locations are not disclosed in this report. Two sites were located in Cowlitz County, two in Grays Harbor County, and one each in Thurston and Pierce counties. One site was unique for its treatment of stormwater in settling ponds, another for being unpaved.

The site selection criteria and methods are consistent with the quality assurance project plan (Golding, 2003). Analytes included those considered to be of potential concern for industrial stormwater discharges. Sampling took place during the winter wet season, defined for this project as being between November 1 and April 30.

In order to assess the variability of pollutant concentrations between storm events, the project plan called for three storm events to be monitored at each facility. Because of the low number of qualifying storm events during the study period, only one storm event per facility was sampled.

Individual samples were collected at two intervals during each storm event, at 20 minutes and 60 minutes from the onset of discharge, or at a single time when sampling did not coincide with the onset of discharge. In some cases, sampling did not occur during the first hour of discharge, and sampling took place at one time only. One facility was sampled on the third consecutive day of rain for comparison purposes.

Sample Collection

The Ecology project manager identified the major discharge from each facility to be sampled as defined by the ISGP. In cases where there was more than one discharge, the discharge with maximum exposure to ground disturbance or equipment operations or the discharge believed to have the highest potential concentration of pollutants was selected. To the extent possible, sampling locations were selected at a distinct discharge point where the flow was rapid and well-mixed.

All samples were collected as individual grabs consistent with the requirements of the ISGP:

- Each storm event must be preceded by at least 24 hours of no measurable precipitation.
- Each storm event must be an intensity of at least 0.1 inches of rain in a 24-hour period.
- The discharge sampled must capture stormwater with the greatest exposure to significant sources of pollution. The discharge point believed to have the highest concentration of pollutants will be sampled.

- All grab samples must be taken within the first hour after discharge begins.
- All samples must be taken as close to the point of discharge as reasonably practical and can be achieved safely as required by the ISGP and described in *How to Do Stormwater Sampling: A guide for industrial facilities* (Ecology, 2002).

The requirement that samples be collected after at least 24 hours of no measurable precipitation limited the days during which samples could be collected, particularly since the winter weather pattern of western Washington is typically of storm events that overlap, causing long periods of precipitation for days or even weeks at a time. The requirement that samples be collected during the first hour of discharge presented logistical challenges.

Samples were collected directly into sample containers or with the container attached to a pole. Sampling containers were held with container openings facing upstream to prevent contamination during sampling. Field personnel wore powder-free nitrile disposable gloves. Each sample was given a field ID, tagged, and kept cool at 4ºC. Chain-of-custody procedures were observed, and samples were delivered to the laboratory within the allowable holding times for each parameter.

A summary of parameters, collection containers, preservation, and holding times appears in Table 1.

Table 1. Sample Size, Container, Preservation, and Holding Time by Parameter.

Parameter	Sample Size	Container	Preservation	Holding Time
Total suspended solids	1000 mL	1000 w/m poly	cool to 4ºC	7 days
Hardness	100 mL	125 mL n/m poly	cool to 4ºC, H_2SO_4 to pH<2	6 months
Turbidity	500 mL	500 mL w/m poly	cool to 4ºC	48 hours
BOD_5	2000 mL	1 gallon cubitainer	cool to 4ºC	48 hours
NH_3	125 mL	125 mL clear w/m poly	cool to 4ºC, H_2SO_4 to pH<2	28 days
NO_2–NO_3	(2 bottles) 125 mL each	125 mL amber *and* clear w/m poly	cool to 4ºC, H_2SO_4 to pH<2	48 hours
Total phosphorus	125 mL	125 mL clear w/m poly	cool to 4ºC, H_2SO_4 to pH<2	28 days
Oil & grease	500 mL (dirty or turbid) to 750 mL (clean)	1 L glass jar (narrow mouth)	cool to 4ºC, HCl to pH<2	28 days
Priority pollutant metals	500 mL	1 L HDPE	HNO_3 to pH<2	6 months
TPH-DX	1000 mL to 1 gallon	1000 mL to 1 gallon glass jar	cool to 4ºC, HCl to pH<2	7 days
TPH-GX	40 mL	40 mL vial with septum	cool to 4ºC	14 days
PAH	1 gallon	1 gallon organics-free glass jar	cool to 4ºC	7 days
Daphnia acute bioassay	1 gallon	1 gallon organics-free glass jar	cool to 4ºC	36 hours

All six log yards were sampled during the beginning of a rain event following at least one day of no significant rainfall. One of the six sites was sampled again during the third day of a rain event, for comparison purposes. Three of the sites were sampled at 20 minutes and 60 minutes from the onset of runoff discharge. The other three were sampled a single time during the early portion of a rain event, but when discharge had already begun and the time of the onset of discharge had not been observed.

Times of sampling by site are shown in Appendix A. The original sample plan called for sampling up to three storm events at each of the six sites. However, the limited number of qualifying storm events during this study, as well as the difficulty in predicting storm events, made it infeasible to sample all six locations during more than one qualifying event.

Analytical Methods

Analytical methods are shown in Table 2.

Table 2. Analytical Methods.

Analyte	Sample Preparation Method	Analytical Method	Method Reporting Limit
Total suspended solids	--	Std Methods 2540	1 mg/L
Hardness	--	Std Methods 2340B	1 mg/L
Turbidity	--	Std Methods 2130	0.5 NTU
BOD_5	--	EPA 405.1 or Std Methods 5210B	1 mg/L
NH_3	--	EPA 350.1	0.01 mg/L
$NO_2 – NO_3$	--	EPA 353.2	0.01 mg/L
Total phosphorus	--	EPA 365.3	0.01 mg/L
Oil & grease	--	EPA 1664 Rev. A	5 mg/L
Priority pollutant metals	Digested with mixture of nitric acid and hydrochloric acid	EPA 200 series	0.1 ug/L except Cr:0.5 Hg:0.05 Se:0.4 Zn:1
TPH-DX	--	Analytical Methods for Petroleum Hydrocarbons (Ecology, 1997)	0.1 mg/L
TPH-GX	--		0.12 mg/L
PAH	--	SW846, Method 3500, modified, 8310	1-5 ug/L
Daphnia acute bioassay	--	EPA 2021.0 and 2002.0	NA

Data Quality

Laboratory duplicates and field replicates allow for a determination of analytical and sampling error. Appendix B shows the results of duplicates and replicates.

Most results met data quality objectives for this project. Laboratory duplicates for general chemistry parameters had relative percent differences (RPDs) at or below 10.5%. Field replicates for general chemistry parameters had RPDs at or below 16.2%. The bioassay field replicate had an RPD of 30%. Metals had field replicates of 14.5% or below, with the exception of thallium. Bioassays met performance standards. The laboratory duplicate and field replicate results are acceptable for a survey level study such as this one.

PAH compounds and thallium did not meet data quality objectives. PAH compounds, with RPDs of 54% or below, failed to meet the quality objective for PAH compounds of 40% accuracy, but the absolute differences were small, as these compounds were found in concentrations 0.052 µg/L or below. Thallium, with an RPD of 46%, did not meet the quality objective of 25% accuracy. The thallium RPD is acceptable because all thallium results were below 0.2 µg/L near reporting limits.

All reporting limits were adequate, above benchmark levels set in the ISGP.

Results

Results of analyses of stormwater from the log yards participating in the study are shown in Appendix A. Median and minimum/maximum results for general chemistry and metals parameters are shown in Appendix C.

Results varied widely:

- Total suspended solids (TSS): 8 – 2,310 mg/L
- Turbidity: 18 – 1,800 NTU
- 5-day biochemical oxygen demand (BOD_5): 16 (est.) – 630 mg/L
- Oil and grease (O&G): nondetect (at 7mg/L est.) – 15 mg/L

Metals results also varied widely, typically by an order of magnitude.

TSS, turbidity, BOD_5, and O&G are parameters that provide an indication of the strength of a wastewater. The median results – 392 mg/L TSS; 790 NTU turbidity, 128 mg/L $BOD_{5,}$ and 9.5 mg/L O&G – are indicative of a high-strength wastewater discharge. O&G levels reached the benchmark of 15 mg/L at two of the ten sites sampled.

Benchmarks, as specified in the ISGP, indicate maximum pollutant levels not likely to cause exceedances of water quality standards. Water quality standards apply to receiving waters, not discharges themselves. If a permittee's sample results are consistently below benchmark levels, the extent of required sampling is reduced. Benchmark levels and results from this study are shown in Table 3.

Table 3. Benchmark Levels and Study Results for the Timber Products Industry.

Parameter	Benchmark Value	Range of Results
Turbidity	25 NTU	18 – 1800 NTU
pH	6-9 SU	4.5 – 5.7 SU
Petroleum – Oil & Grease	15 mg/L	<7 – 15 mg/L
Total Zinc	117 µg/L	25.9 – 537 µg/L
Total Copper	63.6 µg/L	12.6 – 132 µg/L
Total Lead	81.6 µg/L	0.52 – 27.1 µg/L
BOD_5	30 mg/L	16 est. – 630 mg/L

The pH of the discharges was determined with pH paper, and, at two sites, with a pH meter. The oily nature of the discharges made pH meter operation difficult, with the glass probe often becoming clogged. All but one of the sites showed a pH paper measurement of 5.5 standard units (SUs), the sixth site showing 4.5. Two of the sites sampled showing 5.5 SU on pH paper had pH paper determinations verified with meter readings of 5.47 and 5.72 SU. All pH results were outside of the benchmark range of 6 – 9 SU.

The benchmark value of 25 NTU for turbidity was exceeded by all samples but those from Site 3, the site for which there were settling ponds prior to discharge. The benchmark pH range of 6 – 9 SU was not met by any of the samples. The total zinc benchmark of 117 µg/L was exceeded at all but Site 3. The Petroleum-O&G benchmark of 15 mg/L was met at all sites with the exception of the Site 4 sample taken at 20 minutes from the onset of discharge. The timber products industry BOD_5 benchmark of 30 mg/L was exceeded at all sites except Site 3, the site with settling ponds.

All priority pollutant metals were detected in some of the samples.

- Arsenic, chromium, copper, nickel, lead, and zinc were detected in all samples.
- Zinc (total recoverable) was found in the highest concentrations, with a median concentration of 244 µg/L and a maximum value of 537µg/L.
- Copper was found in the next highest concentration, with a median concentration of 36.5 µg/L and a maximum value of 132 µg/L.
- Zinc in the stormwater discharges exceeded the benchmark of 117 µg/L in six of the ten samples and water quality standards in eight of the ten samples.
- Copper exceeded the benchmark of 63.6 µg/L in one of the ten samples and standards in all ten samples.
- Lead in all samples was within the benchmark of 81.6 µg/L.

TPH-Gx (gasoline) was not detected in any of the samples. TPH-Dx (lube oil) was detected in all samples over a wide range of concentrations (3.7 – 11,000 mg/L), with a median concentration of 15 mg/L.

Most of the PAH compounds sampled were not detected. Naphthalene, phenanthrene, fluoranthene, and pyrene were found in all samples. Fluoranthene was found in the highest concentration, with 0.28 µg/L found at Site 1.

Daphnia pulex acute bioassays found toxicity in all but two samples. Four of the five samples showing toxicity did so only at 100% concentration. The fifth sample showed toxicity at 6.25% concentration and all higher concentrations. That sample, from Site 2, was collected downstream of a poorly functioning oil/water separator.

Discussion

Characteristics of the log yards included in the study are summarized and compared with parameters indicating strength in Table 4.

Table 4. Site Characteristics and Indications of Relative Stormwater Strength.

Site #	Site Characteristics	Sample Time	Est. Flow (cfs)	TSS (mg/L)	Turbidity (NTU)	BOD_5 (mg/L)	O&G (mg/L)
1	100% paved	single sample	3	308	230	104	15
2	100% paved	single sample	trickle	520	1800	630	12
3	75% paved	20 minutes	0.01	8	20	17J	8UJ
	treatment ponds	60 minutes		10	18	16J	8UJ
4	75% paved	20 minutes	0.007	104	260	135	15J
		60 minutes	0.1	306	550	175	8J
	third day of rain	single sample	0.8	755	1400	388	11
5	unpaved	single sample	trickle	2310	1030	34	14
6	100% paved	20 minutes	0.07	475	1200	129	8UJ
		60 minutes		496	1100	121	7UJ

The unpaved log yard (Site 5) had higher TSS than the other yards. This site exceeded the next highest by a factor of 3. This reflects the impact on stormwater runoff of log sorting machines operating in deep mud. However, general chemistry and metals parameters for the unpaved site were typical of those for the other sites
(Appendix A).

Site 3 was the only log yard with treatment ponds. Samples from the site had the lowest concentrations of TSS, BOD_5, ammonia (NH_3), and metals, with more nondetected metals than other runoff. The final treatment pond's discharge also had lower levels of PAH, with only three compounds detected, as well as nondetected TPH-DX. It was also the only site with 100% survival at all concentrations for *Daphnia pulex*, though the unpaved Site 5 also showed virtually no toxicity.

TSS levels from the final treatment pond at Site 3 were a factor of 10 lower than at other sites. This suggests the treatment ponds were effective in reducing suspended solids and associated pollutants. However, the pond was sampled only during the first hour of a relatively light rainfall, when discharge was low and the water was likely to have been resident in the ponds for a number of days. Conclusions concerning the effectiveness of treatment ponds would require additional data, including from times of relatively high discharge rates.

Site 2 samples were collected downstream of an oil/water separator. The discharge appeared to be dark and oily, indicating that the oil/water separator was not functioning properly. General chemistry and metals parameters were higher than the median results from all sites. Equivalent or higher oil & grease concentrations were found at two other sites, confirming the poor operation of the oil/water separator. The acute *Daphnia pulex* bioassay found the most toxicity at this log yard.

Discharge from Site 4 took place only after water had pooled in a curbed area approximately 100 feet by 25 feet. The site provided an opportunity to study the application of the criterion that sampling take place during the first hour of discharge, for conditions where there is a small amount of storage capacity and a short detention time before discharge.

On the first day of sampling, discharge began three hours from the beginning of rainfall. Samples taken 20 minutes and 60 minutes from the onset of discharge, as well as during the third day of a storm event, showed that pollutant concentrations increased over time and were highest, not during the first hour of discharge, but on the third day of rainfall. The general permit requirement that samples be taken during the first hour of discharge results, in this case where there is some storage capacity and an opportunity for solids to settle, in higher pollutant concentrations after the first hour of discharge. Samples taken during the first hour under-represented pollutant concentrations from Site 4.

Comparisons with Other Data

Results from this study can be compared with those from an Ecology study of runoff from 12 log sort yards on the Tacoma tide flats (Norton and Johnson, 1985). Samples were collected one day per month during a six-month period. Results from that study and the current study are summarized in Table 5.

Table 5. Summary of Results, 1985 Log Sort Yards Study.

	TSS (mg/L)	Arsenic (µg/L)	Zinc (µg/L)	Copper (µg/L)	Lead (µg/L)	Nickel (µg/L)	Antimony (µg/L)	Cadmium (µg/L)
1985 Study								
Maximum	3,000	12,000	5,340	4,000	2,470	325	380	16
Minimum	11	32	170	84	9	6	<1	<0.2
Mean	719	2,784	1,430	702	425	73	67	2.2
Median	265	2,165	1,135	252	234	60	64	1.7
Current Study								
Maximum	2,300	8.94	537	132	27.1	44.7	1.6	1.49
Minimum	8	0.80	25.9	12.6	0.52	2.62	<0.20	<0.10
Mean	529	4.77	225	45.1	10.9	18.3	0.78	0.44
Median	392	5.25	244	36.5	9.0	16.6	0.77	0.36

All median metals concentrations from the 1985 study were higher than those of the current study. The high metals levels seen in 1985 reflect contamination of soil materials with metal-laden slag from the Asarco smelter in Tacoma. The slag had been used as ballast on the yard surface. The current study includes a log yard on the Tacoma tide flats (Site 1). Cleanup and concrete paving at that site have brought metals concentrations in the runoff down to levels comparable to others in the study. Metals concentrations in runoff found during the current study are similar to the minimum concentrations found in the 1985 study, the median concentrations being a full two orders of magnitude less than those of the 1985 study.

Table 6 shows comparisons of data from the current study with pollutant concentrations from construction and highway runoff data (Kayhanian et al., 2001). These data were collected across California.

Table 6. Comparisons of Current Data with Construction and Highway Runoff.

	Turbidity (NTU)	TSS (mg/L)	Oil & Grease (mg/L)	Copper, Total (µg/L)	Lead, Total (µg/L)	Zinc, Total (µg/L)	Hardness (mg/L)
Current study min.	18	8	<7	12.6	0.52	25.9	24.0
Current study max.	1,800	2,300	15	132	27.1	537	226
Current study mean	761	529	9.0	45.1	10.9	225	75.6
Construction min.	15	12	0.5	3.8	1.0	6.9	13.0
Construction max.	16,000	3,850	22.7	128	291	609	1,680
Construction mean	702	499	2.7	32	44.4	141	114.5
Highway min.	9.9	4	1.0	2.1	1.1	11.0	3.30
Highway max.	140	4,800	226	770	1,530	2,400	365
Highway mean	59	161	14.4	50.2	120.8	232	59.3

The turbidity found in log yard runoff was higher than highway turbidity and similar to that from construction sites, though with a lower maximum. Oil & grease concentrations were similar to those associated with construction but lower than the maximum value for highways. Copper concentrations were similar. Lead concentrations were lower than those associated with construction and highways. Zinc concentrations were similar to those of construction sites but lower than those found at highways.

Occurrence of Qualifying Storm Events

Far fewer than the 18 qualifying events planned for sampling were successfully captured because fewer such events than anticipated occurred during the sampling season. The winter of 2003-2004 was a period of lesser amounts of rainfall than typical. The historical rainfall was analyzed to determine whether this was responsible for the few opportunities to sample or whether relatively few qualifying events occur during any typical sampling season.

"Qualifying events" for this analysis were considered to be those on weekdays (since the permit requires sampling only on workdays) for which 0.1 inches of rainfall fell following at least one day of 0.01 inches of precipitation or less.

Weather data for Olympia from 1999-2004 and for Tacoma from 1996-2004 were evaluated and the results summarized in Figure 1. Rainfall trends by month are seen to be similar between Olympia and Tacoma.

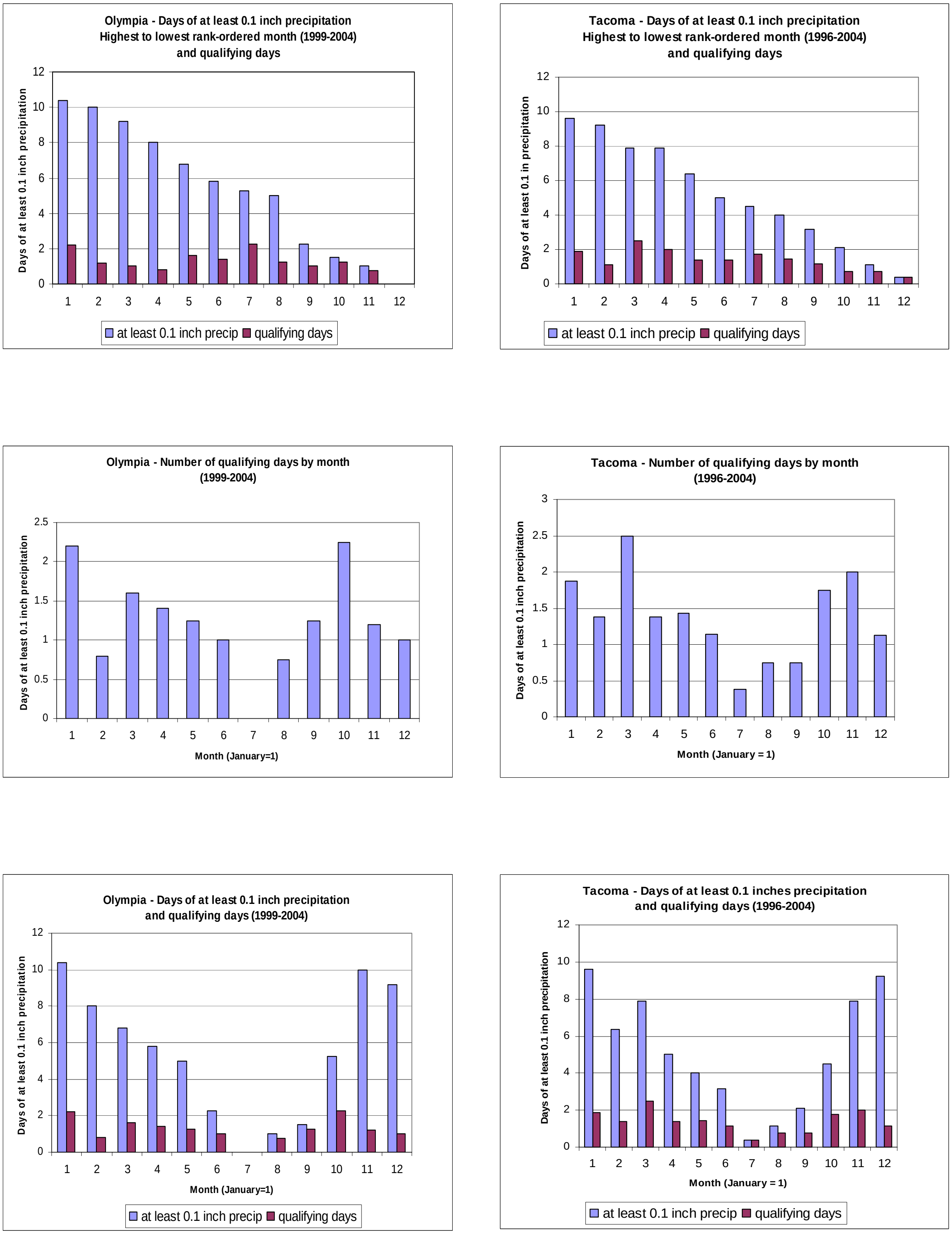

Figure 1. Monthly Precipitation Trends for the Olympia Airport and the Tacoma McChord Air Force Base.

For Olympia, there were seven qualifying sampling days during the 2003-2004 November to April sampling season. This compares with a mean of eight qualifying sampling days during the historic November to April sampling season. For Tacoma the qualifying days for 2003-2004 were seven compared with ten historically.

The topmost two charts in Figure 1 show that although days of at least 0.1 inch precipitation vary considerably by month of the year, the number of qualifying days (days following a day of no significant precipitation, taken to be less than or equal to 0.01 inches of rainfall) is fairly constant. Months of high rainfall did not have more qualifying days than months of low rainfall because few rainy days during wet months are preceded by dry days. The middle two charts of Figure 1 show that, other than July, all months of the year have between 0.5 and 2.5 qualifying days for sampling, typically, for Olympia and Tacoma.

The bottom two charts of Figure 1 make it clear that although the rainy season has considerably more rainy days than does the dry season, qualifying days for sampling are fairly constant throughout the year. Those two charts also show that relaxing the requirement that days of sampling be preceded by 24 hours of no significant precipitation increases considerably the number of qualifying days. For example, qualifying days without that requirement, shown in gray, increase from an average of two days in January to ten. During a drier month, such as June, two or three days become qualifying rather than one or two. This is particularly important for permittees who have reported having difficulty finding qualifying days during the dry season.

Historical data show all months having only 2.5 or fewer qualifying days. Thus, in planning future Ecology studies of industrial stormwater discharge, it is not reasonable to anticipate sampling more than six qualifying events during a wet-weather sampling season.

This estimate of qualifying days appearing in Figure 1 may under-represent actual qualifying days because some days with less than 0.1 inches of rainfall qualify, as long as the intensity of rainfall is 0.1 inches per day or greater. On the other hand, imperfect weather forecasts make it impractical to expect to sample during each qualifying event.

Conclusions

Pollutant concentrations varied considerably among the six log yards sampled.

- The unpaved site had higher total suspended solids concentrations than the other sites, but not correspondingly high concentrations of other pollutants.
- The site with a poorly operating oil/water separator had elevated concentrations of general chemistry parameters and metals and showed the highest toxicity to *Daphnia pulex*.
- The site with the lowest pollutant concentrations had stormwater retention ponds.

The limited data set of this study suggests these as factors affecting stormwater discharge concentrations from log yards. Low flow rates were associated with somewhat higher concentrations of pollutants, but pollutant loading in terms of mass was considerably higher in the high flow-rate discharges. Intensity of precipitation is likely a factor in pollutant concentrations but was outside of the scope of this study.

The requirement of the Industrial Stormwater General Permit (ISGP) that self-monitoring take place during the first hour of discharge presents several problems. At most of the sites sampled, the discharge was not at a readily observable location, and it seems unlikely that personnel on site would monitor the sampling location carefully enough to determine the time of onset of discharge. Anecdotal evidence suggests that personnel were often, in fact, sampling when they found a discharge rather than taking steps to assure that samples were taken during the first hour of discharge.

The intent of the ISGP requirement that sampling take place during the first hour of discharge is to monitor worst-case conditions, presumably during the first flush of a storm, after at least 24 hours of no significant rainfall. This assumes that the first hour of discharge tends to be the highest in pollutant concentration. Evidently, this was not the case at one of the three sites in this study for which a time series was evaluated: Site 3, where retention ponds tend to discharge only a trickle of well-settled stormwater during the first hour of discharge. A more representative sample and one higher in pollutant concentrations could be expected after several days of rain, when flow rate is higher and less settling takes place.

It was also not the case that the first hour of discharge was the worst case for Site 4, for which there was a small capacity of storage before discharge from a curbed area. Samples taken 20 minutes, 60 minutes, and during the third day from the onset of discharge showed progressively higher concentrations of pollutants, with the highest concentrations occurring not during the first hour but, rather, during the third day of rainfall. The worst case was not the first hour of discharge, but subsequent to the first hour.

An analysis of historical rainfall shows that the number of qualifying days during the 2003-2004 sampling season was only slightly lower than typical. Typically, only about eight to ten days per wet-weather season quality as sampling days.

Recommendations

Sampling during the first hour of discharge does not necessarily represent the worst case of pollutant concentrations. Also there are indications that facility personnel do not systematically sample during the first hour of discharge. For these reasons, it is recommended that consideration be given to changing this requirement so that sampling days do not need to be preceded by a day of no significant precipitation. It may even be that sampling can be permitted at random times during discharge from storm events.

Allowing permittees to sample on days with preceding precipitation also has the advantage of giving permittees more opportunity to find qualifying days to sample, an important consideration particularly during the drier months. Also, consideration should be given to sampling more frequently than once per quarter, as this would provide a better representation of stormwater discharge quality.

An analysis of historical weather data suggests that, for future studies, it is reasonable to expect each sampling team to sample only during six qualifying storms per sampling season.

The current set of parameters required for self-monitoring are critical and should be continued. Turbidity, pH, zinc, lead, copper, and oil & grease were all close to or exceeded water quality standards or benchmarks in a high proportion of samples. In addition, TPH-DX should be considered as a self-monitoring parameter requirement, as results varied widely in this study, and extremely high concentrations can indicate problems with the operation of heavy equipment.

Bioassays, while indicating toxicity in many cases, may require expensive testing, which should be considered in deciding whether or not to include them with required self-monitoring.

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Appendices

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Appendix A. Analytical Results by Sampling Event and Parameter

Site Time from discharge onset Sampling date	Site 1 unknown 03/03/04	Site 2 unknown 02/24/04	Site 3 20 min 12/16/03	Site 3 60 min 12/16/03	Site 4 20 min 01/12/04	Site 4 60 min 01/12/04	Site 4 3rd rain day 03/25/04	Site 5 unknown 03/18/04	Site 6 20 min 12/10/03	Site 6 60 min 12/10/03
General Chemistry										
TSS (mg/L)	308	520	8	10	104	306	755	2310	475	496
Turbidity (NTU)	230	1800	20	18	260	550	1400	1030	1200	1100
BOD5 (mg/L)	104	630	17 J	16 J	135	175	>388	34	129	121
Oil and Grease (mg/L)	15	12	8 UJ	8 UJ	15 J	8 J	11	14.00	8 UJ	7 UJ
NH3 (mg/L)	--	--	0.017	0.018	--	--	0.36	--	0.218	0.236
NO2-NO3 (mg/L)	0.051	0.089	0.05 U	0.05 U	0.02 U	0.02 U	1.0 U	0.01	0.10 U	0.10 U
Phosphorus	0.737	2.53	0.161 J	0.157	1.10	1.57	2.20	1.01	--	--
pH (paper)	5.5	5.5	5.5		5.50	4.5		5.5	5.5	
pH (meter)			5.47		5.72					
Metals, Total Recoverable* *(mercury is total)										
Hardness (mg/L)	24.0	226	27.8	27.7	28	39.1	36.8	191	79.4	76.1
Mercury (total -ug/L)	0.050 U	0.11	0.050 U	0.050 U	0.050 U	0.076	0.12	0.050 U	0.11	0.11
Antimony (ug/L)	1.6	1.0	0.20 U	0.20 U	0.46	0.54	1.0	0.44 J	1.5 J	1.3
Beryllium (ug/L)	0.10 U	0.72	0.10 U	0.10 U	0.29	0.38	0.37	0.35	0.54	0.51
Silver (ug/L)	0.10 U	0.22	0.10 U	0.10 U	0.10 U	0.10 U	0.10 U	0.142	0.14	0.11
Arsenic (ug/L)	8.94	7.19	0.85	0.80	3.0	4.15	6.35	1.97	7.53	6.88
Cadmium (ug/L)	0.43	1.49	0.10 U	0.10 U	0.14	0.24	0.37	0.34	0.68	0.61
Chromium (ug/L)	5.66	34.5	1.2	1.2	7.09	13.2	27.2	17.1	21.9	17.1
Copper (ug/L)	16.66	88.7	12.8	12.6	13.6	25.1	47.9	132	55.2	46.1
Nickel (ug/L)	5.71	38.6	2.68	2.62	6.38	11.5	21.3	44.7	27.7	21.8
Lead (ug/L)	5.14	21.0	0.52	0.52	2.73	6.57	11.9	11.5	27.1	21.9
Selenium (ug/L)	0.40 U	1.20	0.50 U	0.50 U	0.40 U	0.40 U	0.40 U	0.57	0.50	0.55
Thallium (ug/L)	0.10 U	0.15	0.10 U	0.10 U	0.10 U	0.10 U	0.16	0.10 U	0.10	0.10 U
Zinc (ug/L)	395	537	25.9	25.7	85.4	154	279	262	263	225
TPH-Gx (gasoline, mg/L)	0.35 U	0.7 U	0.14 U	--	0.35 U	--	0.14 U	0.35 U	0.14 U	--
TPH-Dx (lube oil, mg/L)	15	11000	0.079 U	--	14	--	3.7	16	7.7	--

U - The analyte was not detected at or above the reported result.

UJ - The analyte was not detected at or above the reported estimated result.

J - The analyte was positively identified. The associated numerical result is an estimate.

REJ - The data are unusable for all purposes.

Appendix A (cont'd)

Site Time from discharge onset Sampling date	Site 1 unknown 03/03/04	Site 2 unknown 02/24/04	Site 3 20 min 12/16/03	Site 3 60 min 12/16/03	Site 4 20 min 01/12/04	Site 4 60 min 01/12/04	Site 4 3rd rain day 03/25/04	Site 5 unknown 03/18/04	Site 6 20 min 12/10/03	Site 6 60 min 12/10/03
Semivolatiles: PAH (ug/L)										
Naphthalene	0.07	0.01 J	0.01 J	--	REJ	--	0.01 J	0.01 J	0.036 J	--
2-Methylnaphthalene	0.06 J	0.01 J	0.07 U	--	REJ	--	0.012 J	0.02 J	0.035 J	--
1-Methylnaphthalene	0.04 J	0.01 J	0.07 U	--	REJ	--	0.008 J	0.02 J	0.029 J	--
2-Chloronaphthalene	0.06 U	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.063 U	--
Acenaphthylene	0.02 J	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.007 J	--
Acenaphthene	0.01 J	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.009 J	--
Dibenzofuran	0.06 U	0.01 J	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.019 J	--
Fluorene	0.10	0.03	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.027 J	--
Phenanthrene	0.22	0.04	0.02 J	--	REJ	--	0.052 J	0.09 J	0.12	--
Anthracene	0.06 U	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.007 J	--
Carbazole	0.06 U	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.006 J	--
Fluoranthene	0.28	0.08	0.23	--	REJ	--	0.20 J	0.22 J	0.041 J	--
Pyrene	0.2 J	0.02	0.02 NJ	--	REJ	--	0.047 J	0.08 J	0.049 J	--
Retene	0.49 J	0.06	0.14 U	--	REJ	--	0.13 J	0.24 J	0.13 U	--
Benzo(a)anthracene	0.06 U	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.063 U	--
Chrysene	0.11	0.02 J	0.07 U	--	REJ	--	0.03 J	0.08 J	0.025 J	--
Benzo(b)fluoranthene	0.12 U	0.04 U	0.14 U	--	REJ	--	0.13 UJ	0.13 UJ	0.064 J	--
Benzo(k)fluoranthene	0.12 U	0.04 U	0.14 U	--	REJ	--	0.13 UJ	0.13 UJ	0.13 U	--
Benzo(a)pyrene	0.06 U	0.02 U	0.07 U	--	REJ	--	0.06 UJ	0.06 UJ	0.063 U	--
Ideno(1,2,3-cd)pyrene	0.12 U	0.04 U	0.14 U	--	REJ	--	0.13 UJ	0.13 UJ	0.13 U	--
Dibenzo(a,h)anthracene	0.12 U	0.04 U	0.14 U	--	REJ	--	0.13 UJ	0.13 UJ	0.13 U	--
Benzo(ghi)perylene	0.12 U	0.04 U	0.14 U	--	REJ	--	0.13 UJ	0.13 UJ	0.13 U	--
Bioassay										
Daphnia pulex, acute series										
mean survival at 0%	100	95	95	--	90	--	100	100	100	--
mean survival at 6.25%	95	90	100	--	100	--	100	100	100	--
mean survival at 12.5%	85	**40**	95	--	100	--	100	100	100	--
mean survival at 25%	95	**50**	100	--	100	--	95	100	100	--
mean survival at 50%	100	**30**	100	--	100	--	**65**	100	100	--
mean survival at 100%	**70**	**10**	100	--	**10**	--	**0**	95	**55**	--

bold - bioassay results indicating toxicity to test organisms.

Appendix B. Precision Data

Parameter	Site	Lab Duplicates			
		Date	Sample 1	Sample 2	RPD
TSS	6 - 60 min	12/10/03	496 mg/L	470 mg/L	5.4%
TSS	3 - 60 min	12/16/03	10 mg/L	9 mg/L	10.5%
Turbidity	6 - 60 min	12/10/03	1100 NTU	1100 NTU	0%
Turbidity	3 - 20 min	12/16/03	20 NTU	20 NTU	0%
Turbidity	4 - 60 min	1/12/04	550 NTU	550 NTU	0%
BOD5	6 - 60 min	12/10/03	121 mg/L	120 mg/L	0.8%
BOD5	4 - 60 min	1/12/04	175 mg/L	176 mg/L	0.6%
BOD5	5	3/18/04	34 mg/L	33 mg/L	3.0%
Gasoline	4 - 20 min	1/12/04	0.35 U mg/L	0.35 U mg/L	--
Gasoline	1	3/3/04	0.35 U mg/L	0.35 U mg/L	--
Gasoline	5	3/18/04	0.35 U mg/L	0.35 U mg/L	--
Gasoline	2	2/24/04	0.70 U mg/L	0.70 U mg/L	--
Parameter	Site	Field Replicates			
		Date	Sample 1	Sample 2	RPD
TSS	4 (third day)	3/25/04	730 mg/L	780 mg/L	6.6%
Turbidity	4 (third day)	3/25/04	1400 NTU	1400 NTU	0%
BOD5	4 (third day)	3/25/04	388 G mg/L	386 G mg/L	0.5%
NO2-N03	4 (third day)	3/25/04	1.0 U mg/L	1.0 U mg/L	--
Phosphorus	4 (third day)	3/25/04	2.20 mg/L	2.16 mg/L	1.8%
NH3	4 (third day)	3/25/04	0.36 mg/L	0.31 mg/L	14.9%
Oil&Grease	4 (third day)	3/25/04	11 mg/L	12 mg/L	8.7%
Lube Oil	4 (third day)	3/25/04	3.4 mg/L	4.0 mg/L	16.2%
Bioassay	4 (third day)	3/25/04	LC50 70.7%	LC50 52.4%	30%
Hardness	4 (third day)	3/25/04	36.8 mg/L	35.2 mg/L	4.4%
Mercury	4 (third day)	3/25/04	0.12 µg/L	0.11 µg/L	8.7%
Selenium	4 (third day)	3/25/04	0.40 U µg/L	0.40 U µg/L	--
Zinc	4 (third day)	3/25/04	279 µg/L	277 µg/L	0.7%
Beryllium	4 (third day)	3/25/04	0.37 µg/L	0.32 µg/L	14.5%
Chromium	4 (third day)	3/25/04	27.2 µg/L	24.7 µg/L	9.6%
Nickel	4 (third day)	3/25/04	21.3 µg/L	20.8 µg/L	2.4%
Copper	4 (third day)	3/25/04	47.9 µg/L	47.4 µg/L	1.0%
Arsenic	4 (third day)	3/25/04	6.35 µg/L	6.24 µg/L	1.8%
Silver	4 (third day)	3/25/04	0.10 U µg/L	0.10 U µg/L	--
Cadmium	4 (third day)	3/25/04	0.37 µg/L	0.37 µg/L	0%
Antimony	4 (third day)	3/25/04	1.0 µg/L	1.0 µg/L	0%
Thallium	4 (third day)	3/25/04	0.16 µg/L	0.10 µg/L	46%
Lead	4 (third day)	3/25/04	11.9 µg/L	11.9 µg/L	0%
Naphthalene	4 (third day)	3/25/04	0.01 J µg/L	0.017 J µg/L	52%
2-Methylnaphthalene	4 (third day)	3/25/04	0.012 J µg/L	0.018 J µg/L	40%
1-Methylnapthalene	4 (third day)	3/25/04	0.008 J µg/L	0.014 J µg/L	54%
Phenanthrene	4 (third day)	3/25/04	0.052 J µg/L	0.077 J µg/L	39%
Fluoranthene	4 (third day)	3/25/04	0.20 J µg/L	0.21 J µg/L	4.9%
Pyrene	4 (third day)	3/25/04	0.047 J µg/L	0.06 J µg/L	24%
Retene	4 (third day)	3/25/04	0.13 J µg/L	0.16 J µg/L	21%
Chrysene	4 (third day)	3/25/04	0.03 J µg/L	0.04 J µg/L	29%

U - The analyte was not detected at or above the reported result.
J - The analyte was positively identified. The associated numerical result is an estimate.
G - Greater than, estimated at 400-500 mg/L.   RPD - relative percent difference.

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Appendix C. Ranges of Results by Parameter

Parameter	N	Minimum	Maximum	Median
General Chemistry				
*TSS (mg/L)	10	8	2310	392
Turbidity (NTU)	10	18	1800	790
*BOD5 (mg/L)	10	16 J	630	128
*Oil and Grease (mg/L)	10	7 UJ	15	9.5
NH3 (mg/L)	5	0.017	0.36	0.22
NO2-NO3 (mg/L)	10	0.01	0.089	0.051
Phosphorus	8	0.161 J	2.53	0.92
Metals**				
Hardness (mg/L)	10	24.0	226	38.0
Mercury (total -ug/L)	10	0.050 U	0.12	0.11
Antimony (ug/L)	10	0.20 U	1.6	0.77
Beryllium (ug/L)	10	0.10 U	0.72	0.36
Silver (ug/L)	10	0.10 U	0.22	0.11
Arsenic (ug/L)	10	0.80	8.94	5.25
Cadmium (ug/L)	10	0.10 U	1.49	0.36
Chromium (ug/L)	10	1.2	34.5	15.2
Copper (ug/L)	10	12.6	132	36.5
Nickel (ug/L)	10	2.62	44.7	16.6
Lead (ug/L)	10	0.52	27.1	9.0
Selenium (ug/L)	10	0.40 U	1.20	0.50
Thallium (ug/L)	10	0.10 U	0.16	0.10
*Zinc (ug/L)	10	25.9	537	244
TPH				
TPH-Gx (gasoline, mg/L)	7	<0.14	<0.7	<0.35
TPH-Dx (lube oil, mg/L)	7	3.7	11000	15
Semivolatiles: PAH (ug/L)				
Naphthalene	6	<0.01	0.07	<0.01
2-Methynaphthalene	6	0.01 J	0.06 J	0.026 J
1-Methylnaphtalene	6	<0.008 J	0.04 J	0.024 J
2-Choronaphthalene	6	<0.02	<0.07	<0.06 J
Acenaphthylene	6	<0.02	0.02 J	<0.07
Acenaphthene	6	0.009 J	0.01 J	0.009 J
Dibenzofuran	6	0.01 J	0.019 J	0.01 J
Fluorene	6	0.027 J	0.10	0.03
Phenanthrene	6	0.02 J	0.22	0.052 J
Anthracene	6	0.007 J	0.007 J	0.007 J
Carbazole	6	0.006 J	0.006 J	0.006 J
Fluoranthene	6	0.041 J	0.28	0.2 J
Pyrene	6	0.02	0.2 J	0.047 J
Retene	6	0.06	0.49 J	0.13 J
Benzo(a)anthracene	6	<0.02	<0.07	<0.06
Chrysene	6	<0.02	0.11	0.025
Benzo(b)fluoranthene	6	<0.04	<0.14	<0.12
Benzo(k)fluoranthene	6	<0.04	<0.14	<0.12
Benzo(a)pyrene	6	<0.02	<0.06	<0.06

Appendix C (cont'd)

Parameter	N	Minimum	Maximum	Median
Indeno(1,2,3-cd)pyrene	6	<0.04	<0.14	<0.12
Dibenzo(a,h)anthracene	6	<0.04	<0.14	<0.12
Benzo(ghi)perylene	6	<0.04	<0.14	<0.13
Bioassay				
Daphnia pulex acute series				
mean survival at 0%	7	90	100	100
mean survival at 6.25%	7	90	100	100
mean survival at 12.5%	7	40	100	100
mean survival at 25%	7	50	100	100
mean survival at 50%	7	30	100	100
mean survival at 100%	7	0	100	55

* - Required self-reporting parameter.
** - Total recoverable, except total mercury.
U - The analyte was not detected at or above the reported result.
J - The analyte was positively identified. The associated numerical result is an estimate.
UJ - The analyte was not detected at or above the reported estimated result.