WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Little Squalicum Creek Screening Level Assessment

April 2004

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DEPARTMENT OF
ECOLOGY

Little Squalicum Creek Screening Level Assessment

by
Nigel Blakley

Environmental Assessment Program
Olympia, Washington 98504-7710

April 2004

Waterbody No. WA-01-0050 (Bellingham Bay)

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Abstract

During September 2003, sediments and soils were collected from upper and lower segments of Little Squalicum Creek, a small stream in Bellingham, Washington. The samples were evaluated in accordance with applicable regulations for determining whether chemical contamination presents a threat to human health and the environment. All samples were analyzed for contamination, and sediment samples also were tested with a suite of bioassays to evaluate their toxicity to aquatic life. The study was conducted to assist the City of Bellingham in planning a comprehensive investigation of pollution in Little Squalicum Creek and the creek area prior to developing the site into a community park and trail corridor.

Both sediment and soil samples were analyzed for semivolatile organic compounds, including polycyclic aromatic hydrocarbons (PAHs) and pentachlorophenol. A nearby wood treatment facility reportedly has had spills into the creek of a wood preservative solution that contains these chemicals. Toxicity testing of the sediment samples was conducted using amphipod (10-day *Hyalella*), midge (20-day *Chironomus*), and Microtox® bioassays.

For sediment, both lines of evidence (chemical analysis and biological testing) provide substantiation for contamination at levels of concern in the two stream segments investigated. Almost every sediment sample was toxic in one or more bioassay tests and had chemical concentrations exceeding risk-based numerical values. There was also a general concordance between chemistry and biology: the most heavily contaminated sample failed all bioassay tests, while the least contaminated sample failed none. All but one of the sediment stations tested exceeded recommended freshwater Sediment Quality Standards or Cleanup Screening Level bioassay endpoints.

Chemical analysis of soil also provided substantiation for contamination at levels of concern in the two stream segments investigated. At both soil sampling locations, carcinogenic PAHs exceeded Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Method B Soil Cleanup Levels.

Acknowledgements

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- Karen Bergmann and other staff from the AMEC Earth & Environmental Northwest Bioassay Laboratory.
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Introduction

Background

Little Squalicum Creek is a short stream, approximately 1500 feet long, located in Bellingham that discharges to Bellingham Bay (Figure 1). Depth is generally less than one foot, with a channel width ranging from about three to six feet (Ecology and Environment, Inc., 2001). The creek is fed by stormwater outfalls, two springs, and several small seeps. During wetter seasons, flow is estimated at one to 10 cubic feet per second (cfs), but the creek bed may be exposed during drier seasons. The stream is not tidally influenced except during extreme high tides because it discharges through a beach culvert above high tide levels. It is uncertain, however, whether the creek had historically been naturally tidally influenced.

Over the last century, Little Squalicum Creek and the surrounding ravine have been subjected to considerable physical disturbance and episodes of pollution. The City of Bellingham is now proposing to develop this site into a community park and trail corridor. The City plans to divert the creek into a meandering path through the park and to remove a culvert that is blocking fish passage up the creek. However, before work begins on this project, the City plans to investigate the extent of pollution and evaluate potential cleanup alternatives with a grant from the U.S. Environmental Protection Agency's (EPA) Brownfields program. The City's environmental investigation and evaluation work would be conducted in accordance with the Model Toxic Control Act (Chapter 173-340 WAC), under a legal agreement with the Washington State Department of Ecology.

Past physical alteration of the creek has included a shortening of its length and reduction of its flow due to the diversion of the upper reach through a stormwater drain to nearby Squalicum Creek (Ecology and Environment, Inc., 2001). Sand and gravel were mined from parts of the ravine until the late 1960s. The Ecology and Environment report states, "The entire ravine has been altered substantially from natural conditions with rerouting of the original creek bed and significant changes to the soils and lithology (e.g., backfilling of gravel pit excavations, release of log storage debris, landfilling activities, temporary road maintenance, rail bed and track placement and subsequent track removal, and filling and paving of some areas)."

Known or suspected historical pollution of the creek and ravine is varied (Ecology and Environment, Inc., 2001). The City operated a landfill in the ravine beginning in 1936. Refuse from an adjacent sugar plant also was reportedly dumped in the ravine. Burlington Northern Railroad disposed of wastes (possibly oil wastes) in the vicinity that may have migrated into the ravine through groundwater transport. Storm drain discharges may also have been contributors. An adjacent currently operating wood treating facility, Oeser Company, has had spills into the creek. At least some of these spills were of pentachlorophenol preservative in carrier oil.

A preliminary site characterization of the Oeser Company Superfund Site included sediment sampling from Little Squalicum Creek at 11 stations (Figure 2). Polycyclic aromatic hydrocarbons (PAHs), pentachlorophenol, and dioxin contamination were found at many of these stations (Appendix B). However, from a single-species bioassay evaluation of the sediments (10-day *Hyalella azteca* growth and survival), it was concluded in the Site Characterization Report that current levels of sediment contamination in the creek do not pose a hazard to aquatic life, although growth effects were observed (Ecology and Environment, Inc., 2001).

Study Goals and Objectives

The goal of this study was to provide information on sediment toxicity and chemical contamination in Little Squalicum Creek and the creek area for use by the City of Bellingham in planning further studies under the Model Toxic Control Act and their EPA Brownfields grant.

There were three main objectives:

1. Supplement existing data by investigating areas of the creek not previously sampled in the Oeser Superfund investigation.

2. Evaluate the potential toxicity of sediments in the creek to aquatic life in accordance with Chapter 173-204 WAC, using a full suite of acute and chronic effects freshwater sediment bioassays.

3. Evaluate the potential risk to human health and the environment, in accordance with Chapter 173-340 WAC, posed by streambank soils.

Figure 1. Location of Little Squalicum Creek (line with arrow) and ravine boundary (dashed line).

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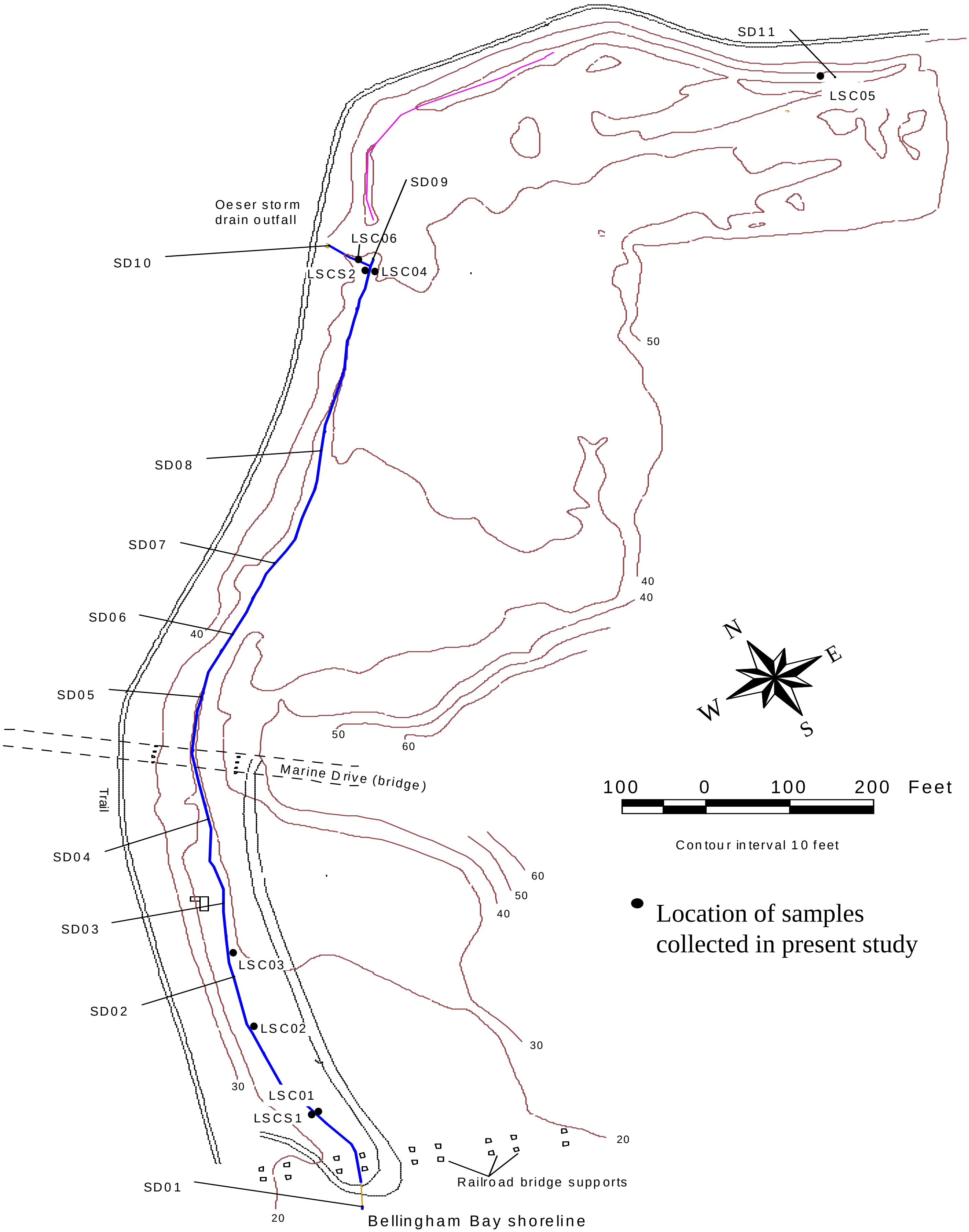

Figure 2. Locations of sediment sample stations (LSC01-LSC06) and streambank soil sample stations (LSCS1-LSCS2) in the present study, and locations of sediment stations (SD01-SD11) sampled in 1999 as part of the Superfund Site characterization (Ecology and Environment, Inc., 2001).

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Methods

Sampling Site Selection

The sampling plan focused on two areas of particular interest in Little Squalicum Creek:

- Upper reach. The upper terminus of Little Squalicum Creek receives periodic flows from the Birchwood Neighborhood stormwater outfall and, a short distance downstream, from the Oeser storm drain channel. Above the channel and creek confluence, station SD09 has previously been sampled to provide "background" data. However, data for the channel and creek segment below it are limited to results for station SD10 and, further downstream, station SD08 (Figure 2). To better characterize this area, station LSC06 was located in the Oeser outfall channel, and a location in the creek below the channel and creek confluence was also selected (station LSC04). In addition, a soil sample was taken from the streambank. This streambank sampling station, LSCS2, was located adjacent to LSC04.

- Lower reach. Near the point of discharge to Bellingham Bay, the creek has a relatively low channel gradient and is potentially an area of past deposition of contaminated sediments. Little data are available for this segment although elevated PAH concentrations were reported at station SD02 (Figure 2 and Appendix B). Three sediment sampling points were selected within this segment (stations LSC01-LSC03). As with the upper reach segment, a soil sample (at station LSCS1) was taken from the streambank adjacent to LSC01. Streambank areas are potentially subject to sediment deposition during high-flow episodes.

In the Oeser Superfund investigation, a sample (at station SD11) was taken from the "pond closest to Bellingham Technical College" and above the creek to provide "background" data. To repeat this aspect of the previous study design, a sample (at station LSC05) was located in a pond from the same vicinity as SD11. However, it is not known whether both samples were located in the same pond.

To evaluate these areas of concern, a total of six sediment and two streambank soil locations were sampled.

Sampling Methods

Sampling was conducted on September 25, 2003, under low-flow conditions. At each sampling location, the top 10 cm of sediment (or soil, for streambank samples) was removed using a stainless steel scoop, placed in a dedicated precleaned stainless steel mixing bowl, homogenized, transferred to containers, and the placed in coolers with ice. Stainless steel scoops and mixing bowls were precleaned with Liquinox® detergent, rinsed with deionized water, 10% nitric acid, and then methanol. After cleaning, the scoops and bowls were wrapped in aluminum foil.

Sample handling, including container types used, conformed with quality assurance procedures specified in the Quality Assurance Project Plan for this study (Blakley, 2003). The only substantive change was that sediment samples to be used for bioassay toxicity tests were transported directly to the contract laboratory on the same day they were collected.

Analytical Methods

Analytical methods for analysis of samples from this project are shown in Table 1.

Table 1. Analytical methods and laboratory reporting limits.

Analyte	Method	Reference	Laboratory
Total Organic Carbon	Combustion/CO_2 Measurement @ 70°C (9060)	PSEP, 1997	MEL
Grain Size	Sieve and Pipet	PSEP, 1986	ARI
SVOCs	Capillary GC/MS, EPA 8270	EPA, 1996	MEL

SVOCs - Semivolatile Organic Compounds
MEL - Manchester Environmental Laboratory
ARI - Analytical Resources Incorporated

The bioassays used to test samples in this project are described in Table 2. More detailed information is provided in Appendix E.

Data Quality

Semivolatile organic compounds

Laboratory quality control samples included analysis of surrogate spikes, internal standards, method blanks, duplicate matrix spikes, and a laboratory control sample. One blind field duplicate was collected at station LSC02. The blind field duplicate was a single sample that was homogenized and split in the field into two separate aliquots for sampling.

The semivolatile organic compounds (SVOC) data are acceptable for a screening-level study, particularly when used in conjunction with the bioassay results. However, due to the effects of high levels of hydrocarbon contamination on data precision, additional sampling may be needed where more precise concentration measurements are needed.

As noted in the Case Narrative (Appendix C), the field samples were heavily contaminated with hydrocarbons, causing interference in compound resolution and measurement. In some cases, one or more sample dilutions were required because concentrations lay outside the calibration range of the instrument.

Table 2. Bioassay test methods.

Bioassay test	**Amphipod**: A 10-day sediment toxicity test that assesses mortality and growth of the amphipod *Hyalella azteca*
Method	ASTM E-1706 and Method 100.1
Reference	EPA, 2000
No. replicates/sample	5
Endpoints	Survival (growth was also measured but SQS or CSL criteria have not been established for this endpoint)
Decision criteria*	Survival statistically different from control (p<0.05) using one-tailed t-test, and: Mortality exceeds control value by at least 10% (SQS exceedance) or Mortality exceeds control value by at least 25% (CSL exceedance)
Bioassay test	**Midge**: A 20-day sediment toxicity test that assesses mortality and growth of midge larvae (*Chironomus tentans*)
Method	Method 100.5
Reference	EPA, 2000
No. replicates/sample	5
Endpoints	Growth and mortality
Decision criteria*	Measurement (growth or percent survival) statistically different from control (p<0.05) using one-tailed t-test, and any of the following: Growth: Growth less than 75% of control (SQS exceedance) or Growth less than 60% of control (CSL exceedance) Mortality: Mortality exceeds control value by at least 15% (SQS exceedance) or Mortality exceeds control value by at least 25% (CSL exceedance)
Bioassay test	**Microtox®** 100 percent sediment porewater extract test: A rapid (15-min) method of assessing toxicity in aqueous media by utilizing the bioluminescent properties of the marine bacteria *Vibrio fischeri*. The test method assumes that light emitted by the bacteria can be used as an accurate assessment of the overall biological condition of the bacteria exposed to chemical compounds and mixtures. Light emitted by the bacteria exposed to potentially toxic samples is compared to light emitted to unexposed bacterial controls. Differences in luminescence are therefore deemed an indication of relative toxicity.
Method	Ecology Protocol
Reference	Ecology, 2003
No. replicates/sample	5
Endpoints	Light output (bioluminescence) after 5 min and 15 min exposure to test sample
Decision criteria*	Statistically significant (p<0.05) reduction in light output from control using one-tailed t-test, and: Test mean output less than 85% of control (SQS exceedance) or Test mean output less than 75% of control (CSL exceedance)

SQS - Sediment Quality Standard.
CSL - Cleanup Screening Level
* - Decision criteria from Michelsen (2003).
Contract laboratory for all three bioassays: AMEC Earth & Environmental Northwest Bioassay Laboratory

Laboratory control sample recovery values averaged 87% (Table C-1). For most compounds, recovery values were within the method performance limit (50-150%).

Surrogate recoveries from field samples were within method limits in almost all cases. Of the eight surrogate compounds used, terphenyl-D14 recovery exceeded the limits in two samples (from stations LSC03 and LSC05), and D5-phenol recovery limits were exceeded at LSC03.

Precision estimates from the duplicate samples at station LSC02 range from a relative percent difference (RPD) of 1% to 75% for PAHs (Table C-2). For other hydrocarbons included in the SVOC analysis, RPDs ranged from 8% to 118%. Given the good recovery results for the laboratory control sample and for surrogates in the field samples, the high RPD values for some hydrocarbons in the field duplicates are attributed to the sample characteristics, rather than instrument problems.

In the matrix spike samples, more analyte recoveries exceeded performance limits than in the laboratory control sample. RPD values ranged from 0% to 200% (Table C-1). The effects of initial analyte concentrations present in the field samples used for matrix spike analyses appear to account for many of the performance limit exceedances. Among analytes that were already present in the field sample before spiking, about 40% had spike recoveries outside performance limits. For analytes not found in the field sample, about 20% had spike recoveries outside performance limits. The field contamination also contributed to variability in spike recovery. Among analytes that were present in the field sample, the average RPD was about 50%, versus 24% for analytes not present in the field sample.

Bioassays

Control acceptability criteria were met for all three of the bioassay tests. There were no deviations from test protocols, and water quality parameters remained within the ranges specified in the corresponding protocols in all tests. A more detailed discussion, with quality control results, is provided in Appendix E.

Results and Discussion

Physical Characteristics

Sediment and soil samples were characterized for solids content, organic carbon content, and grain size (Table 3). In general, sandy grain size classes predominated. The solids content was in the range of 50-80% (median = 69%), and total organic content (TOC) was about 1-10% (median = 4.1%), with the exception of the LSC05 sample. This mucky sediment from a pond at the upper end of the ravine had a much lower solids content (8%) and a high organic content (35%). Although this station was intended to approximate the pond “background location” (SD11) described in Ecology and Environment (2001), the high organic content at LSC05 differs considerably from the 12% TOC value reported for SD11. TOC values of greater than 5% are generally considered highly enriched. The source of the relatively high TOC is currently not known.

Table 3. Physical characteristics of sediment and soil samples.

Sample No.	394040	394041	394046	394042	394043	394044	394045	394047	394048
Station	LSC01	LSC02	LSC02 (field dup)	LSC03	LSC04	LSC05	LSC06	LSCS1 (soil)	LSCS2 (soil)
% Solids	52.0	65.1	69.1	62.2	73.4	8.0	75.8	70.9	69.5
% TOC	4.07	1.97	1.56	2.57	5.02	34.6	3.94	7.59	10.2
Grain size (%)									
Gravel	26.7	13.2	37.7	4.5	46.4	36.8*	45.3	19.2	4.6
Sand	57.1	78.6	57.1	74.8	40.1	42.6*	46.5	67.0	83.6
Silt	10.5	5.9	4.1	15.1	9.5	14.8	6.4	12.1	9.8
Clay	5.7	2.4	1.1	5.5	4.0	5.7	1.6	1.7	1.9

* Values suspected to be overestimates, possibly due to clumping during sample preparation. According to the laboratory report, “During the oven dry stage of the test, sample 39-4044 was baked into hard agglomerations.”

Chemical Data

Semivolatile organic compounds were present at measurable concentrations at every location sampled (Table 4). Chemical contamination was particularly high in the sediment sample at station LSC03, where polycyclic aromatic hydrocarbon (PAH) concentrations were an order of magnitude higher than at any other sampling location.

There was a strong correlation among some chemicals in concentrations across sampling locations. To simplify the comparison of chemical mixtures from different locations, these chemicals were combined into a single group using cluster analysis (Appendix D). Two groups, designated SVOC1 and SVOC2, were identified.

SVOC1 consists primarily of PAHs:

- 1-Methylnaphthalene
- 2-Methylnaphthalene
- 3B-Coprostanol
- Acenaphthene
- Anthracene
- Benzo(a)anthracene
- Benzo(a)pyrene
- Benzo(b)fluoranthene
- Benzo(ghi)perylene
- Benzo(k)fluoranthene
- Carbazole
- Chrysene
- Dibenzo(a,h)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Naphthalene
- Phenanthrene
- Pyrene

SVOC2 consists primarily of phenols, benzoic acid, and benzyl alcohol:

- 2,4,5-Trichlorophenol
- 2,4,6-Trichlorophenol
- 2,4-Dimethylphenol
- 2-Methylphenol
- 4-Methylphenol
- Benzoic Acid
- Benzyl Alcohol
- Hexachloroethane
- Phenol

Table 4. Semivolatile organic compounds (SVOC) analysis results (ug/Kg, dw)

Analyte	Station								
	LSC01	LSC02	LSC02 field dup.	LSC03	LSC04	LSC05	LSC06	LSCS1 (Soil)	LSCS2 (Soil)
PAHs									
1-Methylnaphthalene	**35**	**148**	**104**	**10,200**	**122**	**25** NJ	**363**	**129**	**53** J
2-Methylnaphthalene	**45**	**157**	**109**	**2610**	**171**	**50** J	**344**	**248**	**100**
Acenaphthene	**110**	**328**	**221**	**12,000**	**172**	**15** J	**200**	**83**	**50** NJ
Acenaphthylene	57 UJ	**159**	**161**	12 UJ	**171**	98 U	**179**	**694**	**85**
Anthracene	**543**	**1,740** J	**1,350**	**36,800**	**1,000**	**83** J	**931**	**2,330**	**276**
Benzo(a)anthracene	**386**	**2,280** J	**1,980**	**30,200**	**809**	98 U	**1,800**	**1,340**	**557**
Benzo(a)pyrene	**527**	**2,580** J	**1,890**	**20,700**	**1,900**	98 UJ	**2,290**	**2,740**	**895** J
Benzo(b)fluoranthene	**589**	**3,050** J	**2,190**	**21,900**	**2,030** J	196 UJ	**2,850**	**3,830**	**1,640** J
Benzo(ghi)perylene	**311**	**656** J	**396** J	**6,750**	**552** J	196 UJ	**635** J	**1,080** J	**424** J
Benzo(k)fluoranthene	**447**	**2,020** J	**1,650** J	**13,100**	**1,700** J	196 UJ	**1,680**	**2,040**	**858** J
Chrysene	**1,230**	**5,240** J	**4,140**	**55,500** J	**4,540**	98 U	**3,290**	**5,510**	**1,280**
Dibenzo(a,h)anthracene	**112**	**378** J	**264** J	**1570** J	**287** J	196 UJ	**291** J	**394** J	**117** J
Fluoranthene	**537**	**3,380** J	**3,290**	**86,300** J	**596**	**300**	**2,120**	**2,200**	**1,550**
Fluorene	**112**	**952**	**433**	**17,000**	**360**	**60** J	**348**	**153**	**78**
Indeno(1,2,3-cd)pyrene	**464**	**970** J	**672** J	**10,000**	**867** J	196 UJ	**970** J	**1,520** J	**622** J
Naphthalene	**72**	**187**	**116**	**3,820**	**140**	**76** J	**280**	**247**	**138**
Phenanthrene	**206**	**1,580** J	**770**	**33,000**	**474**	**225**	**1,620**	**1,050**	**739**
Pyrene	**533**	**3,050** J	**2,730**	**78,000** J	**575**	**294**	**2,240**	**1,790**	**1,390**
Phenols									
2,4,5-Trichlorophenol	59 U	48 U	47 U	50 UJ	51 U	393 U	40 U	**7.9** NJ	234 U
2,4,6-Trichlorophenol	59 U	48 U	47 U	50 UJ	51 U	393 U	40 U	**32** J	234 U
2,4-Dimethylphenol	**12** J	**27**	**19** J	25 UJ	**18** J	**133** J	**23**	**77**	**44** J
2-Methylphenol	**6.4** J	**20**	**16**	12 U	**48**	**198**	**16** NJ	**48**	**65**
4-Methylphenol	**24** J	**118**	**101**	**110**	**46**	**552**	**40** NJ	**92**	**114** NJ
Pentachlorophenol	**617**	**1,370** J	**1,150**	**4,330** J	**2,190** J	**1,270** J	**4,270** J	**5,960** J	**673** J
Phenol	**58**	**86**	**110**	25 U	**238**	**2,110**	**121**	**215**	**429**
Phthalates									
Bis(2-Ethylhexyl) Phthalate	567 UJ	**1,120** J	**1,010** J	**658** J	610 UJ	972 UJ	512 UJ	**1,260** J	**6,180** J
Dimethylphthalate	**410**	**783**	**3,050**	25 UJ	**156**	196 U	**97**	**3,130**	**124**
Butylbenzylphthalate	29 U	**151** J	**192** J	25 UJ	26 U	196 U	20 U	**666** J	**425** J
Other									
3B-Coprostanol	293 UJ	242 UJ	236 UJ	**2,800** J	255 UJ	1960 UJ	**638** J	221 UJ	1,170 UJ
Benzoic Acid	**789** J	**1,340** J	**1,140** J	500 UJ	**1,560** J	**8,240** J	401 UJ	**2,800** J	**2,920** J
Benzyl Alcohol	**105** NJ	**147**	**159**	125 U	**751**	**6,290**	**124**	**441**	**467** J
Carbazole	**48** J	**306** J	**124** J	**4,780** J	**142** J	393 UJ	**349** J	**446** J	**166** J
Dibenzofuran	**67**	**584**	**157**	12 UJ	**207**	98 U	**252**	**176**	**68**
Hexachlorobenzene	15 U	12 U	12 U	12 UJ	13 U	98 U	**76**	**12** NJ	**14** NJ
Hexachloroethane	29 U	24 UJ	24 U	25 UJ	26 U	196 U	**7.3** NJ	22 U	117 U
N-Nitrosodiphenylamine	15 U	**173** NJ	12 U	12 UJ	13 U	98 U	10 U	11 U	**24** NJ
Retene	**60**	24 U	24 U	25 UJ	**205**	98 U	**379**	22 U	**125**

Bold: The analyte was present in the sample.
U - The analyte was not detected at or above the reported value.
J - The analyte was positively identified. The associated numerical value is an estimate.
UJ - The analyte was not detected at or above the reported estimated result.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

SVOC1 chemicals predominated at all but one of the sampling locations (Figure 3). At the most downstream station (LSC01), the sediment concentration of SVOC1 chemicals was lower than upstream but soil from the streambank (LSCS1) showed no such reduction. The reference station (LSC05) is distinguished by a unique chemical pattern, with SVOC2 chemicals predominating.

Chemical patterns (or "fingerprints") for each of the sampling locations are shown in Figure 4. The patterns are similar for most locations, with a few exceptions. The distinct pattern at LSC05, dominated by SVOC2 chemicals, was noted earlier. In addition, station LSC03 differs in consisting almost entirely of SVOC1 chemicals. This is primarily due to the large proportion of PAHs such as anthracene, chrysene, fluoranthene, and pyrene. Finally, the soil streambank sample at LSCS2 included an unusually large proportion of phthalates although this was not apparent in the adjacent sediment location (LSC04), nor in the other soil streambank sample taken from downstream (LSCS1).

Pentachlorophenol was detected in every sediment and soil sample, but there was no clear pattern in quantity (Figure 3). The sediment sample at LSC01 had the lowest concentration, while soil from the streambank at that location (LSCS1) had the highest concentration measured. The concentration at LSC03 was relatively high, but on a proportional basis pentachlorophenol was only a minor constituent at that location (Figure 4). Upstream, the concentration below the Oeser storm drain (LSC06) was similar to LSC03 but lower at the adjacent locations (LSC04 and LSCS2).

At all sites except LSC05, the sum of low molecular weight PAH (LPAH) and the sum of high molecular weight PAH (HPAH) formed a relatively constant ratio (Figure 5). The LPAH/HPAH ratio has been used to infer the relative age of PAH contamination, based on the fact that weathering processes can preferentially remove LPAH (Norton, 2000; Merrill and Wade, 1985). The higher LPAH/HPAH ratio at LSC05 is consistent with the assumption that the pond where this sample was taken is subject to ongoing contamination from stormwater discharge. The relatively constant, lower ratio at the other sites suggests historical rather than recent or ongoing releases of contamination.

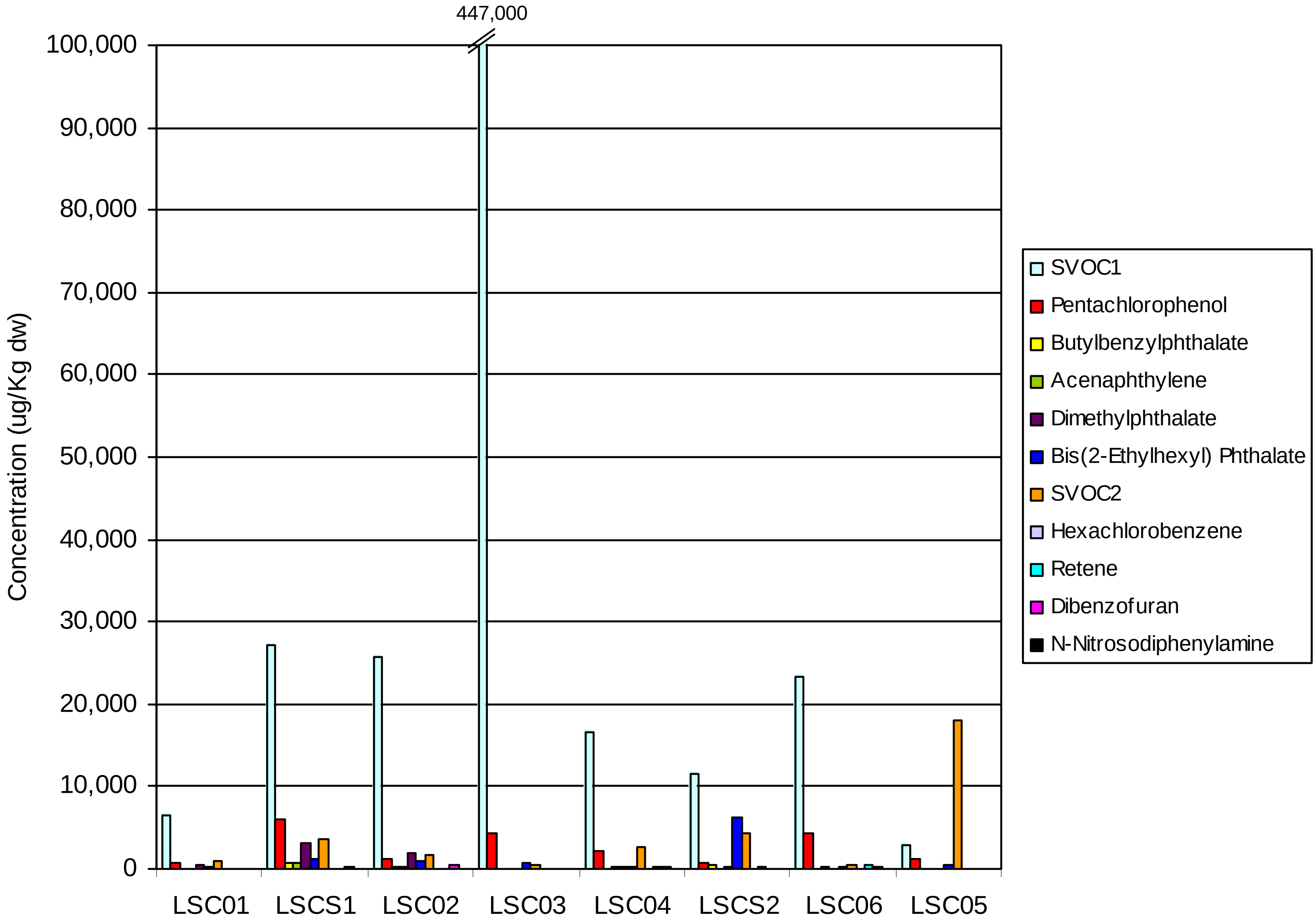


Figure 3. Chemical concentrations at all sampling locations. Station LSC02 data are for averages from two field replicates. Data are from Table 4 and are not TOC normalized.

SVOC1 group:
1-methylnaphthalene, 2-methylnaphthalene, 3B-coprostanol, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, carbazole, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene.

SVOC2 group:
2,4,5-trichlorophenol, 2,4,6-trichlorophenol, 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, benzoic acid, benzyl alcohol, hexachloroethane, phenol.

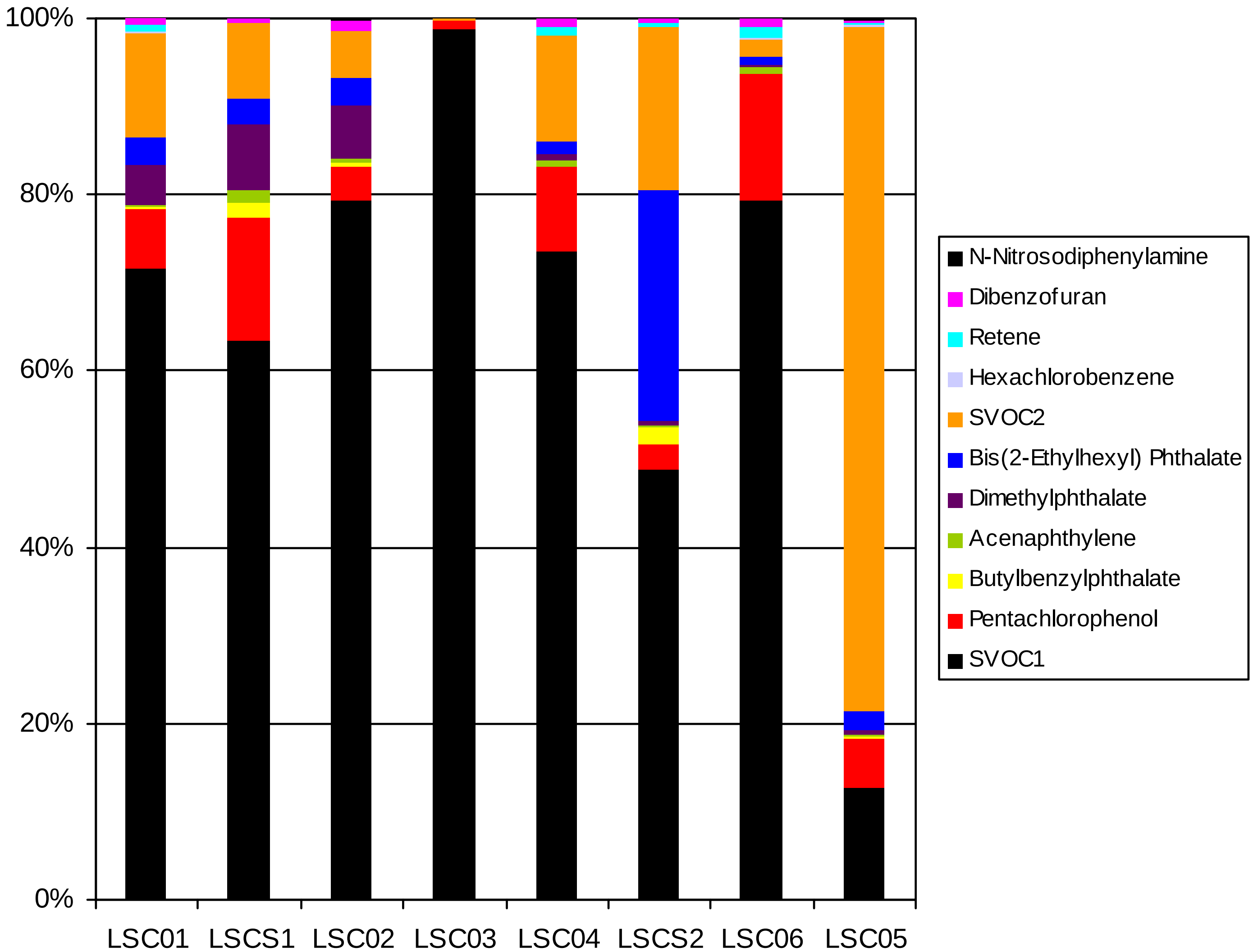


Figure 4. Relative chemical composition for samples collected from Little Squalicum Creek. Station LSC02 data are for averages from two field replicates. Data are from Table 4 and are not TOC normalized.

SVOC1 group:
1-methylnaphthalene, 2-methylnaphthalene, 3B-coprostanol, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, carbazole, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene.

SVOC2 group:
2,4,5-trichlorophenol, 2,4,6-trichlorophenol, 2,4-dimethylphenol, 2-methylphenol, 4-methylphenol, benzoic acid, benzyl alcohol, hexachloroethane, phenol.

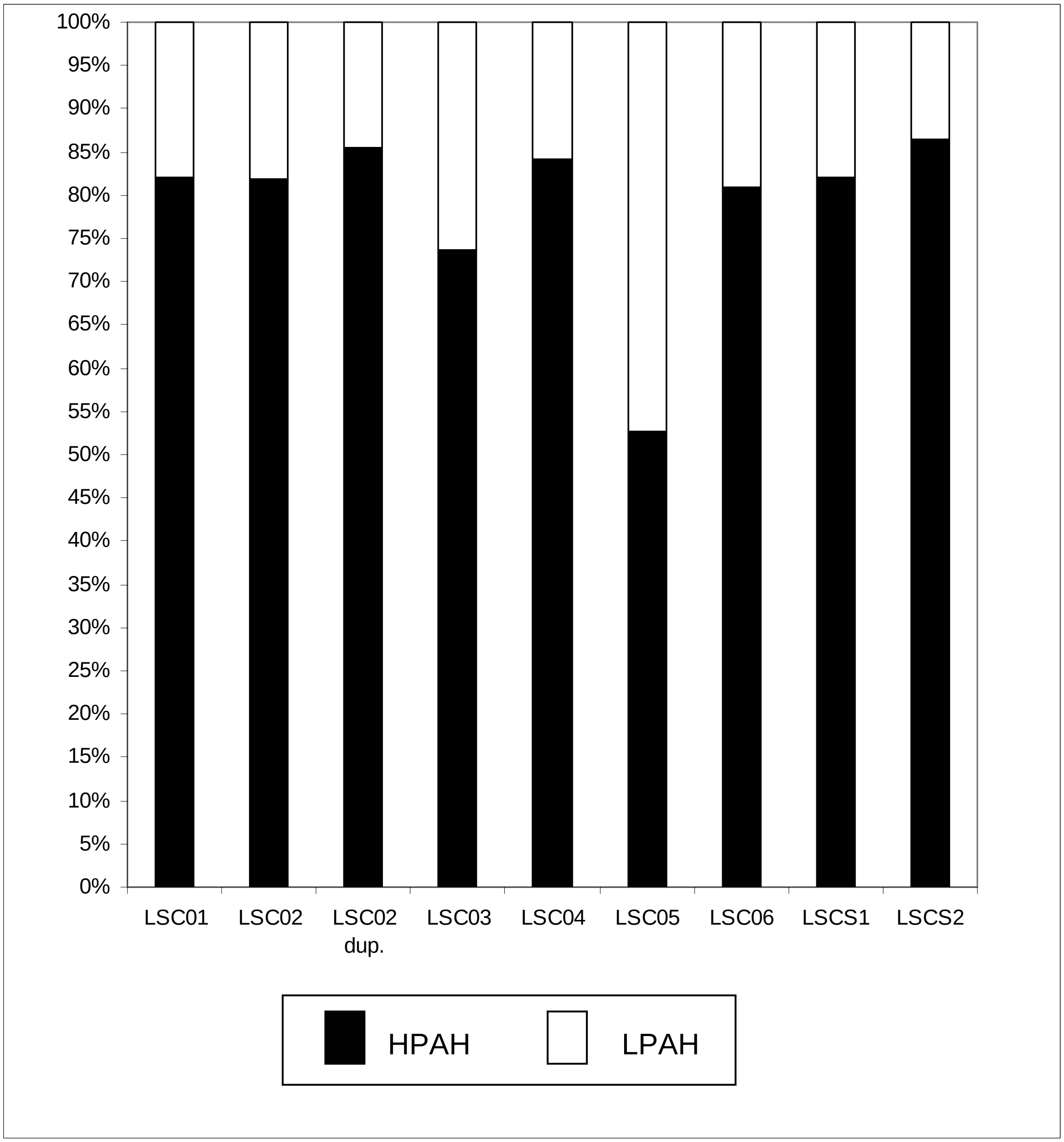


Figure 5. Proportion of LPAH and HPAH at all sampling stations.

Comparison with risk-based numerical criteria

All station samples contained chemical concentrations exceeding risk-based numerical criteria (Table 5). The following criteria were used for this analysis:

Human health:	Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Method B Soil Cleanup Values.
Aquatic life:	Freshwater Sediment 2003 Lowest Apparent Effects Thresholds (Michelsen, 2003). (Recommended values for freshwater sediments.)
	Sediment Management Standards (Chapter 173-204 WAC) Marine Sediment Quality Standards. (Where required, chemical concentrations were organic-carbon normalized for comparisons with sediment quality standards.)
Terrestrial life:	Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals.

PAH concentrations in excess of human health Method B soil values were present at all stations except the reference station (LSC05). These exceedances were particularly high at LSC03 (notably, chrysene concentration was 405 times the Method B value).

One or more freshwater Lowest Apparent Effects Thresholds (LAETs) were exceeded at all locations except the two sediment stations below the Oeser storm drain outfall (LSC04 and LSC06). Freshwater LAETs are not available for all chemicals analyzed, notably including pentachlorophenol. A standard for pentachlorophenol based on protection of marine life is available, however, and this value was exceeded at all locations tested.

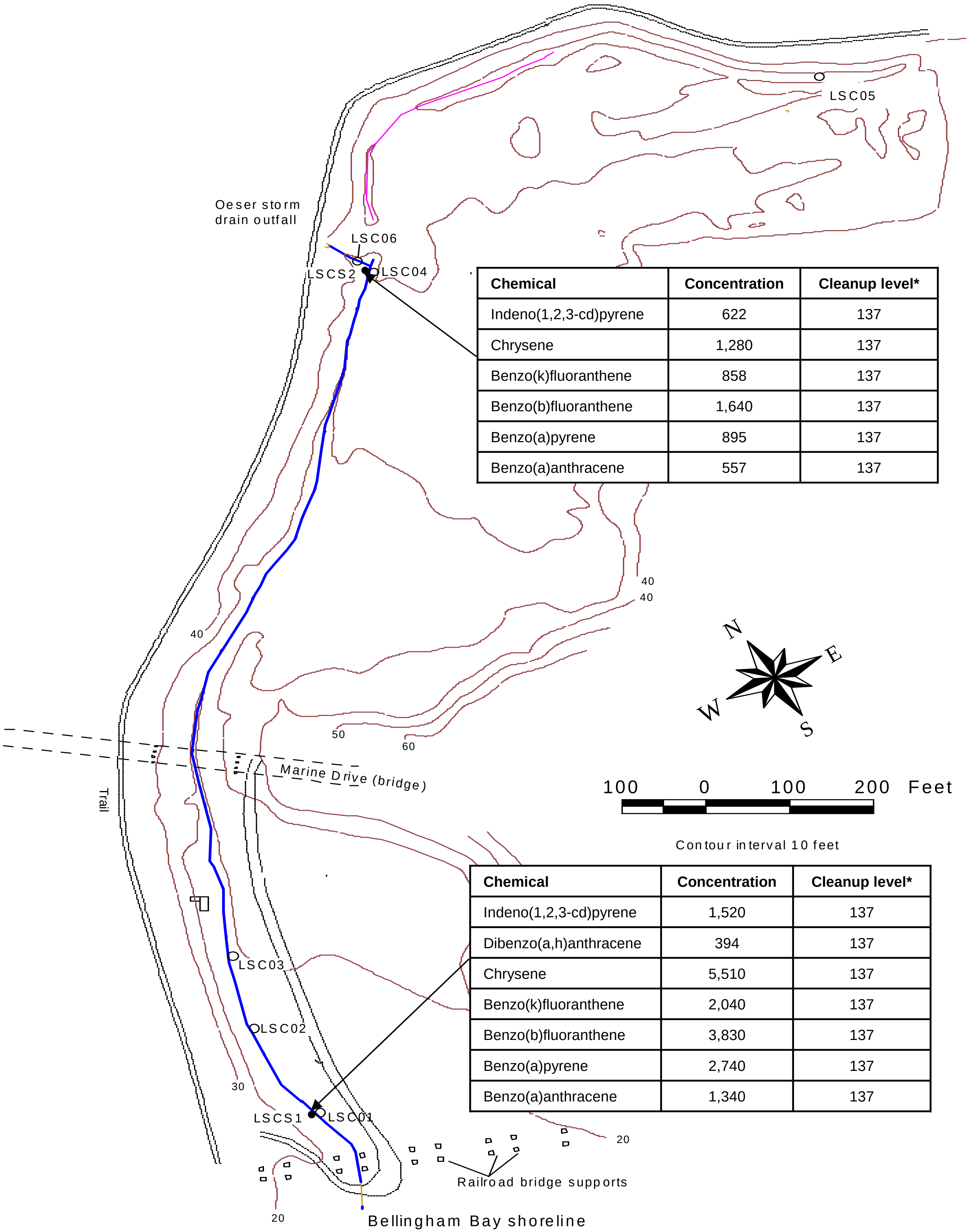
Numerical criteria for protection of terrestrial life are only available for a limited number of chemicals. However, it should be noted that the standard for pentachlorophenol was exceeded at three locations (LSCS1, LSC03, and LSC06).

At both soil sampling locations, carcinogenic PAHs exceeded Method B cleanup levels for the protection of human health (Figure 6). Carcinogenic PAHs include benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene (WAC 173-340-200).

Table 5. Exceedances of risk-based numerical criteria, expressed as multiples of the values. Exceedances of 10 times the risk-based standard or more are highlighted in bold.

Station	LSC01				LSCS1				LSC02				LSC02 dup				LSC03				LSC04				LSCS2				LSC05				LSC06			
	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco	Method B	FW LAET	SMS SQS	Terr Eco
Pyrene																		9×	3×																	
Phenol																											1×				5×					
Phenanthrene																		5×	**13×**																	
Pentachlorophenol			2×				**17×**	2×			4×				3×				**12×**	1×			6×				2×				4×				**12×**	1×
Naphthalene																		7×	2×																	
Indeno(1,2,3-cd)pyrene	3×				**11×**				7×		1×		5×		1×		**73×**	2×	**11×**		6×				5×								7×			
Hexachlorobenzene																																			5×	
Fluorene											2×				1×			**16×**	**29×**																	
Fluoranthene											1×				1×			8×	**21×**																	
Dimethylphthalate		1×				**10×**				3×				**10×**	4×																					
Dibenzofuran										1×	2×																									
Dibenzo(a,h)anthracene					3×				3×		2×		2×		1×		**11×**	2×	5×		2×												2×			
Chrysene	9×				**40×**				**38×**		2×		**30×**		2×		**405×**	9×	**20×**		**33×**				9×								**24×**			
Carbazole																		5×																		
Butylbenzylphthalate						3×	2×				2×				3×											2×										
Bis(2-Ethylhexyl) Phthalate											1×				1×											2×	1×									
Benzyl Alcohol			2×				8×				3×				3×								**13×**				8×				**110×**				2×	
Benzoic Acid			1×				4×				2×				2×								2×			1×	4×			3×	**13×**					
Benzo(k)fluoranthene	3×				**15×**				**15×**				**12×**				**96×**				**12×**				6×								**12×**			
Benzo(ghi)perylene											1×							2×	8×																	
Benzo(b)fluoranthene	4×				**28×**				**22×**				**16×**				**160×**				**15×**				**12×**								**21×**			
Benzo(a)pyrene	4×				**20×**				**19×**		1×		**14×**		1×		**151×**	6×	8×	2×	**14×**				7×								**17×**			
Benzo(a)anthracene	3×				**10×**				**17×**		1×		**14×**		1×		**220×**	7×	**11×**		6×				4×								**13×**			
Anthracene						2×				1×				1×				**30×**	6×																	
Acenaphthylene						1×																														
Acenaphthene											1×							**11×**	**29×**																	
2-Methylphenol																											1×				3×					
2-Methylnaphthalene																		6×	3×																	
2,4-Dimethylphenol						3×																					2×				5×					
Total exceedances	6	1	3		7	5	4	1	7	3	15		7	2	13		7	15	15	2	7		3		6	3	7			1	6		7		3	1

Risk-based standards:
Method B - Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Method B Soil Cleanup Values
FW LAET - Freshwater Sediment 2003 Lowest Apparent Effects Thresholds (Michelsen, 2003)
SMS SQS - Sediment Management Standards (Chapter 173-204 WAC) Marine Sediment Quality Standards
Terr Eco - Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Ecological Indicator Soil Concentrations (mg/kg) for Protection of Terrestrial Plants and Animals.



Chemical	Concentration	Cleanup level*
Indeno(1,2,3-cd)pyrene	622	137
Chrysene	1,280	137
Benzo(k)fluoranthene	858	137
Benzo(b)fluoranthene	1,640	137
Benzo(a)pyrene	895	137
Benzo(a)anthracene	557	137

Chemical	Concentration	Cleanup level*
Indeno(1,2,3-cd)pyrene	1,520	137
Dibenzo(a,h)anthracene	394	137
Chrysene	5,510	137
Benzo(k)fluoranthene	2,040	137
Benzo(b)fluoranthene	3,830	137
Benzo(a)pyrene	2,740	137
Benzo(a)anthracene	1,340	137

Figure 6. Chemicals exceeding soil cleanup levels at soil sampling stations LSCS1 and LSCS2. Concentrations in ug/Kg dw.

* Model Toxics Control Act Cleanup Regulation (Chapter 173-340 WAC) Method B Soil Cleanup Levels

Comparison with previous sampling results

PAH concentrations measured at LSC03 are considerably higher than from other locations in the ravine sampled in either the Oeser Superfund investigation or the present study. For stations other than LSC03, concentrations of PAHs from locations sampled in this study tended to be higher than those reported by Ecology and Environment (2001), although the explanation is unknown. This trend is well illustrated by the data for naphthalene, for example (Figure 7). However, there was more overlap in concentrations from the two studies for other PAHs such as benzo(a)pyrene (Figure 7).

Although the Oeser Superfund investigation did not include the sediments sampled at LSC03, some PAH concentrations were elevated at the closest downstream location sampled (SD02). For example, the highest chrysene concentration observed in the Oeser Superfund investigation was at SD02 (Figure 7), and this PAH was also one of the most abundant constituents at LSC03 (Table 4). Thus the "hotspot" at LSC03 was probably present but not sampled during the Superfund investigation.

Sediment Bioassays

Sediments were toxic to bioassay test organisms at all stations except the most downstream location, LSC01 (Figure 8). Even at that station, there was a statistically significant reduction in growth of *Hyalella* (Appendix E). The broadest toxicity effects were at LSC03, where test criteria were exceeded for all three bioassay tests. One station (LSC06) exhibited toxicity with two bioassay test organisms, and the remainder were toxic to one test organism.

The bioassay results indicate exceedances of the recommended freshwater Sediment Quality Standards (SQS) or Cleanup Screening Level (CSL) endpoints at all stations except LSC01 (Figure 9). A summary of these endpoints is included in Table 2, and detailed bioassay results are provided in Appendix E. In addition to the CSL endpoints for individual bioassays, a station CSL exceedance occurs by definition when any two bioassay tests exceed SQS (WAC 173-204-520(1)(d) and (3)(d)). Thus results for LSC06 represent a CSL exceedance based on the combined results from the *Hyalella* and Microtox bioassays.

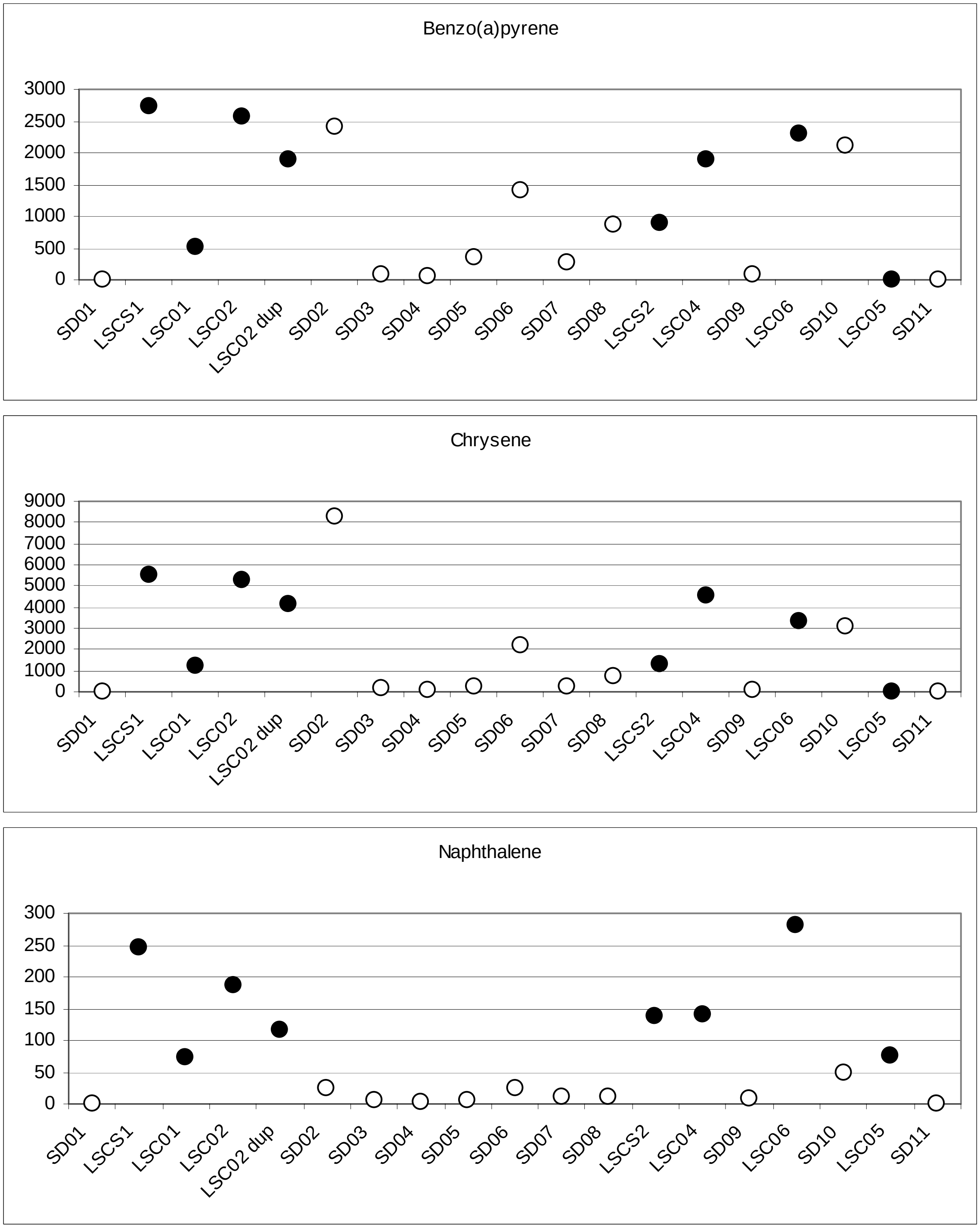


Figure 7. Examples of PAH concentrations reported in this study (●) and in the Oeser Superfund investigation (○). Data for the latter are from Ecology and Environment, Inc. (2001). Stations are rank ordered from downstream to upstream (see Figure 2 for locations). Values for station LSC03 are off-scale and not included. All concentrations are in ug/Kg dry weight.

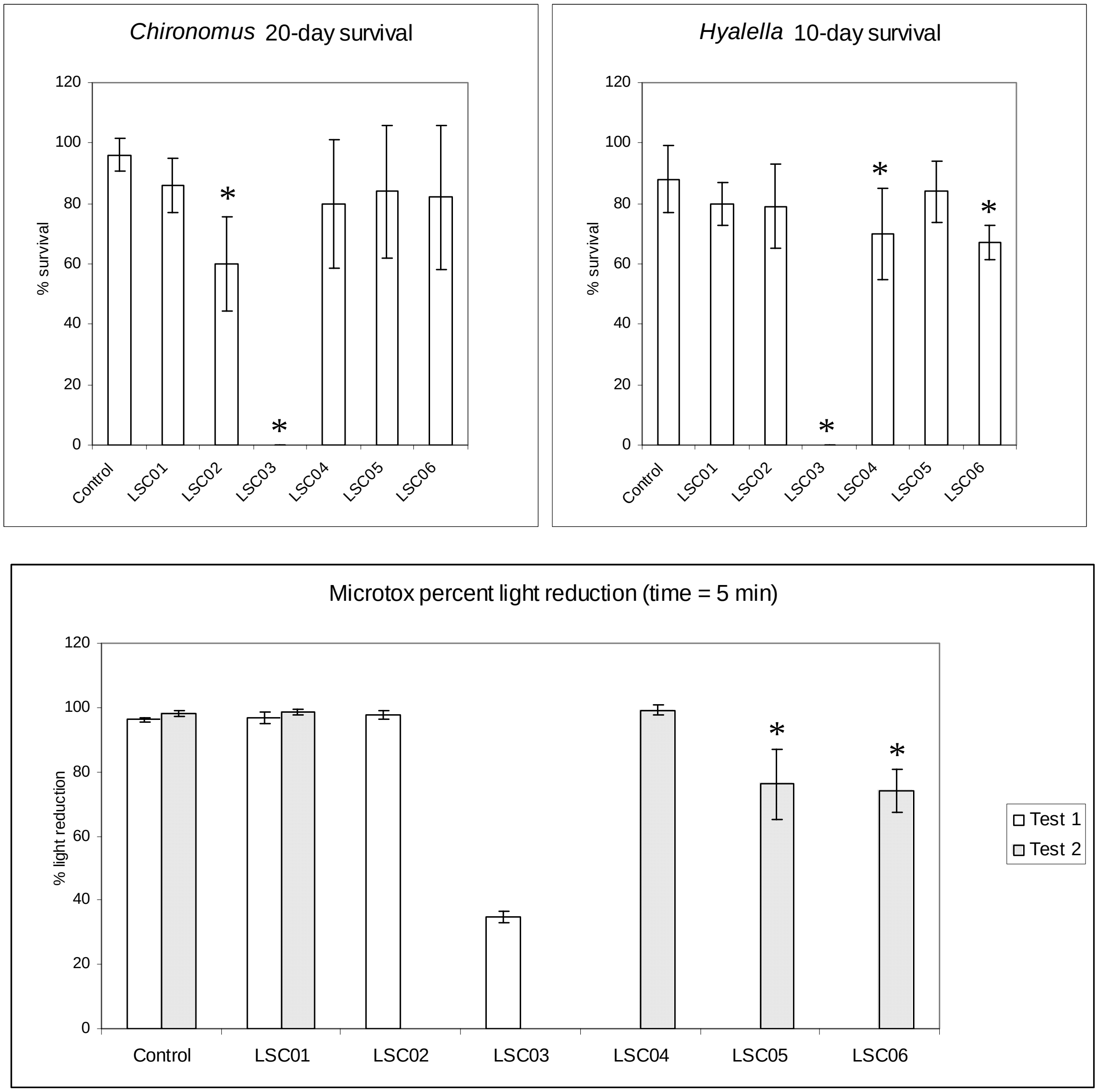


Figure 8. Bioassay results.

Upper charts: *Chironomus* and *Hyalella* survival. Note that survival was 0% for station LSC03 in both bioassays.

Lower chart: Microtox light reduction at 5 minutes. Station samples were tested in two batches (Test 1 and Test 2).

Control = laboratory control. * Significantly different from laboratory control ($p<0.05$). Vertical line on each bar represents ±1 standard deviation. See Laboratory Report (Appendix E) for additional details.

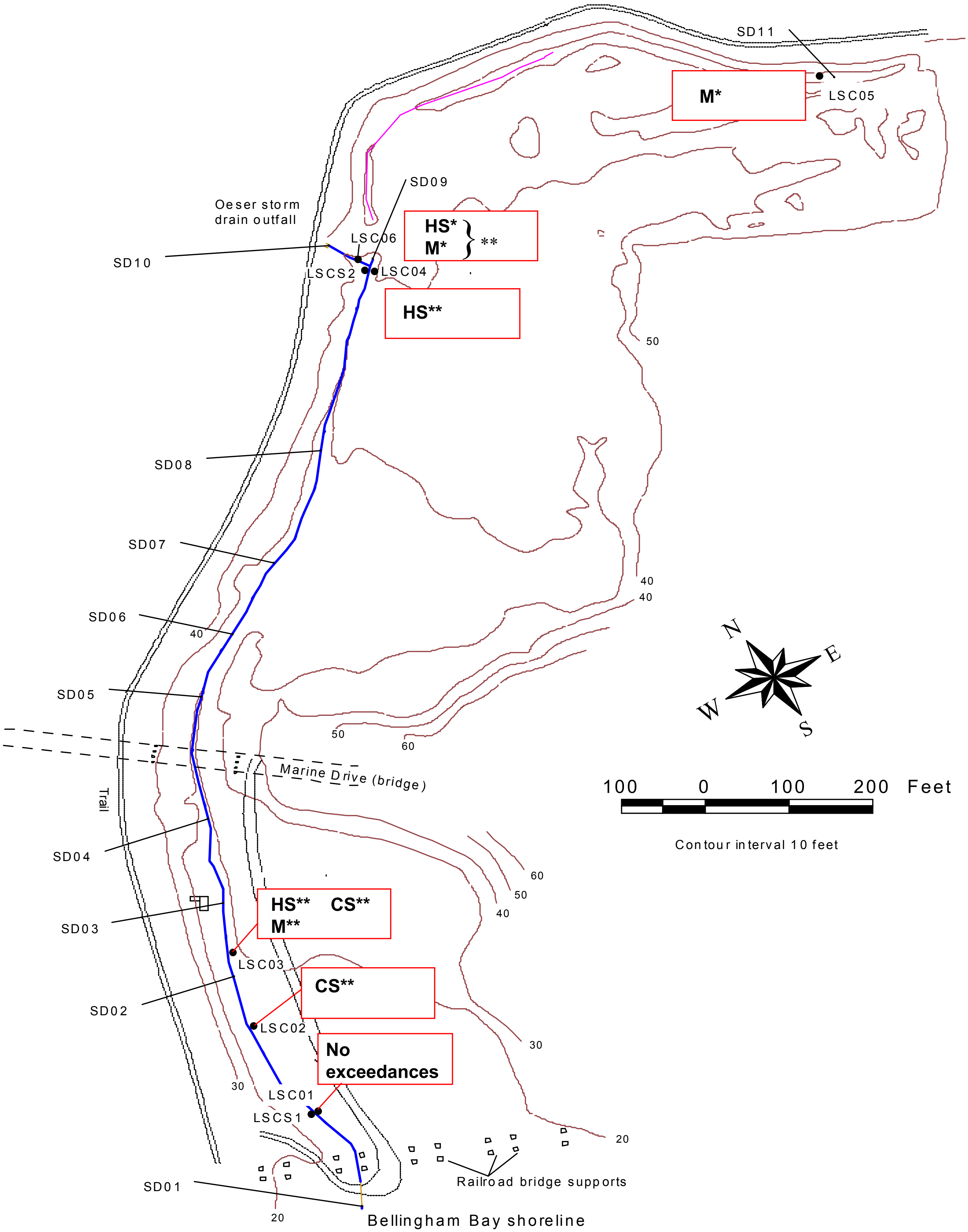


Figure 9. Bioassay results by location.
HS=*Hyalella* survival test, CS=*Chironomus* survival, M=Microtox (results measured at 5 and 15 min. did not differ).
* SQS exceedance ** CSL exceedance

Conclusions

Sediments in both the upper and lower reaches of Little Squalicum Creek are contaminated at levels of concern, based on independent lines of evidence from chemistry and bioassay data. The two lines of evidence also independently suggest higher levels of contamination in the creek sediments than had been found in a previous investigation. Characterization of the nature and extent of contamination will require a more extensive sampling investigation throughout the full extent of the creek. In view of the streambank contamination found in this study, the investigation should extend into areas of the ravine where historic flooding and deposition of contaminants may have occurred.

Sediments in Little Squalicum Creek exceed human health and ecological risk-based chemical criteria and also exceed bioassay toxicity criteria at both the SQS and the higher CSL level. More than three stations exceeded the CSL level, thus necessitating a full evaluation of the sediment cleanup required at the site. Exceedances occurred at both the upper and lower reaches of the creek included in this study. Even at the one station that did not exceed bioassay toxicity criteria (LSC01) and which also had the lowest sediment contaminant levels, the soil from the adjacent streambank still had high contaminant levels, comparable to upstream stations. This observation on streambank contamination also illustrates the potential importance of extending upland soil sampling laterally from the streambed. Even in areas where the creek has a stony bed and where fine sediments are unavailable for sampling, it may be desirable to reevaluate the reach for streambank contamination. At the highly contaminated downstream location (LSC03 "hotspot"), field observations during sampling did suggest that the source may be located in the left bank, rather than in the streambed.

Chemical "fingerprints" for both the upper and lower reach sediment stations are generally similar (Figure 4) and consistent with the reported history of releases of a woodtreating preservative. In contrast, the fingerprint for the reference station pond sediment (LSC05) is distinct and clearly due to a different source. The pond receives runoff from a large adjacent parking lot, and auto fuel combustion products from that location may be a primary contributor.

Among the creek sediment stations, the LSC03 "hotspot" had the most distinct fingerprint, dominated almost entirely by PAHs and lacking in phenols and phthalates, for example, that were found at other stations. The explanation for this fingerprint is unclear, although minor constituents such as phthalates are probably unrelated to releases of a woodtreating preservative.

The explanation for the LSC03 contamination "hotspot" is unknown. It may be an area where contaminated sediments have been deposited, although other possibilities exist. For example, the contamination source might be buried waste adjacent to the creek or contaminated groundwater migrating into the creek at this location.

Although all sediment stations except LSC01 exceeded bioassay toxicity criteria, there was less consistency in which bioassays indicated toxicity. For example, the *Chironomus* survival test indicated toxicity at LSC02 but not at LSC04 or LSC06 (Figure 9). There is no apparent pattern in the chemistry data (Table 4) that would account for the differential toxicity patterns, although the effect could be due to other chemicals present but not included in the analysis.

Microtox toxicity at the reference station LSC05 is consistent with results from the semivolatile organic compounds analysis, showing sediment contamination. This finding is in contrast with results from the Oeser Superfund investigation, where little contamination was found at station SD11. However, since these two reference stations also differed considerably in TOC values, it appears that LSC05, which is located in a pond receiving stormwater flow, does not replicate the location of SD11.

Recommendations

Additional investigation is needed to fully characterize the nature and extent of contamination identified in this study and to identify potential sources. Specifically, additional investigation of the sampling station LSC03 area should be conducted to evaluate the extent of high contamination here and, if possible, to determine its origin. A better understanding of this contaminated area may provide useful information for deciding whether there may be other such areas that a sampling plan should be designed to detect.

Although samples collected in this study were not analyzed for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, these chemicals should be included in future investigations of soils and sediments. These chemicals were found in the Oeser Superfund investigation of Little Squalicum Creek surface soil at concentrations up to 1,561 ng/Kg 2,3,7,8-TCDD TEQ* (Table 4-30 in Ecology and Environment, Inc., 2001). In sediments, concentrations up to 580 ng/Kg 2,3,7,8-TCDD TEQ were found (Table 4-119 in Ecology and Environment, Inc., 2001).

* 2,3,7,8 – tetrachlorodibenzo-p-dioxin toxicity equivalents

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Appendices

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Appendix A

Description of Little Squalicum Creek Sampling Sites

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Table A-1. Description of Sampling Sites in Little Squalicum Creek and Vicinity, September 25, 2003

Station	Sample No.	Description and field notes	Latitude*	Longitude
LSC01	03394040	Time 1040. Stream depth 10 inches. Substrate gravelly sand with clay lenses. Distance from nearest railroad trestle support 48 ft.	48 45.910	122 30.954
LSC02	03394041	Stream depth 2-3 inches. Sand with gravel in bottom channel. At channel edge silty with leaves and sticks.	48 45.916	122 30.960
LSC03	03394042	Time 1230. Stream depth 3 inches. Substrate medium sand with a thin (≈2 mm) layer of organic matter. Sediment has strong petroleum (diesel?) odor. Light sheen on water, coming from left bank.	48 45.950	122 30.946
LSC04	03394043	Time 1400. Streambed at intersection with channel from Oeser outfall.	48 46.071	122 30.748
LSC05	03394044	Pool near Bellingham Technical College parking lot. Sediment flocculent with very high organic matter and sulfurous odor. High mass of decaying leaves in pond. Pond receives storm flow from parking lot through storm drain discharge.	48 46.032	122 30.606
LSC06	03394045	Channel from Oeser outfall to Little Squalicum Creek. Dry, with terrestrial vegetation and invertebrates (earthworms).	48 46.069	122 30.750
LSCS1	03394047	Dry soil from right bank at same sampling location as sediment station LSC01.	48 45.910	122 30.955
LSCS2	03394048	Dry soil from right bank at same sampling location as sediment station LSC04.	48 46.070	122 30.749

*NAD 83 Station coordinates are approximate and derived from both field GPS measurements and GIS maps.

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Appendix B

Summary of Results from EPA (1999) Investigation of Little Squalicum Creek Sediments

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Table 4-119

SUMMARY OF RESULTS FROM LITTLE SQUALICUM CREEK SEDIMENT SAMPLES (JULY 1999) THE OESER COMPANY REMEDIAL INVESTIGATION BELLINGHAM, WASHINGTON

EPA Number	Preliminary	99070520	99070521	99070522	99070523	99070524	99070525	99070526	99070527	99070528	99070529	99070530
Sample Location	Screening	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08	SD09	SD10	SD11
Sample Date	Levels[ab]	7/28/99	7/28/99	7/28/99	7/28/99	7/28/99	7/29/99	7/29/99	7/29/99	7/29/99	7/29/99	7/29/99
Semivolatile Organic Compounds (mg/kg)												
2-Methylnaphthalene	0.48[c]	0.0022 U	0.04	0.011	0.0021 J	0.0024 J	0.026	0.003	0.0052	0.0068	0.065	0.011 U
3&4-Methylphenol	NA	0.011 U	0.013 U	0.008 J	0.006 J	0.012 J	0.1	0.012 U	0.003 J	0.037	0.011 U	0.054 U
7,12-Dimethylbenz(a)anthracene	NA	0.0022 U	0.18 U	0.0027 U	0.0023 U	0.017 U	0.0061 U	0.0025 U	0.0023 U	0.0024 U	0.14	0.011 U
7H-Dibenzo(c,g)carbazole	NA	0.0022 U	0.013	0.0027 U	0.0023 U	0.0026 U	0.0061 U	0.0025 U	0.0023 U	0.0024 U	0.0022 U	0.011 U
Acenaphthene	0.62[c]	0.0022 U	0.012	0.14	0.0035	0.029	0.081	0.011	0.014	0.0054	0.018	0.011 U
Acenaphthylene	0.62[c]	0.0022 U	0.047	0.0099	0.0044	0.022	0.093	0.02	0.054	0.0076	0.21	0.011 U
Anthracene	2.1[d]	0.0022 U	**2.2**	0.049	0.012	0.061	0.56	0.068	0.17	0.044	0.73	0.011 U
Benzo(a)anthracene	5.0[d]	0.003	3.7	0.059	0.022	0.12	1.7	0.14	0.37	0.073	1.3	0.011 U
Benzo(a)pyrene	0.43[c]	0.0041	**2.4**	0.087	0.042	0.34	**1.4**	0.28	**0.86**	0.072	**2.1**	0.011 U
Benzo(b)fluoranthene	11[d]	0.0044 J	0.82 J	0.048 J	0.021 J	0.15 J	0.7 J	0.13 J	0.38 J	0.031 J	1.1 JK	0.011 U
Benzo(g,h,i)perylene	0.66[c]	0.003	0.41	0.042	0.01	0.16	0.4	0.11	0.3	0.0024 U	**0.87**	0.011 U
Benzo(j)fluoranthene	NA	0.0044 J	0.82 J	0.048 J	0.021 J	0.15 J	0.7 J	0.13 J	0.38 J	0.031 J	1.1 JK	0.11 U
Benzo(k)fluoranthene	11[d]	0.0044 J	0.82 J	0.048 J	0.021 J	0.15 J	0.7 J	0.13 J	0.38 J	0.031 J	1.1 JK	0.011 U
Benzoic acid	NA	0.022 UJ	0.026 UJ	0.027 UJ	0.023 UJ	0.026 UJ	0.061 UJ	0.025 UJ	0.023 UJ	0.024 UJ	0.082	0.081 JQ
Chrysene	7.4[d]	0.0098	**8.3**	0.19	0.051	0.23	2.2	0.26	0.73	0.12	3.1	0.011 U
Dibenzo(a,e)pyrene	NA	0.0022 U	0.16	0.02	0.0023 U	0.07	0.0061 U	0.048	0.12	0.0024 U	0.0022 U	0.011 U
Dibenzo(a,h)anthracene	0.23[d]	0.0022 UJ	0.097 J	0.08	0.0023 UJ	0.024 J	0.0061 UJ	0.024 J	0.0087 J	0.0024 UJ	0.16	0.011 U
Dibenzo(a,h)pyrene	NA	0.0022 U	0.053	0.011	0.0023 U	0.04	0.0061 U	0.018	0.08	0.0024 U	0.21 U	0.011 U
Dibenzo(a,i)pyrene	NA	0.0022 U	0.023	0.0027 U	0.0023 U	0.0074 U	0.1	0.0059	0.019	0.0024 U	0.039 U	0.011 U
Dibenzo(a,l)pyrene	NA	0.0022 U	0.0096	0.0027 U	0.0023 U	0.0026 U	0.0061 U	0.0025 U	0.015	0.0024 U	0.034 U	0.011 U
Dibenzofuran	2.0[c]	0.011 U	0.025	0.017	0.0016 J	0.0042 J	0.035	0.0042 J	0.0066 J	0.008 J	0.06	0.054 U
Fluoranthene	2.9[c]	0.022	0.47	0.071	0.11	0.1	**3.2 J**	0.07	0.2	0.11	0.77	0.014
Fluorene	0.54[c]	0.0022 U	0.21	0.082	0.0063	0.034	0.13	0.016	0.034	0.014	0.075	0.011
Indeno(1,2,3-cd)pyrene	NA	0.0022	0.48	0.048	0.024	0.18	0.49	0.12	0.37	0.0024 U	0.96	0.011 U
Naphthalene	0.48[c]	0.0022 U	0.024	0.0054	0.0035	0.0058	0.025	0.012	0.011	0.0068	0.048	0.011 U
Pentachlorophenol	0.36[c]	0.0037 J	0.033	**2 J**	0.024	0.056	**0.46**	0.015	0.16	**1.1**	**2.9**	0.054 UJK
Phenanthrene	2.1[d]	0.0024	0.61	0.11	0.0072	0.041	0.41	0.029	0.08	0.15	0.2	0.012
Phenol	0.048[d]	0.011 U	0.013 U	0.013 U	0.012 U	0.013 U	0.031 U	0.012 U	0.011 U	0.016	0.011 U	0.054 U
Pyrene	0.66[c]	0.015	**0.66**	0.096	0.11	0.096	**2.9 J**	0.13	0.3	0.14	**1.8**	0.011 U
Tetrachlorophenols	NA	0.011 U	0.0054 J	0.03	0.0046 J	0.013 U	0.079	0.012 U	0.018	0.065	0.17	0.054 U
TOC	NA	2800	13000	7500	5200	18000	110000	7200	5400	13000	15000	120000
Petroleum Hydrocarbons (mg/kg)												
C12-C16 Aliphatics	NA	6.1 U	10	6.5 U	6.5 U	6.6 U	21	6.3 U	6.3 U	6.4 U	5.9 U	31 U
C16-C18 Aliphatics	NA	6.1 U	12	6.5 U	6.5 U	6.6 U	36	6.3 U	6.3 U	6.4 U	6.1	31 U
C18-C21 Aliphatics	NA	6.1 U	15	7.7	6.5 U	13	76	6.3 U	6.3 U	6.4 U	16	31 U
C18-C21 Aromatics	NA	6.1 U	30	6.5 U	6.5 U	13	110	6.3 U	9	6.4 U	12	31 U
C21-C28 Aliphatics	NA	6.1 U	64	46	34	100	470	30	23	57	48	220
C21-C28 Aromatics	NA	6.1 U	32	8.1	7.8	19	120	12	17	11	20	31 U
C28-C36 Aliphatics	NA	6.1 U	65	53	51	91	390	30	25	63	38	31 U
C28-C36 Aromatics	NA	6.1 U	50	22	26	38	170	32 J	30 J	30 J	30 J	170 J
Total EPH		NA	278	137	119	274	1393	104 J	104 J	161 J	170 J	390 J

Key is at the end of the table.

Table 4-119

SUMMARY OF RESULTS FROM LITTLE SQUALICUM CREEK SEDIMENT SAMPLES
(JULY 1999)
THE OESER COMPANY REMEDIAL INVESTIGATION
BELLINGHAM, WASHINGTON

EPA Number	Preliminary	99070520	99070521	99070522	99070523	99070524	99070525	99070526	99070527	99070528	99070529	99070530
Sample Location	Screening	SD01	SD02	SD03	SD04	SD05	SD06	SD07	SD08	SD09	SD10	SD11
Sample Date	Levels[ab]	7/28/99	7/28/99	7/28/99	7/28/99	7/28/99	7/29/99	7/29/99	7/29/99	7/29/99	7/29/99	7/29/99
Dioxin/Furans (ng/kg)												
2,3,7,8-TCDD TEQ	7.2[c]	**8.869**	**161.997**	**190.447**	**20.514**	**21.7888**	**305.394**	**53.468**	**122.248**	**9.700**	**579.932**	5.343
2,3,7,8-TCDF	NA	0.491 U	4.771	3.52	0.4 U	0.329 U	0.579 U	0.395 U	4.858	1.374	8.993	1.856 U
1,2,3,7,8-PeCDD	NA	0.568 U	5.319 U	5.929	3	1.85 U	5.553 U	4.504	8.691	2.305	53.971	2.598 U
1,2,3,7,8-PeCDF	NA	1.594	22.305 U	14.531 U	0.568 U	0.287 U	2.904 U	1.184 U	26.92 U	0.496 U	4.473 U	1.264 U
2,3,4,7,8-PeCDF	NA	1.678	22.78 U	13.698	0.575 U	1.074 U	4.237	4.09	26.214 U	0.501 U	32.741	1.278 U
1,2,3,4,7,8-HxCDD	NA	1.073 U	3.808 U	15.386 U	5.923	4.949 U	16.681	12.646	30.14	4.34	196.558	3.44 U
1,2,3,6,7,8-HxCDD	NA	15.151	223.196	185.056	30.114	29.965	79.554	87.119	446.431	13.971	803.393	14.103
1,2,3,6,7,8-HxCDF	NA	3.193 U	39.108 U	11.506	4.958 U	3.649 U	3.51	5.059	19.317	2.118 U	43.159	1.423 U
1,2,3,7,8,9-HxCDD	NA	3.598	38.472	44.913	13.779	11.366	34.804	29.155	69.562	7.971	454.109	8.66
1,2,3,7,8,9-HxCDF	NA	5.055 U	61.91 U	8.047	7.848 U	5.777 U	2.81	3.163 U	4.09	3.352 U	2.525 U	2.253 U
1,2,3,4,6,7,8-HpCDD	NA	479.469	10139.06	12912.84	885.353	977.97	25065.218	2407.607	3407.412	371.542	26154.979	232.022
1,2,3,4,6,7,8-HpCDF	NA	67.368	1951.701	683.376	173.972	163.238	421.466	579.653	1617.347	59.695	6065.149	54.344
1,2,3,4,7,8,9-HpCDF	NA	4.226	68.289	43.759	11.841	10.675	31.611	45.128	116.955	9.421 U	296.912 U	13.489 U
OCDD	NA	5377	126172.735	153224.894	17031.057	60156.579	304146.498	28980.018	43508.543	2866.511	317675.38	1912
OCDF	NA	276.109	11456.75	6422.067	1173.87	1209.836	39422.173	2989.931	3494.816	309.311	50005.429	119.636
Total HpCDD	NA	887.063	18476.967	22450.187	1527.838	1780	43456.6	4163.527	36587.21 JL	642.762	45368.097	413.616
Total HpCDF	NA	71.594	1951.701	727.135	185.812	173.913	453.077	624.781	1734.302	59.695	6065.149	54.344
Total HxCDD	NA	62.162	819.708	787.195	140.106	130.297	380.781	367.808	1575.914	74.294	3910.667 JL	71.957
Total HxCDF	NA	113.917	1798.996	1170.426	179.308	174.872	472.93	515.453	2130.009	73.145	5865.605 JH	45.829
Total PeCDD	NA	0.568 U	5.595	13.393	6.313	1.249	9.851	11.086	18.403	4.369	83.798	2.598 U
Total PeCDF	NA	23.913	336.874	289.761	44.491	31.934	90.913	88.622	383.505	29.516	755.397	1.278 U
Total TCDD	NA	0.449 U	3.397	12.423	0.29 U	0.345 U	2.231	1.618	3.175	1.92	3.785	7.3
Total TCDF	NA	0.491 U	23.039	21.212	2.569	0.558	1.741	0.395 U	14.657	2.828	28.398	1.856 U

(a) - PSLs criteria are provided herein only as a reference point against which to compare on-site and background analyte concentrations.
(b) - Sample Concentrations above PSLs are shaded.
(c) - EPA "Ecotox Threshold Criteria," January 1996 and Ontario Ministry of the Environment, 1993.
(d) - State of Washington Department of Ecology, "Creation and Analysis of Freshwater Sediment Quality Values in Washington State," July 1997. Minimum of the available values.

Key:

EPA	= United States Environmental Protection Agency.
HpCDD	= Heptachlorodibenzo-p-dioxin.
HpCDF	= Heptachlorodibenzofuran.
HxCDD	= Hexachlorodibenzo-p-dioxin.
HxCDF	= Hexachlorodibenzofuran.
J	= The analyte was positively identified. The associated numerical result is an estimate.
JH	= The analyte was positively identified. The associated numerical result is an estimate, biased high.
JK	= The analyte was positively identified. The associated numerical result is an estimate, biased unknown.
JL	= The analyte was positively identified. The associated numerical result is an estimate, biased low.
JQ	= The result is estimated because it is below the Contract Required Detection Limit.
mg/kg	= Milligrams per kilogram.
ng/kg	= Nanograms per kilogram.
NA	= Not applicable.
OCDD	= Octachlorodibenzo-p-dioxin.
OCDF	= Octachlorodibenzofuran.
PeCDD	= Pentachlorodibenzo-p-dioxin.
PeCDF	= Pentachlorodibenzofuran.
PSLs	= Preliminary screening levels.
TCDD	= Tetrachlorodibenzo-p-dioxin.
TCDF	= Tetrachlorodibenzofuran.
TEQ	= Toxicity equivalency quotient.
TOC	= Total organic carbon.
U	= The material was analyzed for, but was not detected. The associated value is the sample quantitation limit.
UJ	= The material was analyzed for, but was not detected. The associated value is the estimated sample quantitation limit.
UJK	= The material was analyzed for, but was not detected. The associated value is the estimated sample quantitation limit, biased unknown.

Appendix C

Quality Assurance Information

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Table C-1. Recovery percentages for matrix spike (MS), matrix spike duplicate (MSD), and laboratory control sample (LCS).

Analyte	MS recovery (%)	MSD recovery (%)	MS/MSD RPD	LCS recovery (%)
4-Nitroaniline	107	108	1%	110
4-Nitrophenol	82	66	22%	82
Benzyl Alcohol	102	96	6%	109
4-Bromophenyl-Phenylether	96	97	1%	98
2,4-Dimethylphenol	103	102	1%	54
4-Methylphenol	99	91	8%	92
1,4-Dichlorobenzene	64	62	3%	74
4-Chloroaniline	0.6*	1.3*	74%	32*
2,2'-Oxybis[1-chloropropane]	67	62	8%	68
Phenol	107	91	16%	94
Pyridine	6.1*	6.1*	0%	4.3*
Bis(2-Chloroethyl)Ether	83	77	8%	82
Bis(2-Chloroethoxy)Methane	89	88	1%	86
Bis(2-Ethylhexyl) Phthalate	97	89	9%	114
Di-N-Octyl Phthalate	256*	237*	8%	116
Hexachlorobenzene	88	85	3%	88
Anthracene	21*	470*	183%	80
1,2,4-Trichlorobenzene	76	77	1%	76
2,4-Dichlorophenol	100	104	4%	98
2,4-Dinitrotoluene	65	58	11%	92
1,2-Diphenylhydrazine	89	84	6%	90
Pyrene	51	223*	126%	91
Dimethylphthalate	98	106	8%	95
Dibenzofuran	61	70	14%	92
Benzo(ghi)perylene	12*	31*	88%	90
Indeno(1,2,3-cd)pyrene	25*	59	81%	101
Benzo(b)fluoranthene	142	303*	72%	94
Fluoranthene	46*	224*	132%	88
Benzo(k)fluoranthene	NC	166*		84
Acenaphthylene	83	92	10%	80
Chrysene	NC	334*		89
Benzo(a)pyrene	38*	166*	125%	81
2,4-Dinitrophenol	0*	0*		62
4,6-Dinitro-2-Methylphenol	13*	0*	200%	67
Dibenzo(a,h)anthracene	37*	53	36%	98
1,3-Dichlorobenzene	64	62	3%	73
Benzo(a)anthracene	46*	516*	167%	96
4-Chloro-3-Methylphenol	99	92	7%	102
2,6-Dinitrotoluene	72	66	9%	94
N-Nitroso-Di-N-Propylamine	92	83	10%	92
Aniline	143	80	57%	95
N-Nitrosodimethylamine	65	72	10%	NAF
Benzoic Acid	50	26*	63%	96
Hexachloroethane	12*	11*	9%	77
4-Chlorophenyl-Phenylether	91	90	1%	91

Analyte	MS recovery (%)	MSD recovery (%)	MS/MSD RPD	LCS recovery (%)
Hexachlorocyclopentadiene	0*	0*		43*
Isophorone	103	108	5%	104
Acenaphthene	75	83	10%	84
Diethylphthalate	90	92	2%	90
Di-N-Butylphthalate	86	88	2%	98
Phenanthrene	4.2*	175*	191%	94
Butylbenzylphthalate	134	133	1%	116
N-Nitrosodiphenylamine	89	96	8%	100
Fluorene	45*	91	68%	90
Carbazole	81	134	49%	94
Hexachlorobutadiene	72	73	1%	74
Pentachlorophenol	45*	61	30%	72
2,4,6-Trichlorophenol	92	87	6%	84
2-Nitroaniline	96	98	2%	100
2-Nitrophenol	78	76	3%	93
Naphthalene	72	77	7%	76
2-Methylnaphthalene	88	90	2%	87
2-Chloronaphthalene	86	86	0%	82
3,3'-Dichlorobenzidine	13*	0*	200%	170*
Benzidine	70	0*	200%	0*
2-Methylphenol	102	90	13%	92
1,2-Dichlorobenzene	68	65	5%	74
2-Chlorophenol	95	90	5%	88
2,4,5-Trichlorophenol	96	94	2%	92
Nitrobenzene	80	78	3%	83
3-Nitroaniline	107	108	1%	110
Mean (%)	74	102		87

MS and MSD recovery values are corrected for initial analyte concentrations present in the field sample. Samples used for MS/MSD recovery analysis are from station LSC02.

RPD = relative percent difference

* = exceeds method performance limit (50-150%)

NC = not calculated

NAF = not analyzed for

Table C-2. Blind Field Duplicate Results for Station LSC02.

Analyte	Sample Number 03394041		03394046		RPD
Percent solids	65.1		69.1		6%
% Total organic carbon	1.97		1.56		23%
Grain size (%):					
Gravel	13.2		37.7		96%
Sand	78.6		57.1		32%
Silt	5.9		4.1		36%
Clay	2.4		1.1		74%
SVOCs (ug/Kg dw)					
PAHs					
1-Methylnaphthalene	148		104		35%
2-Methylnaphthalene	157		109		36%
Acenaphthene	328		221		39%
Acenaphthylene	159		161		1%
Anthracene	1,740	J	1,350		25%
Benzo(a)anthracene	2,280	J	1,980		14%
Benzo(a)pyrene	2,580	J	1,890		31%
Benzo(b)fluoranthene	3,050	J	2,190		33%
Benzo(ghi)perylene	656	J	396	J	49%
Benzo(k)fluoranthene	2,020	J	1,650	J	20%
Chrysene	5,240	J	4,140		23%
Dibenzo(a,h)anthracene	378	J	264	J	36%
Fluoranthene	3,380	J	3,290		3%
Fluorene	952		433		75%
Indeno(1,2,3-cd)pyrene	970	J	672	J	36%
Naphthalene	187		116		47%
Phenanthrene	1,580	J	770		69%
Pyrene	3,050	J	2,730		11%
Phenols					
2,4,5-Trichlorophenol	48	U	47	U	
2,4,6-Trichlorophenol	48	U	47	U	
2,4-Dimethylphenol	27		19	J	35%
2-Methylphenol	20		16		22%
4-Methylphenol	118		101		16%
Pentachlorophenol	1,370	J	1,150		17%
Phenol	86		110		24%
Phthalates					
Bis(2-Ethylhexyl) Phthalate	1,120	J	1,010	J	10%
Dimethylphthalate	783		3,050		118%
Butylbenzylphthalate	151	J	192	J	24%
Other					
3B-Coprostanol	242	UJ	236	UJ	
Benzoic Acid	1,340	J	1,140	J	16%
Benzyl Alcohol	147		159		8%

Analyte	Sample Number 03394041		03394046		RPD
Carbazole	306	J	124	J	85%
Dibenzofuran	584		157		115%
Hexachlorobenzene	12	U	12	U	
Hexachloroethane	24	UJ	24	U	
N-Nitrosodiphenylamine	173	NJ	12	U	
Retene	24	U	24	U	

RPD - Relative percent difference
U - The analyte was not detected at or above the reported value.
J - The analyte was positively identified. The associated numerical value is an estimate.
UJ - The analyte was not detected at or above the reported estimated result.
NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive E, Port Orchard Washington 98366

CASE NARRATIVE

October 30, 2003
January 26, 2004

Subject: Little Squalicum Bio

Samples: 03-394040 to -394048

Project. 199403

Officer: Nigel Blakely

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE COMPOUNDS

Analytical Method(s)

The semivolatile sediment samples were prepared by Soxhlet extraction with acetone following the Manchester modification of the EPA SW 846 8270 with capillary GC/MS analysis of the sample extracts. Normal QA/QC was performed with the sample analysis.

Holding Times

All analysis-holding times were within the recommended limits.

Instrument Tuning

Calibration against DFTPP is acceptable for the initial calibration, continuing calibration and all associated sample analyses.

Calibration

The average relative response factors for target analytes were above the minimums and % Relative Standard Deviations were within the maximum of 15% for the initial calibration except for benzoic acid, benzidine and 2,4-dinitrophenol. Three compounds, benzoic acid, carbazole and coprostanol only had four point calibration curves and all results are “J” qualified.

The October 28th continuing calibration response factors for target analytes were above the minimums and % Relative Standard Deviations were within the maximum of 20% except for carbazole and hexachlorocyclopentadiene which were low. All of these compounds were 'J' qualified. Several compounds, 2-nitrophenol, benzoic acid, 3-nitroaniline, 4-nitroaniline, benzidine, butylbenzylphthalate, 3, 3-dichlorobenzidine, bis-(2-ethylhexyl) phthalate and coprostanol had high responses but were only qualified if detected.

The October 29th continuing used for the dilutions was acceptable except for pentachlorophenol which was low and dibenzo(ah)anthracene which was high. These compounds were "J" qualified if detected and reported in the dilutions.

Blanks

Several target compounds were detected in the laboratory blanks. These included phenol, benzoic acid, acenaphthylene, diethylphthalate, phenanthrene, fluoranthene, butylbenzylphthalate, bis-2-(ethylhexyl) phthalate and di-n-butylphthalate. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample were greater than or equal to five times the area counts of the compounds in the associated method blank.

Surrogates

The surrogate recoveries were reasonable, acceptable, and within QC limits of 25% to 121% for 2-fluorophenol, 24% -113% for d5-phenol, 20% to 130% for d4-2-chlorophenol and d4-1,2-dichlorbenzene, 23%-120% for d5-nitrobenzene, 30% to 115% for 2-fluorobiphenyl, 18% to 137% for d14-terphenyl, and 50% to 150% for d10-pyrene except for d5-phenol 124% and d14-terphenyl 194% in sample -394042. Since the other surrogates were acceptable no additional qualifiers were added. Due to matrix interferences d10-pyrene recovery could not be calculated for this sample and it is reported as "NC' not calculated.

Matrix Spikes

A pair of matrix spikes taken from separate jars was analyzed. Most target recoveries were within acceptable limits except for hexachloroethane, 1, 2-diphenylhydrazine, carbazole, and 3, 3'-dichlorobenzidine. Results for these compounds were "J" qualified. A number of PAH's were out due to matrix interference and high native amounts. These were acceptable in the Lab fortified blank so no qualifiers were added.

Three compounds, hexachlorocyclopentadiene and 4-chloroaniline, 4, 6-dinitro-2methylphenol, 2, 4 dinitrophenol, benzidine and 3, 3-dichlorobenzidine were not recovered in the matrix spikes and all results for these compounds were rejected, "REJ" in the matrix spike sample, 394041.

The relative percent differences (RPD) exceeded 40% for some compounds, aniline, 4-chloraniline and 4, 6-dinitro-2methylphenol. Several other compounds had RPD's >40% but these were possibly due to high native amounts compared to the amount spiked, interferences from hydrocarbons or the fact that separate sample jars were used for the matrix pike and matrix spike duplicate.

Two compounds had significant differences between the matrix spike and matrix spike duplicate. These were di-n-octylphthalate and benzo(k) fluoranthene. These differences were probably due to matrix interference from hydrocarbons present in the sample.

Replicates

Not applicable

Laboratory Control Samples

Laboratory fortified blank (LFB) recoveries were acceptable except for, pyridine, 4-chloroaniline benzidine, 3,3'dichlorobenzidine and hexachlorocyclopentadiene were low and all results for these compounds qualified "J " as estimates.

Comments

The sediments were heavily contaminated with hydrocarbons which interfered in the analysis and resulted in higher reporting limits. This also required dilution or multiple dilutions to bring the concentrations into the calibration range of the instrument.

All results for sample -394042 (undiluted) beginning with nitrobenzene to benzo(ghi)perylene were "J" qualified due to low internal standard area counts resulting from the high hydrocarbon interferences.

The last dilution ran on sample -394042 (DIL3) was analyzed after the 40mday extract time had expired. Consequently all results for that analysis are qualified "J" as estimates.

No other significant problems were encountered in the analysis. The data is acceptable as qualified

DATA QUALIFIER CODES:

U	The analyte was not detected at or above the reported value.
J	The analyte was positively identified. The associated numerical value is an estimate.
UJ	The analyte was not detected at or above the reported estimated result.
REJ	The data are unusable for all purposes.
NAF	Not analyzed for.
N	For organic analytes there is evidence the analyte is present in this sample.
NJ	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
Bold	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Appendix D

Cluster Analysis

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Cluster Analysis

Grouping of analytes using cluster analysis was conducted to simplify the data presentation in this report, and the method described below may not be appropriate or acceptable for making regulatory decisions. Hierarchical clustering of the SVOC analysis data (Table 4) was conducted using SYSTAT Version 10. For non-detect results, half the detection limit was substituted (WAC 173-340-740(7)(f)(i)). The single linkage joining algorithm was used, and distances were computed using 1 minus the Pearson product-moment correlation coefficient for each pair of analytes.

Figure D-1 shows the resulting cluster tree and the two clusters at the 0.1 linkage distance, labeled SVOC1 and SVOC2.

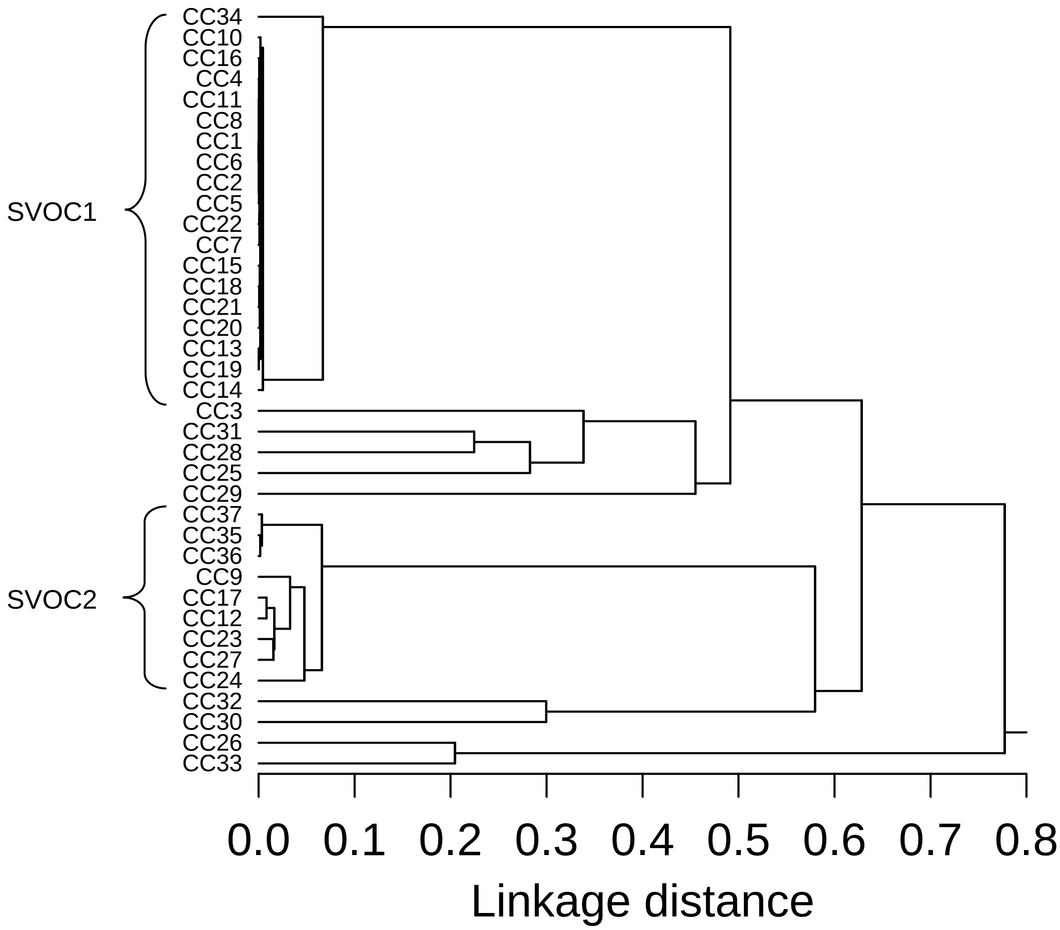

Figure D-1. Chemical groupings identified through cluster analysis applied to SVOC data in Table 4.

Names of chemicals labeled CC1-CC37 are given in Table D-1. Distances represent 1 minus the Pearson product-moment correlation coefficient (r) for each pair of analytes.

Within groupings SVOC1 and SVOC2, chemical concentrations were highly correlated across sampling locations. Clusters are apparent at linkage distance = 0.1 (r = 0.9).

Table D-1. Key to chemical codes in cluster tree shown in Figure D-1.

Code	Analyte	SVOC1 group	SVOC2 group
CC1	Pyrene	X	
CC2	Phenanthrene	X	
CC3	Pentachlorophenol		
CC4	Naphthalene	X	
CC5	Fluorene	X	
CC6	Fluoranthene	X	
CC7	Anthracene	X	
CC8	Acenaphthene	X	
CC9	4-Methylphenol		X
CC10	2-Methylnaphthalene	X	
CC11	1-Methylnaphthalene	X	
CC12	Phenol		X
CC13	Indeno(1,2,3-cd)pyrene	X	
CC14	Dibenzo(a,h)anthracene	X	
CC15	Chrysene	X	
CC16	Carbazole	X	
CC17	Benzyl Alcohol		X
CC18	Benzo(k)fluoranthene	X	
CC19	Benzo(ghi)perylene	X	
CC20	Benzo(b)fluoranthene	X	
CC21	Benzo(a)pyrene	X	
CC22	Benzo(a)anthracene	X	
CC23	2-Methylphenol		X
CC24	2,4-Dimethylphenol		X
CC25	Dimethylphthalate		
CC26	Dibenzofuran		
CC27	Benzoic Acid		X
CC28	Acenaphthylene		
CC29	Bis(2-Ethylhexyl) Phthalate		
CC30	Retene		
CC31	Butylbenzylphthalate		
CC32	Hexachlorobenzene		
CC33	N-Nitrosodiphenylamine		
CC34	3B-Coprostanol	X	
CC35	Hexachloroethane		X
CC36	2,4,6-Trichlorophenol		X
CC37	2,4,5-Trichlorophenol		X

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Appendix E

Bioassays

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Toxicity Evaluation of Squallicum Creek Sediments

Prepared for
Washington State Department of Ecology
Manchester Laboratory
7411 Beach Drive East
Manchester, WA 98366-8204

Prepared by
AMEC Earth & Environmental
Northwest Bioassay Laboratory
5009 Pacific Hwy. E., Suite 2
Fife, WA 98424
253-922-4296

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Introduction

As part of an environmental program being conducted by the Washington State Department of Ecology, toxicity tests were conducted on freshwater sediment collected from Squallicum Creek, located in Bellingham, Washington. Sediment toxicity tests were performed using the amphipod *Hyalella azteca* (10-day exposure), the larval midge *Chironomus tentans* (20-day exposure) and the bacterium *Vibrio fischeri*. This report documents the results of these tests.

Methods and Materials

Sediment samples were collected on 25 September 2003 and received the day of collection. Samples were held in the dark at 4 ± 2°C prior to initiation of the tests.

The sediments were identified as follows:

Station ID	Sample ID
LSC-01	394040
LSC-02	394041
LSC-03	394042
LSC-04	394043
LSC-05	394044
LSC-06	394045

The *H. azteca* test was conducted according to procedures described in USEPA (2000) and ASTM (2000), and summarized in Table 1. This test involves a 10-day exposure of the test species to whole sediments, after which the organisms are evaluated for survival and growth.

The *C. tentans* test was conducted according to procedures described in USEPA (2000) and ASTM (2000). These procedures are summarized in Table 2. The test organisms were exposed to the whole sediments for 20 days, and were evaluated for survival and growth at the end of the test period. The weight of sediment remaining in the gut of *C. tentans* at test termination can misrepresent the actual growth of the organisms. Consequently, ash-free dry weight (AFDW) of the larvae was measured and tissue weight of the larvae was determined by subtracting the AFDW from the dried weight.

Microtox® tests were conducted in accordance with WDOE (2003) and the procedures are summarized in Table 3. This test involves an evaluation of inhibition of light emission by the bacterium *V. fischeri* following an exposure to porewater for five and fifteen minute periods. Sediment LSC-06 was too dry to extract porewater. Sample for the Microtox test was prepared by mixing 500 milliliters (ml) of moderately hard synthetic water with 500-ml sample, held at 25°C for 24 hours, and then prepared following the WDOE method.

Ammonia was measured in the overlying water in the water quality replicate of each sample at the beginning and end of the *H. azteca* and *C. tentans* tests, as well as at 5-day intervals during the *C. tentans* test. Ammonia was also measured in the interstitial water at test initiation for each of the three test species.

Reference toxicant tests using copper chloride ($CuCl_2$) were conducted for *H. azteca* and *C. tentans* and using phenol for Microtox to determine whether the sensitivity of the test organisms was appropriate.

Statistical Analyses

Statistical analyses were performed using GraphPad Prism software, Version 3.0. Multiple comparison procedures using a one-tailed t-test were used to assess differences between the control and each sample. Prior to the analysis, deviations from a normal distribution of the data were evaluated using the Kolmogorov-Smirnov test. Survival data, expressed as a percentage, were arcsine square root transformed prior to analysis to normalize the distribution of the data and satisfy statistical assumptions of the method. Growth data expressed as milligrams (mg) growth per organism and bacterial luminescence were not transformed prior to analysis.

Maximum Likelihood-Probit analyses were used to calculate the median lethal concentration (LC_{50}) values and associated confidence intervals for reference toxicant tests using ToxCalc Comprehensive Toxicity Data Analysis and Database Software, Version 5.0.

Table 1. Summary of testing conditions for the10-d *H. azteca* test.

Test initiation date	3 October 2003
Test organism source	Aquatic BioSystems; Fort Collins, Colorado
Organism age at test initiation	11-13 days
Feeding	1 ml of Tetramin mixture every 2 to 3 days; frequency reduced if excess food observed
Test chamber	300-ml glass beaker
Test sediment depth	2 centimeters
Dilution water type & volume	250 ml Moderately Hard Synthetic Water (MHSW)
Control sediment	Sand mixed with peat (2% by weight)
Number of organisms/replicate	20
Number of replicates/sample	5
Test temperature	23 ± 1ºC
Illumination	16 hours light : 8 hours dark
Aeration	Continuous, approximately 3 bubbles/second
Reference toxicant	Copper chloride

Table 2. Summary of testing conditions for the 20-d *C. tentans* test.

Test initiation date	3 October 2003
Test organism source	Aquatic BioSystems; Fort Collins, Colorado
Organism age at test initiation	2 days post hatch, 1^{st} instar
Feeding	1 ml of Tetramin mixture every 2 to 3 days; frequency reduced if excess food observed
Test chamber	300-ml glass beaker
Test sediment depth	2 centimeters
Dilution water type & volume	250 ml Moderately Hard Synthetic Water (MHSW)
Control sediment	Sand mixed with peat (2% by weight)
Number of organisms/replicate	10
Number of replicates/sample	5
Test temperature	20 ± 1ºC
Illumination	16 hours light : 8 hours dark
Aeration	Continuous, approximately 3 bubbles/second
Reference toxicant	Copper chloride

Table 3. Summary of testing conditions for the Microtox test.

Test date	16 October 2003
Test organism source	Strategic Diagnostics
Batch number and expiration date	Lot # 3B2159, Expiration date 03/05
Control	Salt water (20 ppt) prepared with 40 Fathoms Sea Salts
Sample preparation	Centrifugation at 3500 G for 30 minutes; salinity adjustment to 20 ppt using 40 Fathoms Sea Salts; pH adjustment to 7.8 – 8.2 with HCl or NaOH
Test chamber	Glass cuvette
Test volume	1 mL
Volume of inoculum/replicate	10 µL
Number of replicates/sample	5
Test temperature	15 ± 1ºC
Aeration	None
Reference toxicant	Phenol

Results

Results of toxicity tests conducted using *H. azteca*, *C. tentans* and Microtox are summarized in Tables 4, 5 and 6 and results of ammonia measurements conducted during these tests are provided in Table 7. A summary of the data is in Appendix A. Water quality data, reference toxicant data, and chain-of-custody forms are provided in Appendices B, C, and D, respectively.

QA/QC

Control acceptability criteria were met for all three of the toxicity tests. There were no deviations from the test protocols and water quality parameters remained within the ranges specified in the corresponding protocols in all tests.

Results from reference toxicant tests for all three test species fell within the corresponding acceptable ranges of historical sensitivity (mean ± 2 standard deviations) for previous tests conducted in this laboratory. Thus, the data from these tests indicate that the sensitivity of the test organisms used in this study was appropriate. Data from these tests are provided in Appendix C.

Table 4. Mean and standard deviation for survival and growth of *H. azteca*. Shaded data indicates significant differences (p<0.05) relative to the control.

Sample	Survival (%)			Growth (mg/organism)		
Control	88.0	±	11.0	0.16	±	0.03
LSC-01	80.0	±	7.1	0.08	±	0.02
LSC-02	79.0	±	13.9	0.06	±	0.02
LSC-03	0	±	0	Not applicable		
LSC-04	70.0	±	15.0	0.08	±	0.02
LSC-05	84.0	±	10.2	0.11	±	0.01
LSC-06	67.0	±	5.7	0.09	±	0.02

Table 5. Mean and standard deviation for survival and growth of *C. tentans*. Shaded data indicates significant differences (p<0.05) relative to the control.

Sample	Survival (%)			Growth (mg/organism)		
Control	96.0	±	5.5	1.04	±	0.25
LSC-01	86.0	±	8.9	1.56	±	0.35
LSC-02	60.0	±	15.8	1.82	±	0.37
LSC-03	0.0	±	0.0	Not applicable		
LSC-04	80.0	±	21.2	2.01	±	0.51
LSC-05	84.0	±	21.9	1.93	±	0.36
LSC-06	82.0	±	23.9	2.11	±	0.36

Table 6. Mean and standard deviation light output in Microtox tests. Shaded data indicates significant differences (p<0.05) relative to the control.

Sample	Percent light output at I_5			Percent light output at I_{15}		
Test 1						
Control	96.2	±	0.7	89.3	±	1.9
LSC-01	96.6	±	1.8	90.2	±	0.9
LSC-02	97.8	±	1.3	92.3	±	1.2
LSC-03	34.8	±	2.0	36.9	±	2.7
Test 2						
Control	98.2	±	0.9	93.3	±	0.6
LSC-01	98.6	±	1.1	92.1	±	1.6
LSC-04	99.1	±	1.6	96.0	±	1.9
LSC-05	76.1	±	10.8	72.9	±	10.2
LSC-06	74.1	±	6.6	72.9	±	6.6

Table 7. Total ammonia measurements in interstitial water (IW) and overlying water (OW) in *H. azteca*, *C. tentans* and Microtox tests.

	10-day *H. azteca*			20-day *C. tentans*						Microtox
	IW	OW Day 0	OW Day 10	IW	OW Day 0	OW Day 5	OW Day 10	OW Day 15	OW Day 20	IW
Control	NT	1.2	5.7	NT	1.2	2.6	4.0	6.1	8.9	NT
LSC-01	0.9	0.8	0.9	0.9	<1.0	2.0	1.0	1.2	<1.0	0.9
LSC-02	1.1	1.0	1.0	1.0	1.1	1.4	<1.0	<1.0	<1.0	1.1
LSC-03	1.2	0.9	3.8	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	1.2
LSC-04	0.7	1.2	1.0	0.7	1.2	1.2	<1.0	<1.0	<1.0	0.7
LSC-05	2.4	1.9	7.0	2.4	1.9	1.7	1.0	<1.0	1.1	2.4
LSC-06	NT	1.1	0.8	NT	1.1	1.4	<1.0	<1.0	<1.0	NT

NT Not tested. Note that for sample LSC-06 ammonia was not tested in the interstitial water because the sediment was too dry.

References

American Society of Testing and Materials (ASTM). 2000. Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates. ASTM Designation E 1706-00.

U.S. Environmental Protection Agency (USEPA). 2000. Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. EPA/600/R-99/064.

Washington Department of Ecology (WDOE). 2003. Microtox® 100 Percent Sediment Porewater Toxicity Assessment. 15 January 2003.

APPENDIX A

RESULT SUMMARIES

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Hyalella azteca

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Appendix Table A-1. 10-Day Solid Phase Amphipod Survival & Growth (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Initiated 03 October 2003

Site	Replicate	# Alive	% Survival	Mean % Survival	Growth per Org (mg)	Mean Growth per Org (mg)	Compared to Control p-values [a] Survival	Compared to Control p-values [a] Growth	Compared to Reference p-values [a] Survival	Compared to Reference p-values [a] Growth
	1	18	90		0.137					
	2	14	70		0.204					
Control	3	18	90	88	0.129	0.155				
	4	20	100		0.148					
	5	18	90		0.159					
	1	15	75		0.076					
LSC-01	2	17	85		0.097					
Reference	3	15	75	80	0.063	0.077	0.091	**<0.001**		
Sediment	4	15	75		0.058					
	5	18	90		0.089					
	1	17	85		0.081		0.208	**<0.001**	0.445	**0.043**
	2	14	70		0.060					
LSC-02	3	13	65	79	0.055	0.057				
	4	15	75		0.048					
	5	20	100		0.039					
	1	0	0		-					
	2	0	0		-					
LCS-03	3	0	0	0	-	NA	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	4	0	0		-					
	5	0	0		-					
	1	11	55		0.115					
	2	17	85		0.089					
LSC-04	3	14	70	70	0.066	0.084	**0.029**	**<0.001**	0.107	---
	4	11	55		0.082					
	5	17	85		0.069					
	1	20	100		0.095					
	2	17	85		0.125					
LCS-05	3	15	75	84	0.108	0.114	0.327	**0.017**	---	---
	4	15	75		0.129					
	5	17	85		0.110					
	1	13	65		0.071					
	2	15	75		0.071					
LSC-06	3	12	60	67	0.094	0.086	**0.015**	**0.001**	**0.006**	---
	4	13	65		0.111					
	5	14	70		0.082					

[a] One-tailed t-test. Survival data arcsine square-root transformation prior to t-test.
NA-Not Available
--- Site response greater than control or reference sediment response.

Initial Weights

	# org.	Tare Wgt (mg)	Total Wgt. (mg)	Weight per Org (mg)	Mean Weight (mg)
1	10	568.28	568.95	0.067	
2	10	578.98	579.50	0.052	
3	10	585.79	586.21	0.042	
4	10	569.47	569.83	0.036	
5	10	607.59	607.98	0.039	0.047

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Chironomus tentans

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Appendix Table A-2. 20-Day Solid Phase Midge Larvae Survival & Growth (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Initiated 03 October 2003

Site	Replicate	Survival: # Alive	Survival: % Survival	Survival: Mean % Survival	Growth: Weight per Org (mg)	Growth: Mean Weight per Org (mg) [a]	Compared to Control p-values [b]: Survival	Compared to Control p-values [b]: Growth	Compared to Reference p-values [b]: Survival	Compared to Reference p-values [b]: Growth
Control	1	9	90	96	0.656	1.044				
	2	10	100		1.064					
	3	10	100		1.349					
	4	9	90		1.006					
	5	10	100		1.147					
LSC-01 Reference Sediment	1	10	100	86	1.051	1.564	0.052	---		
	2	8	80		1.675					
	3	8	80		1.924					
	4	8	80		1.794					
	5	9	90		1.374					
LSC-02	1	5	50	60	2.448	1.824	**0.001**	---	**0.006**	---
	2	8	80		1.833					
	3	7	70		1.533					
	4	4	40		1.698					
	5	6	60		1.608					
LSC-03	1	0	0	0	-	NA	**<0.001**	**<0.001**	**<0.001**	**<0.001**
	2	0	0		-					
	3	0	0		-					
	4	0	0		-					
	5	0	0		-					
LSC-04	1	10	100	80	2.377	2.005	0.100	---	0.288	---
	2	7	70		2.031					
	3	10	100		1.289					
	4	8	80		1.753					
	5	5	50		2.576					
LSC-05	1	6	60	84	2.303	1.927	0.210	---	0.427	---
	2	10	100		1.496					
	3	10	100		1.849					
	4	10	100		1.688					
	5	6	60		2.298					
LSC-06	1	9	90	82	1.681	2.113	0.093	---	0.370*	---
	2	9	90		2.334					
	3	9	90		2.082					
	4	10	100		1.877					
	5	4	40		2.590					

[a] Larvae were 2 days old at test initiation and weight was below detection limit.
[b] One-tailed t-test. Survival data arcsine square-root transformation prior to t-test.
--- Site response greater than control or reference sediment response.
* Unequal variance. Welch's correction applied.

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MICROTOX

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Appendix Table A-3a. Microtox 100 Percent Sediment Porewater Test
Squallicum Creek
Washington State Department of Ecology
Test Date: 16 October 2003

Site	Light Reading									Change in light readings compared to initial control	Change in light readings compared to final control	Evaluation of initial light output
	Replicate											
	Reading	1	2	3	4	5	Mean	$T_{(mean)}/R_{(mean)}$	$T_{(mean)}/C_{(mean)}$	$I_{(t)(mean)}/I_{(0)C(mean)}$	$I_{(t)(mean)}/I_{(t)C(mean)}$	$I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	96	109	107	111	111	107					
	$I_{(5)}$	92	105	102	108	107	103			0.96		
	$I_{(15)}$	84	98	93	101	101	95			0.89		
	$C_{(5)}$	0.96	0.96	0.95	0.97	0.96	0.96					
	$C_{(15)}$	0.88	0.90	0.87	0.91	0.91	0.89					
LSC-01 Reference Sediment	$I_{(0)}$	102	96	81	82	97	92					0.86
	$I_{(5)}$	96	95	79	79	93	88				0.86	
	$I_{(15)}$	91	88	73	74	87	83				0.87	
	$R_{(5)}$	0.94	0.99	0.98	0.96	0.96	0.97					
	$R_{(15)}$	0.89	0.92	0.90	0.90	0.90	0.90					
LSC-02	$I_{(0)}$	111	96	96	92	96	98					0.92
	$I_{(5)}$	108	94	92	91	95	96					
	$I_{(15)}$	101	88	88	86	90	91					
	$T_{(5)}$	0.97	0.98	0.96	0.99	0.99	0.98	1.01	1.02			
	$T_{(15)}$	0.91	0.92	0.92	0.93	0.94	0.92	1.02	1.03			
LSC-03	$I_{(0)}$	33	37	38	38	35	36					0.34
	$I_{(5)}$	34	38	39	39	36	37					
	$I_{(15)}$	35	41	42	41	38	39					
	$T_{(5)}$	0.32	0.36	0.37	0.37	0.34	0.35	0.36	0.36			
	$T_{(15)}$	0.33	0.38	0.39	0.38	0.36	0.37	0.41	0.41			

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?

   $I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=96%

   $I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=89%

Control results are acceptable

2. Does the reference final mean exceed 80% of control final mean?

   $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=86%

   $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=87%

Reference site results are acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?

   $I_{R(mean)}/I_{C(mean)}$=86%

Reference initial mean used to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?

   LSC-02: $I_{T(mean)}/I_{C(mean)}$=92%, use to calculate change in light readings.

   LSC-03: $I_{T(mean)}/I_{C(mean)}$)=34%, use control initial mean readings to calculate change in light readings.

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Appendix Table A-3b. Microtox 100 Percent Sediment Porewater Test
Squallicum Creek
Washington State Department of Ecology
Test Date: 16 October 2003

Site	Light Reading									Change in light readings compared to initial control	Change in light readings compared to final control	Evaluation of initial light output
	Replicate											
	Reading	1	2	3	4	5	Mean	$T_{(mean)}/R_{(mean)}$	$T_{(mean)}/C_{(mean)}$	$I_{(t)(mean)}/I_{(0)C(mean)}$	$I_{(t)(mean)}/I_{(t)C(mean)}$	$I_{(0)(mean)}/I_{(0)C(mean)}$
Control	$I_{(0)}$	95	81	111	111	112	102					
	$I_{(5)}$	93	79	110	108	111	100			0.98		
	$I_{(15)}$	88	75	104	104	105	95			0.93		
	$C_{(5)}$	0.98	0.98	0.99	0.97	0.99	0.98					
	$C_{(15)}$	0.93	0.93	0.94	0.94	0.94	0.93					
LSC-01 Reference Sediment	$I_{(0)}$	100	80	109	84	80	91					0.89
	$I_{(5)}$	100	78	108	83	78	89				0.89	
	$I_{(15)}$	92	74	103	77	72	84				0.88	
	$R_{(5)}$	1.00	0.98	0.99	0.99	0.98	0.99					
	$R_{(15)}$	0.92	0.93	0.94	0.92	0.90	0.92					
LSC-04	$I_{(0)}$	82	95	79	86	88	86					0.84
	$I_{(5)}$	79	94	79	86	88	85					
	$I_{(15)}$	76	92	77	83	85	83					
	$T_{(5)}$	0.96	0.99	1.00	1.00	1.00	0.99	1.00	1.01			
	$T_{(15)}$	0.93	0.97	0.97	0.97	0.97	0.96	1.04	1.03			
LSC-05	$I_{(0)}$	62	78	90	75	85	78					0.76
	$I_{(5)}$	61	77	89	75	86	78					
	$I_{(15)}$	58	73	84	74	83	74					
	$T_{(5)}$	0.60	0.75	0.87	0.74	0.84	0.76	0.77	0.77			
	$T_{(15)}$	0.57	0.72	0.82	0.73	0.81	0.73	0.79	0.78			
LSC-06	$I_{(0)}$	78	84	70	77	67	75					0.74
	$I_{(5)}$	76	84	70	80	68	76					
	$I_{(15)}$	73	84	70	78	67	74					
	$T_{(5)}$	0.75	0.82	0.69	0.78	0.67	0.74	0.75	0.75			
	$T_{(15)}$	0.72	0.82	0.69	0.76	0.66	0.73	0.79	0.78			

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

Quality Control Steps:

1. Is control final mean output greater than 72% control initial mean output?

   $I_{(5)}$: $F_{c(mean)}/I_{c(mean)}$=98%

   $I_{(15)}$: $F_{c(mean)}/I_{c(mean)}$=93%

Control results are acceptable.

2. Does the reference final mean exceed 80% of control final mean?

   $I_{(5)}$: $F_{R(mean)}/F_{C(mean)}$=89%

   $I_{(15)}$: $F_{R(mean)}/F_{C(mean)}$=88%

Reference site results are acceptable to be used in statistical analyses.

3. Is the reference initial mean > 80% of control initial mean?

   $I_{R(mean)}/I_{C(mean)}$=89%

Reference initial mean used to calculate change in light readings at $I_{(5)}$ and $I_{(15)}$ for reference site.

4. Are test initial mean values > 80% of control initial mean values?

   LSC-04: $I_{T(mean)}/I_{C(mean)}$=84%, use to calculate change in light readings.

   LSC-05: $I_{T(mean)}/I_{C(mean)}$)=76%, use control initial mean readings to calculate change in light readings.

   LSC-06: $I_{T(mean)}/I_{C(mean)}$=74%, use control initial mean readings to calculate change in light readings.

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Appendix Table A-3c. Microtox 100 Percent Sediment Porewater Test
Squallicum Creek
Washington State Department of Ecology
Test Date: 16 October 2003

Site	Reading	Light Reading Replicate 1	2	3	4	5	Mean	p-values Compared to Control	p-values Compared to Reference Site	Relative Percent Difference Compared to Control	Relative Percent Difference Compared to Reference Site
Control	$I_{(0)}$	96	109	107	111	111	107				
	$I_{(5)}$	92	105	102	108	107	103				
	$I_{(15)}$	84	98	93	101	101	95				
	$C_{(5)}$	0.96	0.96	0.95	0.97	0.96	0.96				
	$C_{(15)}$	0.88	0.90	0.87	0.91	0.91	0.89				
LSC-01 Reference Sediment	$I_{(0)}$	102	96	81	82	97	92				
	$I_{(5)}$	96	95	79	79	93	88				
	$I_{(15)}$	91	88	73	74	87	83				
	$R_{(5)}$	0.94	0.99	0.98	0.96	0.96	0.97	---		-0.3	
	$R_{(15)}$	0.89	0.92	0.90	0.90	0.90	0.90	---		-1.0	
LSC-02	$I_{(0)}$	111	96	96	92	96	98				
	$I_{(5)}$	108	94	92	91	95	96				
	$I_{(15)}$	101	88	88	86	90	91				
	$T_{(5)}$	0.97	0.98	0.96	0.99	0.99	0.98	---	---	-1.6	-1.6
	$T_{(15)}$	0.91	0.92	0.92	0.93	0.94	0.92	---	---	-3.4	-3.4
LSC-03	$I_{(0)}$	33	37	38	38	35	36				
	$I_{(5)}$	34	38	39	39	36	37				
	$I_{(15)}$	35	41	42	41	38	39				
	$T_{(5)}$	0.32	0.36	0.37	0.37	0.34	0.35	**<0.001**	**<0.001**	63.8	63.9
	$T_{(15)}$	0.33	0.38	0.39	0.38	0.36	0.37	**<0.001**	**<0.001**	58.7	59.1

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

* Unequal Variance. Welch's correction applied

--- Site response greater than Control or reference sediment response.

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Appendix Table A-3d. Microtox 100 Percent Sediment Porewater Test
Squallicum Creek
Washington State Department of Ecology
Test Date: 16 October 2003

Site	Light Reading							p-values		Relative Percent Difference	
		Replicate									
	Reading	1	2	3	4	5	Mean	Compared to Control	Compared to Reference Site	Compared to Control	Compared to Reference Site
Control	$I_{(0)}$	95	81	111	111	112	102				
	$I_{(5)}$	93	79	110	108	111	100				
	$I_{(15)}$	88	75	104	104	105	95				
	$C_{(5)}$	0.98	0.98	0.99	0.97	0.99	0.98				
	$C_{(15)}$	0.93	0.93	0.94	0.94	0.94	0.93				
LSC-01 Reference Sediment	$I_{(0)}$	100	80	109	84	80	91				
	$I_{(5)}$	100	78	108	83	78	89				
	$I_{(15)}$	92	74	103	77	72	84				
	$R_{(5)}$	1.00	0.98	0.99	0.99	0.98	0.99	---		-0.4	
	$R_{(15)}$	0.92	0.93	0.94	0.92	0.90	0.92	0.052*		1.2	
LSC-04	$I_{(0)}$	82	95	79	86	88	86				
	$I_{(5)}$	79	94	79	86	88	85				
	$I_{(15)}$	76	92	77	83	85	83				
	$T_{(5)}$	0.96	0.99	1.00	1.00	1.00	0.99	---	---	-0.9	-0.9
	$T_{(15)}$	0.93	0.97	0.97	0.97	0.97	0.96	---	---	-2.9	-2.9
LSC-05	$I_{(0)}$	62	78	90	75	85	78				
	$I_{(5)}$	61	77	89	75	86	78				
	$I_{(15)}$	58	73	84	74	83	74				
	$T_{(5)}$	0.60	0.75	0.87	0.74	0.84	0.76	**0.005***	**0.004***	22.5	22.8
	$T_{(15)}$	0.57	0.72	0.82	0.73	0.81	0.73	**0.005***	**0.007***	21.8	20.8
LSC-06	$I_{(0)}$	78	84	70	77	67	75				
	$I_{(5)}$	76	84	70	80	68	76				
	$I_{(15)}$	73	84	70	78	67	74				
	$T_{(5)}$	0.75	0.82	0.69	0.78	0.67	0.74	**0.001***	**0.001***	24.5	24.8
	$T_{(15)}$	0.72	0.82	0.69	0.76	0.66	0.73	**0.001***	**0.001***	21.8	20.8

$I_{(0)}$ is the light reading after the initial five minute incubation period

$I_{(5)}$ is the light reading five minutes after $I_{(0)}$

$I_{(15)}$ is the light reading fifteen minutes after $I_{(0)}$

$C_{(t)}$, $R_{(t)}$, and $T_{(t)}$ are the changes in light readings from the intial reading in each sample container for the control, reference sediment and test sites. $I_{(t)}/I_{(0)}$

* Unequal Variance. Welch's correction applied

--- Site response greater than Control or reference sediment response.

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APPENDIX B

WATER QUALITY RESULTS

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Hyalella azteca

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Appendix Table B-1. 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

Control						
Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH3 (mg/L) Interstitial	Overlying
0	23.6	8.5	7.71	339	---	1.2
1	22.6	8.3	7.67	446	---	---
2	22.6	8.2	7.73	441	---	---
3	22.3	8.1	7.82	495	---	---
4	22.6	8.3	7.81	512	---	---
5	22.2	8.0	7.88	524	---	---
6	22.4	7.0	7.98	529	---	---
7	22.5	7.7	7.98	558	---	---
8	22.3	7.8	8.01	562	---	---
9	22.5	7.9	8.03	572	---	---
10	23.6	7.6	7.93	674	---	5.7

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Appendix Table B-1(cont). 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-01						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.4	7.76	262	0.9	0.8
1	22.5	8.4	7.88	317	---	---
2	22.6	8.2	7.96	313	---	---
3	22.1	8.2	8.02	318	---	---
4	22.5	8.4	7.96	316	---	---
5	22.5	8.2	8.00	327	---	---
6	22.4	7.0	8.02	332	---	---
7	22.5	7.7	8.07	363	---	---
8	22.3	7.8	8.08	372	---	---
9	22.4	7.9	8.08	375	---	---
10	23.6	7.4	8.03	377	---	0.9

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Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-02						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.4	7.83	288	1.1	1.0
1	22.7	8.4	7.96	363	---	---
2	22.6	8.3	8.04	374	---	---
3	22.2	8.2	8.12	387	---	---
4	22.5	8.5	8.07	410	---	---
5	22.5	8.3	8.10	406	---	---
6	22.4	7.0	8.13	417	---	---
7	22.5	7.6	8.08	444	---	---
8	22.3	7.2	8.09	452	---	---
9	22.5	7.5	8.10	465	---	---
10	23.6	7.5	8.07	460	---	1.0

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Appendix Table B-1(cont). 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-03						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.3	7.67	262	1.2	0.9
1	22.5	8.3	7.76	323	---	---
2	22.7	8.2	7.82	328	---	---
3	22.4	8.2	7.86	331	---	---
4	22.6	8.5	7.85	334	---	---
5	22.5	8.4	7.86	346	---	---
6	22.4	7.0	7.95	354	---	---
7	22.5	7.2	7.94	379	---	---
8	22.3	7.1	8.02	382	---	---
9	22.5	7.5	8.01	391	---	---
10	23.6	7.3	8.06	389	---	3.8

Appendix Table B-1(cont). 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-04						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.3	7.87	286	0.7	1.2
1	22.4	8.3	7.97	371	---	---
2	22.7	8.2	8.13	387	---	---
3	22.3	8.2	8.20	387	---	---
4	22.5	8.4	8.19	415	---	---
5	22.3	8.2	8.26	432	---	---
6	22.4	6.8	8.33	452	---	---
7	22.5	7.3	8.26	489	---	---
8	22.7	7.1	8.28	502	---	---
9	22.5	7.2	8.35	509	---	---
10	23.6	7.4	8.36	548	---	1

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Appendix Table B-1(cont). 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-05						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.3	7.79	249	2.4	1.9
1	22.4	8.5	7.86	299	---	---
2	22.4	8.3	8.04	288	---	---
3	22.1	8.3	8.03	284	---	---
4	22.4	8.5	8.02	286	---	---
5	22.4	8.4	8.04	287	---	---
6	22.4	7.0	8.13	291	---	---
7	22.5	8.1	8.11	311	---	---
8	22.3	8.1	8.11	312	---	---
9	22.7	8.2	8.15	315	---	---
10	23.6	7.6	8.10	341	---	7.0

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Appendix Table B-1(cont). 10-Day Solid-Phase Results (*Hyalella azteca*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-06						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH3 (mg/L) Interstitial**	**Overlying**
0	23.6	8.2	7.72	276	NA	1.1
1	22.1	8.5	7.91	254	---	---
2	22.2	8.4	8.05	337	---	---
3	22.1	8.2	8.08	341	---	---
4	22.2	8.5	8.10	352	---	---
5	22.3	8.4	8.15	376	---	---
6	22.4	7.1	8.19	379	---	---
7	22.5	7.5	8.17	408	---	---
8	22.3	7.2	8.21	412	---	---
9	22.5	7.4	8.23	413	---	---
10	23.6	7.7	8.28	437	---	0.8

NA-Not available. Site LSC-06 was very dry with no porewater available for testing.

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Chironomus tentans

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Appendix Table B-2. 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

Control						
Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH_3 (mg/L) Interstitial	Overlying
0	19.6	8.5	7.71	339	---	1.2
1	19.5	9.2	7.82	372	---	---
2	19.5	8.8	7.85	388	---	---
3	19.4	8.9	7.66	397	---	---
4	19.7	8.7	7.66	406	---	---
5	19.7	8.6	7.71	424	---	2.6
6	19.8	7.9	7.75	433	---	---
7	20.0	9.4	7.86	457	---	---
8	19.9	8.5	7.87	462	---	---
9	20.0	8.7	7.92	473	---	---
10	19.5	8.0	7.96	494	---	4
11	19.6	9.2	8.01	494	---	---
12	19.4	9.0	7.84	505	---	---
13	19.3	8.6	7.87	500	---	---
14	20.0	9.2	7.86	510	---	---
15	20.1	8.8	7.91	435	---	6.1
16	20.0	8.5	7.83	501	---	---
17	19.4	9.6	7.88	548	---	---
18	19.5	8.1	7.97	561	---	---
19	19.6	7.9	7.92	616	---	---
20	19.5	8.6	8.00	753	---	8.9

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Appendix Table B-2 (cont). 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-01

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH_3 (mg/L) Interstitial	Total NH_3 (mg/L) Overlying
0	19.4	8.4	7.76	262	<1.0	<1.0
1	19.3	9.0	7.95	273	---	---
2	19.3	8.8	7.95	277	---	---
3	19.3	8.6	7.91	279	---	---
4	19.4	8.7	7.85	292	---	---
5	19.5	8.5	7.83	296	---	2.0
6	19.8	7.9	7.90	303	---	---
7	20.0	8.5	8.00	326	---	---
8	19.8	8.4	7.95	335	---	---
9	19.9	8.3	8.02	337	---	---
10	19.7	8.5	8.02	348	---	1
11	19.1	8.9	8.10	344	---	---
12	19.2	8.7	8.04	364	---	---
13	19.2	8.5	8.04	355	---	---
14	20.0	9.0	8.10	359	---	---
15	19.5	8.7	8.07	340	---	1.2
16	20.0	9.0	8.12	363	---	---
17	19.1	8.3	8.02	365	---	---
18	20.6	8.1	8.09	365	---	---
19	19.6	8.1	8.04	363	---	---
20	19.4	7.6	7.62	378	---	<1.0

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Appendix Table B-2 (cont). 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-02						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH_3 (mg/L) Interstitial**	**Overlying**
0	19.4	8.4	7.83	288	1.1	1.0
1	19.2	8.9	8.01	313	---	---
2	19.3	8.7	8.02	327	---	---
3	19.3	8.4	7.98	343	---	---
4	19.3	8.7	7.92	359	---	---
5	19.4	8.4	7.96	368	---	1.4
6	19.6	7.6	7.99	378	---	---
7	20.0	8.7	8.06	401	---	---
8	19.7	8.2	7.98	412	---	---
9	19.8	8.3	8.07	421	---	---
10	19.7	8.5	8.12	450	---	<1.0
11	19.1	9.5	8.16	435	---	---
12	19.3	8.7	8.09	438	---	---
13	19.2	8.5	8.05	428	---	---
14	20.0	9.8	8.11	412	---	---
15	19.5	9.0	8.01	387	---	<1.0
16	20.1	8.3	7.96	398	---	---
17	19.0	8.5	8.03	437	---	---
18	19.3	7.0	8.04	447	---	---
19	19.8	7.6	7.94	464	---	---
20	19.5	7.8	7.92	474	---	<1.0

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Appendix Table B-2 (cont). 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-03						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH_3 (mg/L) Interstitial**	**Overlying**
0	19.5	8.3	7.67	262	1.2	<1.0
1	19.3	8.8	7.85	275	---	---
2	19.3	8.6	7.84	284	---	---
3	19.3	8.3	7.69	297	---	---
4	19.4	8.6	7.72	313	---	---
5	19.4	8.4	7.73	330	---	<1.0
6	19.8	7.3	7.76	333	---	---
7	20.0	8.5	7.81	352	---	---
8	19.9	8.2	7.85	357	---	---
9	20.1	8.3	7.87	355	---	---
10	20.0	8.3	7.93	373	---	<1.0
11	19.0	9.4	7.94	365	---	---
12	19.5	8.4	7.90	364	---	---
13	19.3	8.2	7.97	363	---	---
14	20.0	9.8	7.96	361	---	---
15	19.5	8.7	7.86	330	---	<1.0
16	20.0	8.4	7.92	350	---	---
17	19.0	8.3	8.14	401	---	---
18	19.2	9.1	8.06	394	---	---
19	19.4	8.0	8.01	386	---	---
20	19.5	8.2	8.06	460	---	<1.0

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Appendix Table B-2 (cont). 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-04

Day	Temp (°C)	D.O. (mg/L)	pH (units)	Conductivity (umhos/cm)	Total NH_3 (mg/L) Interstitial	Total NH_3 (mg/L) Overlying
0	19.4	8.3	7.87	286	<1.0	1.2
1	19.3	7.9	7.66	330	---	---
2	19.2	8.6	8.16	358	---	---
3	19.3	8.3	8.15	375	---	---
4	19.4	8.7	8.12	383	---	---
5	19.4	8.3	8.14	407	---	1.2
6	19.7	7.5	8.16	388	---	---
7	20.0	8.5	8.20	409	---	---
8	19.9	8.2	8.15	389	---	---
9	20.1	8.3	8.22	410	---	---
10	19.7	8.3	8.20	450	---	<1.0
11	19.1	10.0	8.30	437	---	---
12	19.3	9.3	8.23	445	---	---
13	19.5	9.0	8.22	470	---	---
14	20.0	9.6	8.27	473	---	---
15	19.5	8.9	8.14	443	---	<1.0
16	20.1	9.0	8.19	453	---	---
17	19.0	8.3	8.23	484	---	---
18	19.1	7.9	8.26	481	---	---
19	19.4	7.9	8.10	473	---	---
20	19.4	7.3	7.84	308	---	<1.0

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Appendix Table B-2 (cont). 20-Day Solid-Phase Results (*Chironomus tentans*)
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-05						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH_3 (mg/L) Interstitial**	**Overlying**
0	19.6	8.3	7.79	249	2.4	1.9
1	19.4	8.5	7.99	247	---	---
2	19.4	8.5	8.04	243	---	---
3	19.5	8.3	7.89	239	---	---
4	19.3	8.6	7.98	229	---	---
5	19.5	8.3	8.00	244	---	1.7
6	19.7	7.6	7.97	251	---	---
7	20.0	8.4	8.03	262	---	---
8	19.9	8.3	8.01	272	---	---
9	19.9	8.4	8.03	275	---	---
10	19.5	8.5	7.95	277	---	1.0
11	19.0	10.7	8.13	284	---	---
12	19.4	9.7	8.07	288	---	---
13	19.5	8.9	8.05	299	---	---
14	20.0	9.9	8.07	298	---	---
15	19.5	8.6	7.93	281	---	<1.0
16	20.0	8.5	7.99	312	---	---
17	19.2	8.0	7.96	301	---	---
18	19.2	7.4	8.01	299	---	---
19	19.0	7.1	7.74	288	---	---
20	19.3	7.0	7.93	301	---	1.1

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Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Initiated 03 October 2003

LSC-06						
Day	**Temp (°C)**	**D.O. (mg/L)**	**pH (units)**	**Conductivity (umhos/cm)**	**Total NH_3 (mg/L) Interstitial**	**Overlying**
0	19.8	8.2	7.72	276	NA	1.1
1	19.4	8.7	8.00	295	---	---
2	19.4	8.5	8.07	307	---	---
3	19.4	8.3	8.01	318	---	---
4	19.4	7.8	7.95	347	---	---
5	19.5	8.3	8.01	362	---	1.4
6	19.6	7.6	8.10	363	---	---
7	20.0	8.6	8.14	389	---	---
8	19.9	8.2	8.17	392	---	---
9	20.0	8.4	8.21	395	---	---
10	19.7	8.5	8.19	429	---	<1.0
11	19.1	9.8	8.25	436	---	---
12	19.3	8.1	7.98	463	---	---
13	19.5	8.0	7.96	441	---	---
14	20.0	10.1	7.96	435	---	---
15	19.5	9.0	8.05	407	---	<1.0
16	19.9	8.6	8.16	401	---	---
17	19.2	8.1	7.98	432	---	---
18	19.3	7.5	7.99	440	---	---
19	19.6	7.6	7.90	411	---	---
20	19.3	7.6	7.82	449	---	<1.0

NA-Not Available. Sediment LSC-06 was very dry. There was no porewater available for testing.

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MICROTOX

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Appendix Table B-3. Microtox Results
Squallicum Creek
Washington State Department of Ecology
Water Quality Data

Test Date 16 October 2003

Site	Initial Salinity (ppt)	Final Salinity (ppt)	Initial D.O. (mg/L)	Final D.O. (mg/L)	Initial pH (units)	Final pH (units)	Final Porewater Conc	Total NH_3 (mg/L)
Control	0.0	20.0	7.5	7.7	8.52	7.94	99.6%	NT
LSC-01	0.1	20.0	7.4	7.4	8.05	8.05	100%	0.9
LSC-02	0.2	19.5	7.2	7.2	7.65	7.92	99.8%	1.1
LSC-03	0.2	19.7	7.1	7.1	7.99	7.99	100%	1.2
LSC-04	0.1	19.9	7.7	7.7	8.43	8.10	99.7%	0.7
LSC-05	0.1	20.2	7.2	7.2	7.40	7.99	99.5%	2.4
LSC-06	0.1	19.5	7.9	7.9	7.38	8.15	99.5%	NT

NT-Not tested.

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APPENDIX C

REFERENCE TOXICANT TESTS

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HYALELLA AZTECA

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Appendix Table C-1. 10-Day Solid-Phase Results (*Hyalella azteca*)
Reference Toxicant Data*
Initiated 3 October 2003

$CuCl_2$	Rep	Temp. (°C)					D.O. (mg/L)					pH (units)					Cond (umhos/cm)					Survival	
Concentration		**0**	**24**	**48**	**72**	**96**	**0**	**24**	**48**	**72**	**96**	**0**	**24**	**48**	**72**	**96**	**0**	**24**	**48**	**72**	**96**	**0**	**96**
Control	1	23.5	23.4	22.5	23.5	23.6	8.8	8.7	8.9	9.0	8.7	7.86	7.84	7.85	7.99	8.11	264	290	297	383	335	10	10
	2																					10	10
	3																					10	9
	4																					10	9
187.5 µg/L	1	23.5	23.5	22.6	23.5	23.7	8.7	8.6	8.3	9.0	8.7	8.06	7.91	7.91	8.01	8.14	284	291	298	304	325	10	7
	2																					10	6
	3																					10	7
	4																					10	6
375 µg/L	1	23.5	23.2	22.6	23.5	23.8	8.3	8.6	8.5	9.3	8.9	7.95	7.87	7.94	8.02	8.16	285	290	298	304	318	10	4
	2																					10	2
	3																					10	5
	4																					10	5
750 µg/L	1	23.5	23.2	22.5	23.5	23.7	8.7	8.2	8.4	9.0	8.9	7.95	7.91	7.96	0.80	8.15	284	292	301	308	299	10	4
	2																					10	4
	3																					10	3
	4																					10	1
1500 µg/L	1	23.5	23.1	22.5	23.5	23.7	8.5	8.6	8.5	9.1	9.0	7.77	7.87	7.94	8.05	8.11	258	276	276	277	290	10	2
	2																					10	1
	3																					10	0
	4																					10	2
3000 µg/L	1	23.5	23.2	22.5	23.5	23.5	8.5	8.4	8.5	9.3	9.1	7.49	7.92	7.95	8.02	8.13	283	295	309	318	324	10	0
	2																					10	0
	3																					10	0
	4																					10	0

*** Test conducted with organisms from population used in 10-day Amphipod test initiated 3 October 2003.**

TABLE C-1 BACK

CHIRONOMUS TENTANS

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Appendix Table C-2. 10-Day Solid-Phase Results (*Chironomus tentans*)
Reference Toxicant Data*
Initiated 13 October 2003

$CuCl_2$ Concentration	Rep	Temp. (°C) 0	24	48	72	96	D.O. (mg/L) 0	24	48	72	96	pH (units) 0	24	48	72	96	Cond (umhos/cm) 0	24	48	72	96	Survival 0	96
Control	1	20.0	19.7	19.6	19.7	20.0	7.9	8.8	8.8	8.7	7.9	7.99	7.86	7.69	7.94	8.00	278	264	265	269	283	10	9
	2																					10	9
	3																					10	10
	4																					10	8
250 µg/L	1	20.0	19.6	19.6	19.6	20.1	7.9	9.7	8.7	8.7	8.6	7.98	7.85	7.77	7.91	8.14	277	267	268	272	282	10	4
	2																					10	5
	3																					10	6
	4																					10	5
500 µg/L	1	20.0	19.5	19.7	19.5	19.8	8.0	8.4	8.9	8.8	9.0	7.96	7.83	7.73	7.86	8.04	258	266	268	272	282	10	0
	2																					10	0
	3																					10	1
	4																					10	0
1000 µg/L	1	20.0	19.5	19.4	19.5	19.5	8.1	8.9	8.8	9.0	NA	7.80	7.87	7.75	7.85	NA	256	266	270	277	NA	10	0
	2																					10	0
	3																					10	0
	4																					10	0
2000 µg/L	1	20.0	19.4	19.5	19.5	19.7	8.4	8.7	9.1	8.9	8.8	7.60	7.85	7.75	7.87	7.97	276	266	268	270	279	10	2
	2																					10	0
	3																					10	0
	4																					10	0
4000 µg/L	1	20.0	19.6	19.6	19.5	19.9	8.2	8.9	9.2	8.9	8.8	7.20	7.69	7.70	7.74	7.92	273	267	270	273	282	10	0
	2																					10	0
	3																					10	0
	4																					10	0

*** Test conducted with organisms from population used in 20-day Chironomus test initiated 3 October 2003.**
NA-Not available. The overlying water was lost prior to measuring values.

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MICROTOX

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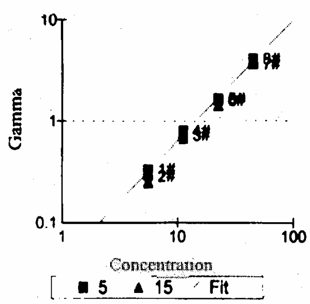
MicrotoxOmni Test Report

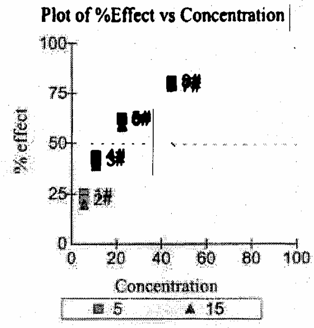
Date: 10/16/2003 04:52 PM

Test Protocol: Basic Test
Sample: 102 mg/L Phenol
Toxicant: 102 mg/L Phenol
Reagent Lot no.: 3B2159 Exp 3/05
Test description: Reference Toxicant Test
Test name: RT101603VF
Database file: C:\Program Files\MicrotoxOmni\Edge Analytical.mdb

Plot of Gamma vs Concentration



Plot of %Effect vs Concentration



Sample	Conc	Io	5 Mins Data: It	Gamma	% effect	15 Mins Data: It	Gamma	% effect
Control	0.000	97.51	87.96	0.9021 #		87.94	0.9019 #	
Control	0.000	67.37	64.94	0.9639 #		65.88	0.9779 #	
1	5.625	64.74	45.15	0.3378 #	25.25%	48.56	0.2530 #	20.19%
2	5.625	62.66	45.33	0.2897 #	22.46%	47.33	0.2443 #	19.63%
3	11.25	65.03	35.14	0.7266 #	42.08%	36.83	0.6595 #	39.74%
4	11.25	82.53	42.89	0.7953 #	44.30%	45.61	0.7007 #	41.20%
5	22.50	69.42	24.28	1.668 #	62.51%	27.26	1.393 #	58.22%
6	22.50	83.77	30.15	1.592 #	61.42%	32.26	1.441 #	59.03%
7	45.00	86.43	17.30	3.661 #	78.55%	17.50	3.642 #	78.46%
8	45.00	87.56	15.98	4.112 #	80.44%	16.73	3.919 #	79.67%

- used in calculation; * - invalid data; D - deleted from calcs.
Autocalc has been used.

Calculations on 5 Mins data:
EC50 Concentration:14.62% (95% confidence range: 13.90 to 15.38)
95% Confidence Factor: 1.052
Estimating Equation:LOG C =0.8300 x LOG G +1.165
Coeff. of Determination (R^2):0.9958
Slope: 1.200
Correction Factor: 0.9330

Calculations on 15 Mins data:
EC50 Concentration:16.22% (95% confidence range: 15.43 to 17.05)
95% Confidence Factor: 1.051
Estimating Equation:LOG C =0.7758 x LOG G +1.210
Coeff. of Determination (R^2):0.9959
Slope: 1.284
Correction Factor: 0.9399

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REFERENCE TOXICANT CONTROL CHARTS

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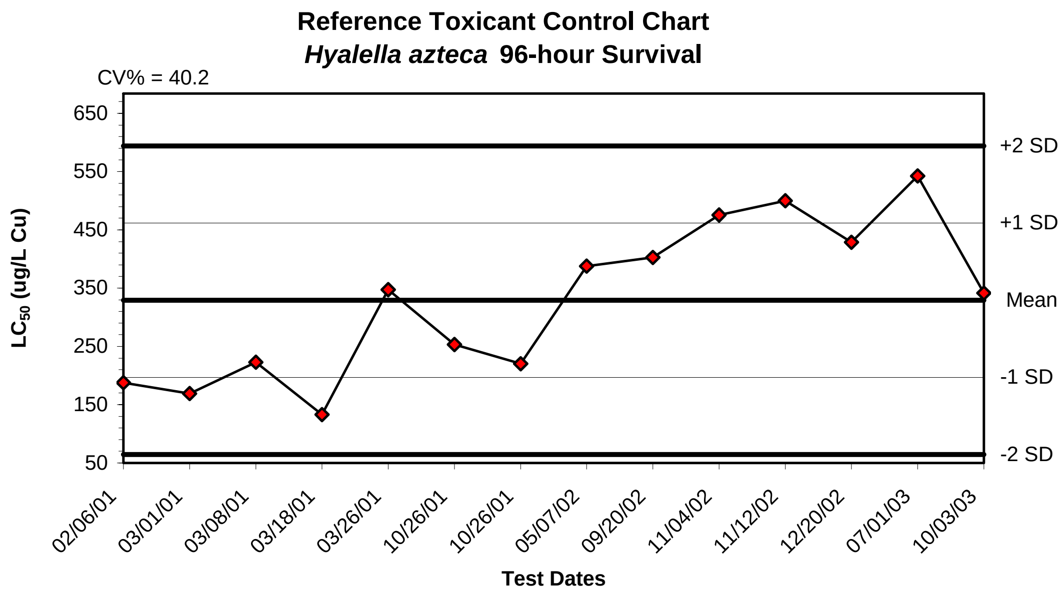

Dates	Values	Mean	-1 SD	-2 SD	+1 SD	+2 SD
02/06/01	187.9825	329.4149	196.9467	64.4784	461.8831	594.3513
03/01/01	169.3743	329.4149	196.9467	64.4784	461.8831	594.3513
03/08/01	222.8646	329.4149	196.9467	64.4784	461.8831	594.3513
03/18/01	132.8283	329.4149	196.9467	64.4784	461.8831	594.3513
03/26/01	347.4598	329.4149	196.9467	64.4784	461.8831	594.3513
10/26/01	253.1055	329.4149	196.9467	64.4784	461.8831	594.3513
10/26/01	220.4106	329.4149	196.9467	64.4784	461.8831	594.3513
05/07/02	387.5000	329.4149	196.9467	64.4784	461.8831	594.3513
09/20/02	402.7778	329.4149	196.9467	64.4784	461.8831	594.3513
11/04/02	475.2931	329.4149	196.9467	64.4784	461.8831	594.3513
11/12/02	500.0000	329.4149	196.9467	64.4784	461.8831	594.3513
12/20/02	428.5714	329.4149	196.9467	64.4784	461.8831	594.3513
07/01/03	542.4136	329.4149	196.9467	64.4784	461.8831	594.3513
10/03/03	341.2267	329.4149	196.9467	64.4784	461.8831	594.3513

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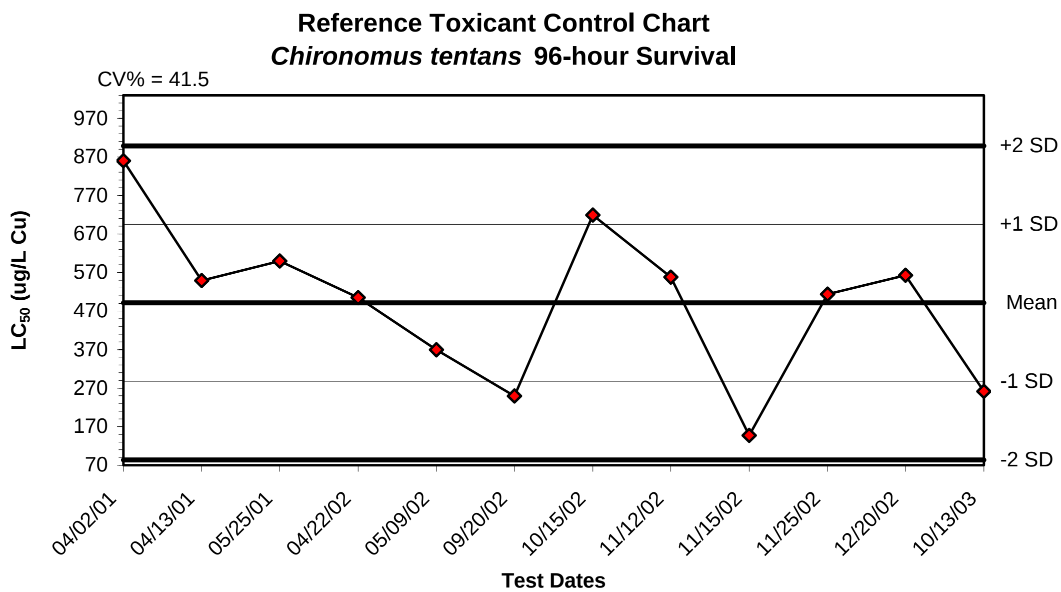

Dates	Values	Mean	-1 SD	-2 SD	+1 SD	+2 SD
04/02/01	860.2941	491.3385	287.5210	83.7036	695.1559	898.9734
04/13/01	549.1071	491.3385	287.5210	83.7036	695.1559	898.9734
05/25/01	600.0000	491.3385	287.5210	83.7036	695.1559	898.9734
04/22/02	505.1020	491.3385	287.5210	83.7036	695.1559	898.9734
05/09/02	369.3182	491.3385	287.5210	83.7036	695.1559	898.9734
09/20/02	250.0000	491.3385	287.5210	83.7036	695.1559	898.9734
10/15/02	718.7500	491.3385	287.5210	83.7036	695.1559	898.9734
11/12/02	557.6923	491.3385	287.5210	83.7036	695.1559	898.9734
11/15/02	147.6459	491.3385	287.5210	83.7036	695.1559	898.9734
11/25/02	513.5731	491.3385	287.5210	83.7036	695.1559	898.9734
12/20/02	562.5000	491.3385	287.5210	83.7036	695.1559	898.9734
10/13/03	262.0790	491.3385	287.5210	83.7036	695.1559	898.9734

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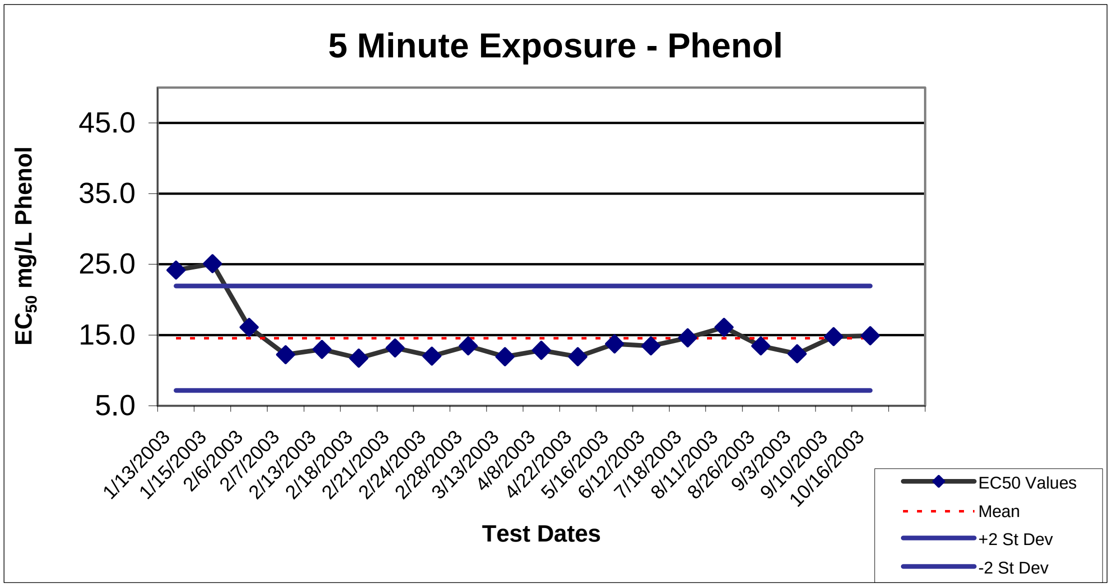
Reference Toxicant Control Chart
Microtox

CV% = 25.3



Date	Time	EC50 %	EC50 mg/L Phenol [a]	Mean	StDev	-2 SD	+2 SD
1/13/2003	1518	23.7	24.2	14.6	3.69	7.2	21.9
1/15/2003	1610	24.6	25.1	14.6	3.69	7.2	21.9
2/6/2003	1516	15.8	16.1	14.6	3.69	7.2	21.9
2/7/2003	1158	12	12.2	14.6	3.69	7.2	21.9
2/13/2003	1300	12.7	13.0	14.6	3.69	7.2	21.9
2/18/2003	1532	11.5	11.7	14.6	3.69	7.2	21.9
2/21/2003	1442	12.9	13.2	14.6	3.69	7.2	21.9
2/24/2003	1149	11.8	12.0	14.6	3.69	7.2	21.9
2/28/2003	1459	13.2	13.5	14.6	3.69	7.2	21.9
3/13/2003	1517	11.7	11.9	14.6	3.69	7.2	21.9
4/8/2003	1645	12.6	12.9	14.6	3.69	7.2	21.9
4/22/2003	1523	11.7	11.9	14.6	3.69	7.2	21.9
5/16/2003	1503	13.5	13.8	14.6	3.69	7.2	21.9
6/12/2003	1540	13.2	13.5	14.6	3.69	7.2	21.9
7/18/2003	1635	14.3	14.6	14.6	3.69	7.2	21.9
8/11/2003	1225	15.8	16.1	14.6	3.69	7.2	21.9
8/26/2003	1612	13.2	13.5	14.6	3.69	7.2	21.9
9/3/2003	1739	12.1	12.4	14.6	3.69	7.2	21.9
9/10/2003	1746	14.5	14.8	14.6	3.69	7.2	21.9
10/16/2003	1642	14.6	14.9	14.6	3.69	7.2	21.9

a - Highest concentration of Phenol is 102 mg/L

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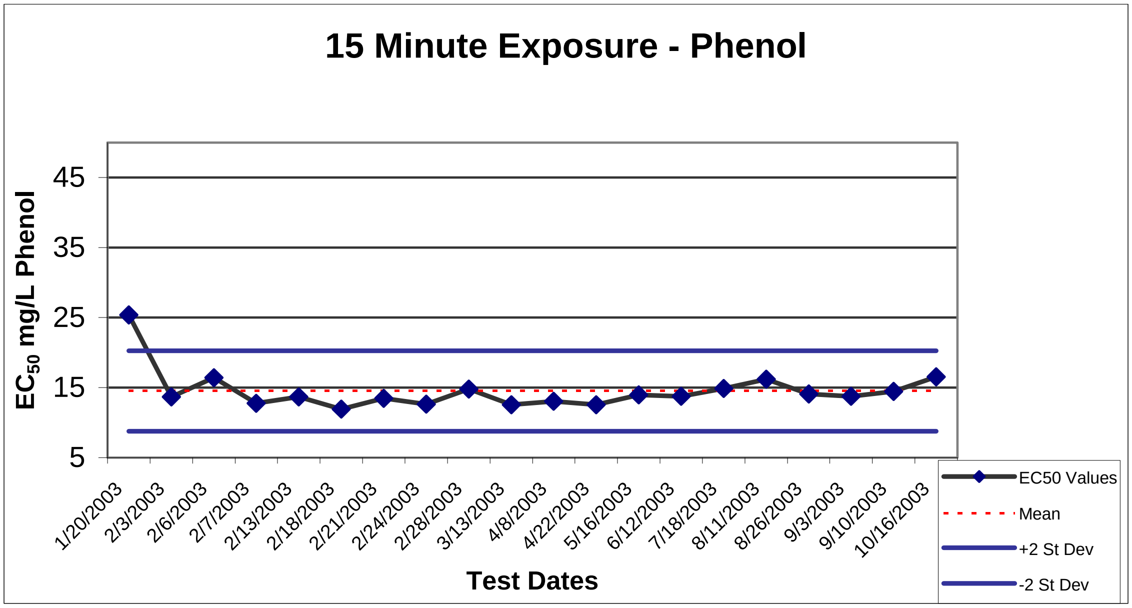
Reference Toxicant Control Chart
Microtox

CV% = 19.8



Date	Time	EC50 %	EC50 mg/L Phenol [a]	Mean	StDev	-2 SD	+2 SD
1/20/2003	1606	24.9	25.4	14.5	2.87	8.8	20.3
2/3/2003	1401	13.4	13.7	14.5	2.87	8.8	20.3
2/6/2003	15516	16.1	16.4	14.5	2.87	8.8	20.3
2/7/2003	1158	12.5	12.8	14.5	2.87	8.8	20.3
2/13/2003	1300	13.4	13.7	14.5	2.87	8.8	20.3
2/18/2003	1532	11.7	11.9	14.5	2.87	8.8	20.3
2/21/2003	1442	13.2	13.5	14.5	2.87	8.8	20.3
2/24/2003	1149	12.4	12.6	14.5	2.87	8.8	20.3
2/28/2003	1459	14.5	14.8	14.5	2.87	8.8	20.3
3/13/2003	1517	12.3	12.5	14.5	2.87	8.8	20.3
4/8/2003	1645	12.8	13.1	14.5	2.87	8.8	20.3
4/22/2003	1523	12.3	12.5	14.5	2.87	8.8	20.3
5/16/2003	1503	13.7	14.0	14.5	2.87	8.8	20.3
6/12/2003	1540	13.5	13.8	14.5	2.87	8.8	20.3
7/18/2003	1635	14.6	14.9	14.5	2.87	8.8	20.3
8/11/2003	1225	15.9	16.2	14.5	2.87	8.8	20.3
8/26/2003	1612	13.8	14.1	14.5	2.87	8.8	20.3
9/3/2003	1739	13.5	13.8	14.5	2.87	8.8	20.3
9/10/2003	1749	14.2	14.5	14.5	2.87	8.8	20.3
10/16/2003	1652	16.2	16.5	14.5	2.87	8.8	20.3

a - Highest concentration of Phenol is 102 mg/L