

Chemical and Toxicological Characterization
of Tidal Freshwater Areas
in the James River, Virginia
Between Jordan Point and Richmond

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ABSTRACT

In October 2001, sediment at a series of 8 stations in the James River from Jordan Point to Hopewell plus a single station in the lower Appomatox was sampled to characterize the region both with respect to chemical contaminants and toxicity. In the same period, Dr. Dan Dauer of Old Dominion University conducted a related study of the benthic communities at these 9 stations. This latter study provides the third leg of the Sediment Quality Triad.

Sediment samples contained small amounts of metals in the sediment, particularly copper, lead and zinc, but not at concentrations considered toxicologically significant. Based on the SEM/AVS ratio, sediments from all stations seem to have additional metal binding capacity. Sediments contained small amounts of PAH. In general concentrations only exceeded the ERL and not the ERM. Pesticides (organochlorine, organophosphate, and herbicides) were below detection limits with the exception of Kepone, once released near Hopewell. Curiously, Kepone was detected at the detection limit near the Richmond Terminal in addition to being found at the three stations nearest Hopewell as expected. PCBs were rarely above the detection limit at any station. Based on the entire suite of analytes, there was no expectation of a toxic effect in this reach.

Sediment samples were not toxic to amphipods or chironomid larvae. Effects observed for fathead minnow embryos were apparently related to biological infections rather than toxicity.

While there was no evidence of chemical or toxicological effects of sediments from these 9 stations, the benthic community was degraded at all but one station (2-JMS096.93). The 8 stations with degraded benthic communities were all dominated by oligochaetes, most notably *Limnodrilus* sp. In contrast, the non-degraded community consisted of insect species exclusively and was totally lacking in oligochaete species.

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As with any project of this logistical complexity, we are indebted to a number of people and organizations for help. If we fail to mention anyone, we apologize in advance.

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1.0 INTRODUCTION

1.1 Need for Regional Characterization

For over a decade, the Chesapeake Bay Program, through its Toxics Subcommittee, has supported a series of studies designed to characterize sections of the Bay from both a chemical and toxicological perspective. Beginning with the pilot studies of Hall *et al.* (1991, 1992, 1994 and 1997) and continuing through the ambient toxicity reports of 2000 (Hall *et al.* 1998a, 1998b, 2000a, 2000b, Roberts *et al.* 2000, McGee *et al.* 2001, Roberts *et al.*, 2002), much of the Bay system has been characterized from the mouth to the tidal limits. In a characterization report for the Chesapeake Bay (U.S. EPA, 1999), some significant areas were identified as lacking sufficient data to be characterized. Included among these areas in Virginia were the tidal freshwater portions of the James River upstream of Jamestown Island, and the Pamunkey and Mattaponi Rivers that form the York River at West Point. McGee et al (2001) occupied some stations in this region but the amount of data was limited and the area of the tidal freshwater James River covered by the study was very limited. Roberts *et al.* (2002) occupied 20 stations in the James River from Jamestown Island upstream to Jordan Point, just downstream of Hopewell, VA. The tidal freshwater reach continues from Hopewell another 35 miles to Richmond, VA that remained uncharacterized until now.

1.2 Objectives

- Assess ambient sediment chemistry and toxicity in tidal freshwater portion of the James River from Jordan Point upstream to Richmond
- Assess the condition of the benthic community
- Characterize the condition of sediment in this reach of the James River

2.0 MATERIALS AND METHODS

2.1 Station Selection

The reach of the upper James River from Jordan Point to Richmond is a relatively deep (ca. 30 ft) and narrow stretch ending upstream at the fall line. Two industrialized cities, Hopewell and Richmond, are bookends of the reach. Between these cities the land is predominantly wooded or agricultural, with a few industrial sites. A large industrial site between the cities is the Chesterfield Power Plant. In addition there are several sand and gravel facilities, most associated with Tarmac Corporation. There is a containerized cargo port on the western bank of the river at about mile 104. Hopewell is located at the confluence of the Appomatox River with the James River.

To insure that sampling sites were representative of the river segments subject to differing land use, the reach was subdivided into four strata. Stratum 1 included the stretch from the Richmond Lock downstream to Cornelius Creek, a highly industrialized reach. Stratum 2 extended from Cornelius Creek through the oxbow region ending just upstream of the Appomatox-James confluence, a largely agricultural reach. Stratum 3 included the remainder of the James downstream to Jordan Point, the reach within which the river widens dramatically. Long an industrialized area, chemical industries in Hopewell, VA continue to discharge contaminants into the river. Stratum 4 included the lower Appomatox. Strata 1 and 3 were allocated 3 stations each, Stratum 2 was allocated 2 stations, and Stratum 4 was allocated a single station. Thus there were 9 stations established in this reach of the river.

Kevin Summers of the EPA EMAP program provided random station locations within the defined strata plus three alternate locations for each. After plotting these stations, it was concluded that a reconnaissance cruise was essential.

Criteria for final station selection during the reconnaissance cruise were accessibility and sediment type. Only the most upstream station selections were found unacceptable. All alternates were inaccessible because they were in the lower rapids of the falls. The site was arbitrarily relocated to the final study location just upstream of the Ancarrow Landing and directly across the channel from the mouth of Gillie Creek. The sediment at this station was gravelly sand. No safe location was found with finer texture. In Stratum 2, one station was selected within an oxbow, and the second was located to adjacent a dredged thoroughfare. The station in Stratum 4 was also relocated in an attempt to avoid excessively sandy bottom.

Final station selections are listed in Table 1 and plotted in Figure 2.1 along with the strata demarcations. Nichols *et al.* (1991) characterized the texture of the sediments in this region as sandy, and generally >75% sand.

2.2 Sediment Collection

Sediment samples for all analyses were collected on three separate cruises between 11 and 22 October 2001. The four most upstream stations were sampled on 11 October. The remaining stations in the James River were sampled on 18 October. The single station in the Appomattox was sampled on 22 October.

Three randomly chosen samples were collected from a 100 by 100 m grid centered on the coordinates for each station. The upper 2 cm of sediment were retained for toxicological tests. Multiple grabs were made at each point with a Ponar dredge until sufficient sediment had been collected. Sediment was then homogenized and distributed among the sample containers. At each station, 3 separate sediment samples were collected for toxicity studies in order to evaluate field variability. Samples for particle size and total organic carbon (TOC) from each sample site were stored and analyzed separately. AVS/SEM samples were collected and stored separately, but composited under nitrogen before analysis.

All samples were placed on ice and transported to the testing laboratories with delivery on the day of collection or early the following day. Once in the testing laboratories, all sediment was maintained in a 4°C cold room prior to processing and analysis. The intent was to test for toxicity within the 14-day holding time specified for the project, but as will be noted below, this was not entirely possible for all test species.

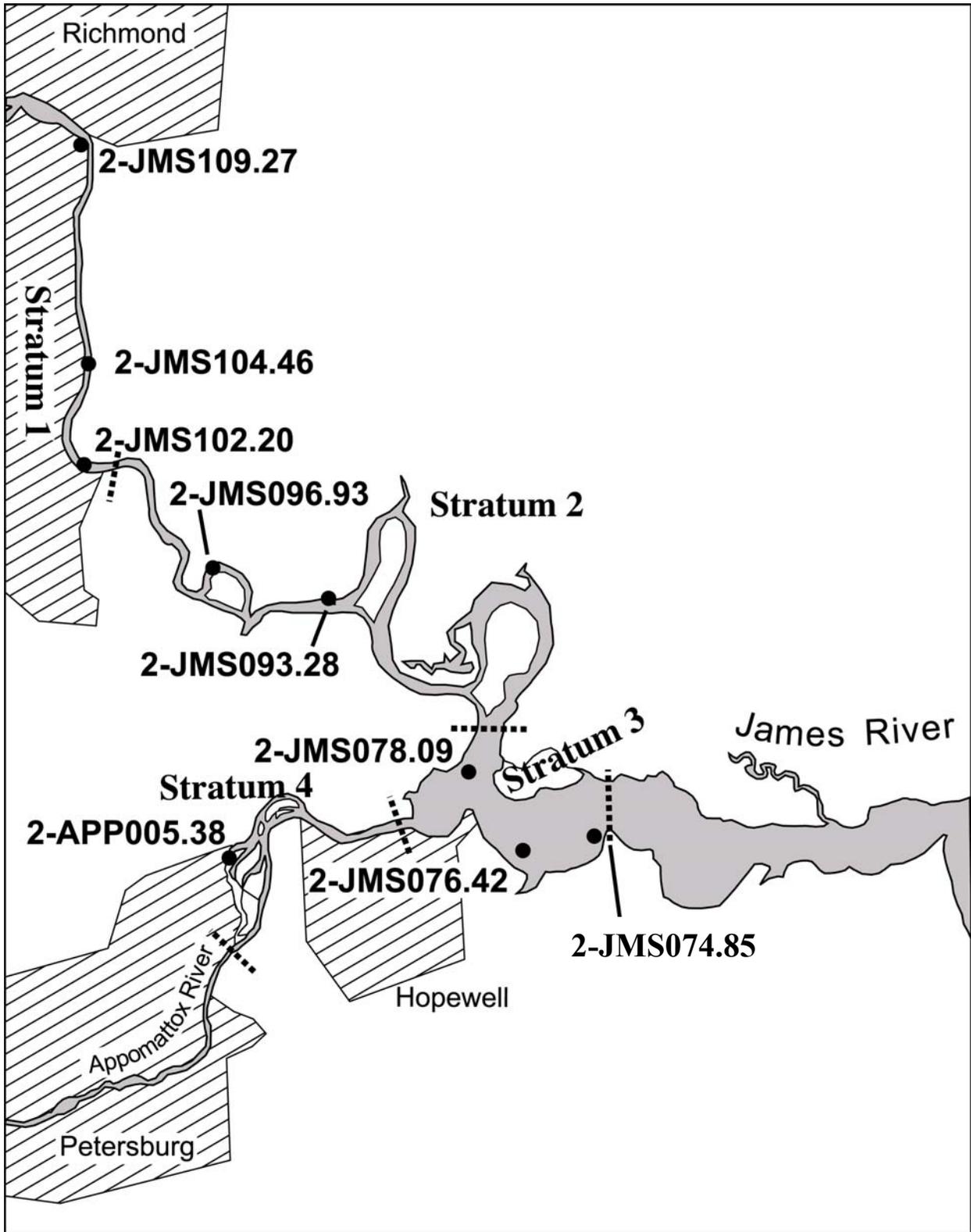
Control sediment for the toxicity tests was collected from the freshwater/non-tidal portion of an unnamed tributary of the Severn River (37°20'36.7" N, 76°29'38.8" W; Rt. 614, 0.25 mile east of U.S. Rt. 17, White Marsh, VA). Sediment from the same site served as one of the control sediments in the study of Roberts, *et al.* (2002).

While at each station, a Hydrosonde III was deployed to measure surface and bottom temperature (°C), conductivity ($\mu\text{mhos}/\text{cm}^2$), salinity (g/kg), dissolved oxygen (mg/l), pH (S.U.) and sampling depth (m). Surface conditions were measured at ca 0.5 m below the water surface, and bottom conditions at about 1 m above the sediment.

Table 2.1. Station locations in the four strata of the upper tidal freshwater section of the James and lower Appomatox Rivers.

Stratum	Station Designation	Latitude	Longitude		Depth (m)
1	2-JMS109.27	37°31'18.5"	77°25'8.5"	Richmond, just upstream of Ancarrow Landing	6.9
	2-JMS104.46	37°27'25.4	77°25'08.04"	Across river from upstream end of Richmond Deepwater Terminal	5.1
	2-JMS102.20	37°25'28.9"	77°25'27.1"	Off Drewry's Bluff between Falling Creek and Cornelius Creek	9.2
2	2-JMS096.93	37°23'25.32"	77°22'24.18"	In old main channel behind Hatcher Island	2.0
	2-JMS093.28	37°22'47.82"	77°19'25.56"	Mouth oxbow around Jones Neck (check description)	8.0
3	2-JMS078.09	37°19'35.2"	77°16'33.7"	Just Upstream of Buoy R122 at the mouth of the Appomatox River	7.0
	2-JMS076.42	37°18'13.0"	77°15'29.8"	At the upstream end of Bailey Bay, inshore of Daymarker G "A"	1.0
	2-JMS074.85	37°18'28.7"	77°13'31.7"	At downstream end of Bailey Bay, just downstream of natural channel along shore	1.0
4	2-APP005.38	37°18.5'34"	77°22'6.48"	Channel, the undredged channel of the Appomatox mouth along the north and west sides of Cat Island	1.0

Figure 2.1. Map of the James River from Jordan Point to Richmond with portion of lower Appomattox River on which are shown all station locations.



2.3 Chemical Analyses

Sediment samples for bulk metal analyses were oven dried, weighed, and digested in nitric and hydrochloric acids by microwave technology. After cooling, the samples were brought up to 50 ml volume, mixed and allowed to settle overnight prior to analysis. From the digested sample, metals are analyzed by ICPMS. The following elements are analyzed by this method: Al, Sb, As, Be, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Th, and Zn. In addition, acid volatile sulfides and simultaneously extractable metals (AVS/SEM) were determined on sediment samples using the methods of Leonard *et al.* (1996, 1999).

Various organic chemicals in sediments were determined including semi-volatile organic compounds (SVOC), organophosphate pesticides, organochlorine pesticides, polychlorinated biphenyls (PCB), and herbicides. For SVOCs, sediment samples were ground with anhydrous sodium sulfate and Soxhlet extracted with methylene chloride for 18 to 24 hours. The extracts were concentrated and the sulfur content reduced using high performance GPC on porous styrene-divinylbenzene copolymer gel. The extracts were then concentrated and fractionated on a semipreparative aminosilane HPLC using step gradients; this resulted in three fractions containing broad compound classes ranging from aliphatic to polar. The fractionated extracts were then analyzed by capillary gas chromatography / mass spectrometry.

A flame photometric detector (FPD) operating in the phosphorous mode was used to identify and quantitate organophosphates. A halogen specific detector (XSD) was used to measure organochlorine pesticides and polychlorinated biphenyls (PCB). Portions of the extracts were subjected to water/ methylene chloride partitioning to remove residual acid and water-soluble interferences. The extracts are then methylated, concentrated to volume, and analyzed by gas chromatography utilizing a halogen specific detector (XSD) to identify and quantitate herbicides.

Sediment samples for Kepone analysis were first dried and then extracted using Soxhlet apparatus. The extracts were cleaned up by Florasil chromatography prior to gas chromatographic analysis. This method is based on Moseman *et al.* (1977).

Methods are fully described in the work plan submitted for this project.

2.4 Sediment Analyses

Sediment texture on composite subsamples from the field stations was determined by DCLS using the Folk (1974) method. A sediment sample is dried and passed through geological screens: 4 mm and 62.5 μm . Material retained on the 4 mm sieve represents gravel (weight not determined), and that passing the 4 mm sieve but retained on the 62.5 μm sieve is sand. The remainder of the sediment passing through the finest sieve is moistened and suspended in water. At fixed times after complete mixing, samples are drawn from specified depths, placed in tared weighing pans, dried and weighed. From this information, the amount of silt and clay can be calculated.

A subsample of the sediment was dried, weighed, incinerated, and reweighed to determine the dry weight and ash-free dry weight. The difference is the total organic carbon that is then expressed as a percentage of the original sample weight.

Coastal Bioanalysts provided subsamples of the sediment samples from each station replicate used for toxicity test for analysis in the VIMS Analytical Services Laboratory using the Folk methodology. In this case, the gravel fraction was weighed. In addition, CBI measured percent pore water, pore water ammonia, and pore water pH for each sediment replicate from each station.

2.5 Toxicological Analyses

Sub-samples of sediment from all stations were examined for indigenous amphipods, chironomids or predators in preparation for tests. To do this, aliquots of sediment were wet sieved through stacked 1000, 500, and 250 μm sieves, and the collected material examined under a microscope. *Cyathura polita*, a potential predator of amphipods and possibly insect larvae, was found at three stations. No amphipods or chironomids were observed in the sub-samples. To remove the predators and insure that all sediments were treated uniformly, sediments from all stations except 2-JMS109.27 were press sieved through a 500 μm mesh screen (stainless steel). Station 2-JMS109.27 sediment, predominantly sand and gravel, would not pass a 500 μm mesh and was therefore sieved through a 1000 μm mesh.

Approximately 200 ml of sediment was placed in each 1-l glass test chamber and overlain with 750 ml of dilution water. The dilution water was laboratory control water consisting of moderately hard synthetic freshwater prepared using ASC reagent-grade chemicals and ASTM Type I deionized water. Ranges of water quality parameters for batches of water used for setup and renewals were: Hardness: 91-100 mg/l as CaCO_3 , Alkalinity: 57-59 mg/l as CaCO_3 , Conductivity: 261-282 μMhos , pH: 7.89-8.05 S.U. Three laboratory replicates were prepared from each field replicate. After a 1-day settling time, tests were initiated by adding test animals.

Tests with each species were conducted in accordance with standard protocols of the testing laboratory (CBI SOPs STS004B-AMB, STS005B-AMB, and STS021-AMB in Workplan). Summaries of essential elements of these test methods are provided in Tables 2a-c. Tests with each species were initiated on a staggered schedule to manage time conflicts and level the workload. Amphipod tests were initiated on 23 October, chironomid tests on 26 October, and fathead minnow tests on 28 October. As a result, the fathead minnow tests were started slightly after the 14-day hold time has passed. There is no reason to believe that this deviation affected the outcome of the tests.

Amphipod tests were conducted with 20 animals per test replicate. Initial ash-free dry weights were obtained for three groups of 20 animals. YCT (a mixture of yeast, cereal and Tetramin) was added daily (0.75ml YCT/chamber/day). Dead and emergent amphipods were noted daily. After a 10-day exposure, the contents of each chamber were wet sieved through a 410 μm mesh sieve to recover the amphipods. Live amphipods were counted and transferred to plastic portion cups with a minimal amount of water. Animals were killed by addition of several drops of 6 N HCl

and transferred to small (5-9 mg) tared aluminum foil pans. After drying overnight at 100°C, dry weights were measured to the nearest 0.01 mg and the mean weight per individual calculated.

For chironomid tests, 20 3rd-instar animals were placed in each replicate test chamber. Initial ash-free dry weights were obtained for three groups of 20 animals. A fourth group of 20 animals was preserved in sugar formalin for measurement of head capsule width. Chironomids were fed 6.0 mg Tetramin/chamber/day. Dead and emergent chironomids were noted daily.

After a 10-day exposure, the contents of each chamber were wet sieved through a 500 µm mesh sieve to recover the chironomids. Live chironomids were counted and transferred to plastic portion cups with a minimal amount of water. Animals were killed by addition of several drops of 6 N HCl and transferred to small (5-9 mg) tared aluminum foil pans. Ash-free dry weights were calculated from the difference in pan weights after drying for 24 hr at 100°C followed by 4 hr in a muffle furnace at 550°C.

Fathead minnow embryo tests were conducted as daily renewal tests lasting 10 days. Embryos were exposed in egg baskets made of 3" diameter PVC thin-wall pipe with 200 µm Nitex solvent-welded to one end. The egg baskets were placed in the test chambers, screen end down and pushed slightly into the sediment surface. Twenty embryos were added to each egg basket. Each day until egg hatching was complete, the baskets were removed from the test chambers and placed in a dish of clean dilution water. Embryos were observed for viability, rinsed of debris, and hatchlings tallied. Obviously dead embryos were removed and discarded. After returning the egg basket to the test vessel, approximately 50% of the water was removed and replaced with fresh dilution water. *Artemia* nauplii were added to each test chamber at a rate of 0.1 g/chamber on test days 3-6 and at a rate of 0.15 g/chamber on test days 7-9. The surviving fish fry in each test chamber were counted on day 10 to terminate the test.

Table 2.2a. Required conditions for 10-day sediment toxicity tests with *Hyallolella azteca*

TEST TYPE:	Whole sediment toxicity test
RENEWAL FREQUENCY:	None for sediment or overlying water
REPLICATES:	3 with 20 animals each
RANDOMIZATION:	Test chambers arranged in randomized block (by replicate) design
TEST CHAMBERS:	1000 ml glass beakers
SEDIMENT VOLUME:	200 ml
OVERLYING WATER VOLUME:	750 ml
OVERLYING WATER:	Synthetic freshwater, moderately hard
TEMPERATURE:	23 ± 1°C
PHOTOPERIOD:	16 h light: 8 h darkness
LIGHT INTENSITY:	10-20 µE/m ² /s (500-1000 ft-c) (ambient laboratory illumination)
SIZE AND LIFE STAGE OF AMPHIPODS:	3-5 mm, no mature males or females
DISSOLVED OXYGEN:	Aerate all chambers at a rate of 100 small bubbles/min
FEEDING:	0.75 ml YCT/chamber/day
AERATION:	Overnight before start of test, and throughout test; trickle-flow aeration maintains ≥40% saturation of dissolved oxygen concentration
CLEANING:	None
WATER QUALITY MEASUREMENTS:	Total water quality (hardness, alkalinity, ammonia, pH, conductivity, D.O., temperature) days 0 and 9 or 10 each treatment; temperature and D.O. daily on one replicate/treatment
TEST DURATION:	10 days
TEST TERMINATION:	Tally survival, pool animals for each replicate, dry and weigh
ENDPOINTS:	Survival, growth (dry weight)
ACCEPTABILITY CRITERIA:	Control survival 80%
SAMPLE HOLDING TIME:	2 weeks
TEST TREATMENTS:	Site and control sediment

¹A concurrent acute reference test using the same batch of animals is performed using KCl as the reference toxicant.

Table 2.2b. Required conditions for 10-day sediment toxicity tests with *Chironomus tentans*.

TEST TYPE:	Whole sediment toxicity test
RENEWAL FREQUENCY:	None for sediment or overlying water
REPLICATES:	3 with 20 animals each
RANDOMIZATION:	Test chambers arranged in randomized block (by replicate) design
TEST CHAMBERS:	1000 ml glass beakers
SEDIMENT VOLUME:	200 ml
OVERLYING WATER VOLUME:	750 ml
OVERLYING WATER:	Synthetic freshwater, moderately hard
TEMPERATURE:	23 ± 1 °C
PHOTOPERIOD:	16 h light: 8 h darkness
LIGHT INTENSITY:	10-20 µE/m ² /s (500-1000 ft-c) (ambient laboratory illumination)
SIZE AND LIFE STAGE OF MIDGES	2 nd (head capsule width 0.13 to 0.23 mm) to 3 rd instar (head capsule width 0.33 to 0.45 mm); ≥ 50% 3 rd instar ¹
DISSOLVED OXYGEN:	Overnight before start of test, and throughout test; trickle-flow aeration maintains ≥40% saturation of dissolved oxygen concentration
FEEDING:	6.0 mg dry wt. Tetramin (60 ul slurry)/chamber/day
CLEANING:	None
WATER QUALITY MEASUREMENTS:	Measure total water quality (hardness, alkalinity, ammonia, pH, conductivity, D.O., temperature) days 0 and 9 or 10 each treatment; temperature and D.O. daily on one replicate/ treatment
TEST DURATION:	10 days
TEST TERMINATION:	Tally survival, pool animals for each replicate, dry and weigh
ENDPOINTS:	Survival, growth (ash-free dry weight)
SAMPLE HOLDING TIME:	2 weeks
TEST TREATMENTS:	Site and control sediment

¹ A concurrent acute reference test using the same batch of animals is performed using KCl as the reference toxicant.

Table 2.2c. Required conditions for 10-day sediment toxicity tests with *Pimephales promelas* Embryo-larvae

TEST TYPE:	Static renewal, whole sediment
RENEWAL FREQUENCY:	Daily renew 50% of overlying water
REPLICATES:	3 with 10 animals each (i.e. 30 animals/sample tested)
RANDOMIZATION:	Test chambers oriented in randomized block (by replicate) design
TEST CHAMBERS:	1000 ml beakers, borosilicate glass & PVC-Nitex egg baskets
SEDIMENT VOLUME:	200 ml sediment
OVERLYING WATER VOLUME:	750 ml overlying water
OVERLYING WATER:	Synthetic freshwater, moderately hard
TEMPERATURE:	25 ± 1°C (23.5-26.4°C)
PHOTOPERIOD:	16 h light/8 h darkness
LIGHT INTENSITY:	10-20 µE/m ² /s (50-100 ft-c) (ambient laboratory illumination)
AGE:	≤ 48 h post-fertilization ¹
DISSOLVED OXYGEN:	Aerate all chambers at a rate of 100 small bubbles/min
FEEDING:	Newly hatched (<24 h) <i>Artemia</i> nauplii; 0.1 g/replicate days 3-6 (earlier if hatching occurs); 0.15 g/replicate days 7-9
AERATION:	Overnight before start of test, and throughout test; trickle-flow aeration maintains >40% saturation of dissolved oxygen
CLEANING:	Siphon excess food and other debris daily and during renewal
WATER QUALITY MEASUREMENTS:	Temperature, conductivity, pH, D.O. daily in one replicate of both “old” and “new” solution
TEST DURATION:	10 days
TEST TERMINATION:	Tally survival
EFFECTS MEASURED:	Embryo and fry survival, egg hatching
ACCEPTABILITY CRITERIA:	Control survival 80%
SAMPLE HOLDING TIME:	2 weeks
TEST TREATMENTS:	Site and control sediment

¹A concurrent acute reference test using the same batch of animals is performed using KCl as the reference toxicant.

2.6 Benthic Community Collection

Sediment samples were collected at 9 stations in the upper James River on September 13, 2001. These 9 stations were in addition to the 25 random locations are sampled each year in the tidal James River to assess the health of the benthic communities (see e.g., Dauer and Rodi 1999, 2001). The additional stations were selected for macrobenthic community analysis to increase the spatial coverage and to support the chemical and toxicological toxics characterizations the upper and middle James River.

At each station, two Young grab samples (surface area of 440 cm²) were collected. One sample was sieved on a 0.5 mm screen and preserved in the field. This sample was sorted, enumerated and identified to the lowest possible taxon. Ash-free dry weight biomass was determined for each taxon. The second sample was analyzed for grain size and TOC to characterize the sediment using the method of Folk (1974). Percent silt-clay and TOC were calculated on a dry weight basis.

2.7 Benthic Community Analysis

Weisberg *et al.* (1997) defined the Benthic Index of Biotic Integrity (B-IBI) for various habitats in the Chesapeake Bay system including the tidal freshwater areas. The original index was based on four metrics (Shannon-Weaver Diversity Index, abundance, biomass and abundance of pollution-indicative taxa) which were scored and averaged. In recent years, the metrics used as measures of macrobenthic community structure have changed, and now include abundance, species numbers, life mode, pollution tolerance, pollution sensitivity, ash-free dry weight, and other community parameters (Dauer and Rodi, 2001; Alden *et al.* 2002). These measures were compared to values expected at non-polluted sites of similar water and sediment quality, a rank was established for each measure and the mean range calculated as the B-IBI.

3.0 RESULTS

3.1 Water quality:

All water quality parameters were within the normal range for the season (Table 3.1). For all but three stations, there was sufficient water depth to measure both surface and bottom conditions. The remaining three stations were only 1.0 m deep and therefore only a single value was obtained.

Temperature ranged from 17.4 to 23.6°C. Temperature differences were related to stratum rather than sampling date, with Stratum 2 having a slightly higher temperature than Strata 1 or 3. The two most downstream stations in Stratum 3 exhibited slightly elevated (>750 µmhos/cm) conductivity compared to all other stations (300-535 µmhos/cm), perhaps related to local industrial activity. Dissolved oxygen was slightly lower in the industrialized portion of Stratum 1 from the Richmond Terminal to Cornelius Creek than elsewhere. pH ranged from 7.06-8.47. The reported salinity is consistent with the conductivity measurements and characteristic of freshwater. For all parameters, there were only minor differences between surface and bottom measurements.

Table 3.1. Water quality measured at the time of collection at each site. All river miles are in the James River except 2-APP005.38, located in the Appomatox River.

Sampling Date	Station	Sample Location	Temp (°C)	Conductivity (µmhos/cm)	DO (mg/l)	pH	Depth (meters)	Salinity (g/kg)	Weather Conditions
10/11/01	2-JMS109.27	Surface	18.3	465	9.79	7.70	0.3	0.23	Sunny, mid to upper 60s
		Bottom	17.4	419	9.17	7.67	6.4	0.21	
	2-JMS104.46	Surface	19.6	496	7.80	7.25	0.3	0.25	Sunny, mid to upper 60s
		Bottom	18.6	413	7.90	7.20	4.6	0.21	
	2-JMS102.20	Surface	19.7	534	7.67	7.13	0.3	0.27	Sunny, mid to upper 60s
		Bottom	19.6	535	7.63	7.11	8.7	0.27	
	2-JMS096.93	Surface	23.6	460	9.63	7.69	0.3	0.23	Sunny, mid to upper 60s
		Bottom	23.5	458	9.71	7.69	1.5	0.23	
10/18/01	2-JMS093.28	Surface	21.8	453	8.10	7.60	1.0	0.23	Sunny, mid 50s, NW wind
		Bottom	21.1	447	8.06	7.63	8.0	0.22	
	2-JMS078.09	Surface	19.6	468	9.28	7.88	1.0	0.24	Sunny, mid 50s, NW wind
		Bottom	19.2	473	8.85	7.71	7.0	0.24	
	2-JMS076.42	Surface	18.8	752	12.39	8.47	1.0	.39	Sunny, mid 50s, NW wind
		Bottom							
	2-JMS074.85	Surface	17.5	755	8.97	7.85	1.0	0.39	Sunny, mid 50s, NW wind
		Bottom							
10/22/02	2-APP005.38	Surface	17.7	300	10.30	7.06	1.0	0.15	Sunny, high 60s, SW wind
	Bottom								

3.2 Sediment Characteristics:

Sediment texture varied noticeably among station replicates in many cases (Table 3.2). For example, the three replicates from the station in the Appomatox River ranged in sand content from 28.4 to 92.7%. At a few stations, replicate samples were highly consistent. For example at station 2-JMS109.27, the three replicate samples varied in sand content only from 90.2 to 96.3%. TOC varied as well, but not always consistently with the variation in sand/silt/clay. It should be noted that gravel was not reported in this data set although samples from some stations were known to have a high gravel content.

Most stations were moderately to predominantly sand with mean sand content ranging from 33.2 to 93.7%. Two stations had a sand content below this range: Station 2-JMS074.85 with 5.0% sand and Station 2-JMS104.46 with 15.5% sand. The downriver station is located in Bailey Bay where sediment has accumulated from Bailey Creek and perhaps also dredge material disposal. The upriver station is located in the turning basin for the Richmond Terminal, and may reflect sediment exposed by dredging the basin or sediment trapped in the dredged bottom. These two stations had high acid volatile sulfide concentration, and the upriver station had moderately high TOC.

Subsamples of sediment provided for the toxicity tests from the same replicate stations were independently analyzed for grain size in which case gravel content was determined (Table 3.3). With regard to percent TOC, sand, silt, and clay, the two data sets are similar, though different laboratories performed the analyses. These samples were also evaluated for percent moisture, pore water pH and pore water ammonia content.

Gravel-size particles were observed at Stations 2-APP005.38, 2-JMS076.42, 2-JMS093.28, 2-JMS102.20, and 2-JMS109.27. The gravel content varied dramatically among replicate samples from these stations. Stations 2-JMS102.20 and 2-JMS109.27 had the highest single values (10.43% and 9.44% respectively) in a replicate sample and the highest average gravel content (3.98% and 5.73% respectively).

Pore water ammonia was elevated at stations 2-JMS093.28, 2-JMS096.93, 2-JMS102.20, and 2-JMS104.46. Pore water percentages were inversely proportional to percent sand.

Table 3.2. Sediment characteristics at each station sampled in October 2001. Each station is represented by 3 field replicates selected randomly from within a grid centered on the station coordinates. The VDCLS analyzed the sample for grain size, TOC and acid volatile solids.

Station	Field Replicate	Percent TOC	Acid Volatile Sulfide (composited)	Percent Sand	Percent Silt	Percent Clay
2-APP005.38	A	0.79	--	92.7	2.65	4.67
	B	4.58	--	44.8	23.5	31.6
	C	2.28	5.566	28.4	44.6	27.0
2-JMS074.85	A	2.69	--	3.7	59.4	36.9
	B	2.63	--	7.24	54.8	38.0
	C	2.81	19.198	3.93	53.6	42.5
2-JMS076.42	A	3.07	--	64.3	23.1	12.6
	A (FD)	3.52	--	58.1	28.2	13.8
	B	2.93	--	65.3	22.7	12.0
	B (FD)	3.47	--	52.4	30.1	17.5
	C	3.26	6.368	55.5	30.9	13.6
	C (FD)	4.25	5.438	55.3	28.4	16.3
2-JMS078.09	A	1.53	--	88.4	5.5	6.1
	B	0.68	--	84.4	9.0	6.6
	C	1.96	6.884	75.0	15.3	9.6
2-JMS093.28	A	3.34	--	41.8	31.6	26.6
	B	2.31	--	12.1	45.5	42.4
	C	1.56	11.029	59.1	20.9	20.0
2-JMS096.93	A	1.08	--	59.4	24.0	16.6
	B	1.60	--	59.8	23.2	17.0
	C	4.10	8.388	89.4	4.9	5.7
2-JMS102.20	A	2.14	--	74.2	19.4	6.4
	B	3.09	--	5.9	47.3	46.8
	C	3.83	12.043	19.5	44.0	36.5
2-JMS104.46	A	3.44	--	8.2	48.6	43.2
	B	3.67	--	18.0	43.7	38.3
	C	4.54	14.176	20.4	41.7	37.9
2-JMS109.27	A	0.60	--	90.2	4.98	4.82
	B	< 0.2	--	94.6	2.52	2.88
	C	< 0.2	5.352	96.3	1.22	2.46

FD = Field Duplicate

Acid Volatile Sulfide was measured after all three field replicates were composited.

Table 3.3. Characteristics of sediment from each station sampled in October 2001. Each station is represented by 3 field replicates selected randomly from within a grid centered on the station coordinates. The VIMS Analytical Services Laboratory provided the grain size and TOC data and Coastal Bioanalysts, Inc. provided the pore water information.

Station	% Gravel	% Sand	% Silt	% Clay	% TOC	Pore Water NH3 (mg/l)	Pore Water pH	% Water
005.38A	0.29	93.63	0.80	5.28	0.25	1.0	6.95	32.0
005.38B	0.00	53.78	9.54	36.67	4.46	11.0	6.66	71.8
005.38C	0.86	31.47	47.76	19.9	2.15	6.0	6.77	55.8
074.85A	0.00	9.01	51.16	39.83	3.37	8.0	6.90	61.1
074.85B	0.00	9.76	57.47	32.77	3.66	6.0	6.93	62.5
074.85C	0.00	11.56	55.20	33.25	3.52	8.0	6.94	63.7
076.42A	0.95	76.46	14.80	7.78	4.05	2.0	7.16	45.4
076.42B	0.00	51.28	29.42	19.31	4.27	4.0	7.10	43.1
076.42C	0.37	69.24	12.10	18.29	3.48	3.0	7.01	48.8
078.09A	0.00	81.51	9.30	9.19	4.59	6.0	7.08	41.4
078.09B	0.00	88.09	2.72	9.19	0.70	8.0	7.41	34.3
078.09C	0.00	91.91	4.88	4.21	0.55	14.0	7.28	36.2
093.28A	0.00	55.00	25.54	19.46	1.97	22.0	6.97	41.3
093.28B	0.39	16.33	44.80	38.47	2.55	24.0	6.87	50.0
093.28C	0.00	59.34	21.00	19.66	1.28	12.0	7.37	35.1
096.93A	0.00	64.98	21.47	13.54	1.54	7.0	6.86	47.4
096.93B	0.00	57.88	26.46	15.66	2.10	16.0	6.75	50.3
096.93C	0.00	91.28	5.08	3.64	1.61	3.0	6.60	34.8
102.20A	10.43	72.27	10.19	7.11	0.86	8.0	6.77	39.8
102.20B	1.51	9.94	46.21	42.34	3.42	27.0	6.82	70.4
102.20C	0.00	39.21	26.36	34.44	8.16	38.0	6.68	69.4
104.46A	0.00	11.57	41.64	46.79	4.30	36.0	6.60	70.5
104.46B	0.00	14.79	42.92	42.29	4.55	26.0	6.73	70.8
104.46C	0.00	23.39	46.40	30.21	5.06	20.0	6.72	71.8
109.27A	0.00	95.23	2.69	2.09	0.74	7.0	7.04	28.3
109.27B	7.83	88.91	1.74	1.53	0.14	6.0	7.40	24.5
109.27C	9.44	86.27	1.07	3.22	0.08	4.0	7.03	24.0
Reference	0.00	53.72	31.20	15.08	4.37	5.0	6.85	50.2

3.3 Chemical Characterization

3.3.1 Metals: Antimony, arsenic, beryllium, cadmium, selenium, silver and thallium were at or below the detection limit for bulk sediment samples at all stations. Aluminum, chromium, copper, iron, lead, manganese, mercury, nickel and zinc were all present in readily measured amounts (Table 3.4).

To assess the significance of observed metal concentrations, the results were compared to sediment quality guidelines (SQGs). In Table 3.4, three guidelines are included for comparisons. The ER-L and ER-M of Long *et al.* (1995) was derived from estuarine and marine data and a diversity of taxa. The ER-L and ER-M of Ingersoll *et al.* (1996) was derived from a single consistent set of data for freshwater crustaceans and is therefore most appropriate to the data collected in this study. The TEC and PEC of MacDonald *et al.* (2000), based on a consensus of several guidelines, is often used in these evaluations.

None of the metals determined in the sediment samples had concentrations exceeding the ER-M or PEC. In several cases, however, there were exceedances of the ER-Ls or TEC, mainly at 2-JMS074.85 (the most downstream station in Bailey Bay), 2-JMS093.28 (adjacent to Jones Neck), and 2-JMS104.46 (adjacent to the Port of Richmond). While no major toxicological impacts would be likely in these cases, it does serve to identify stations that are more contaminated than others, albeit only slightly. These exceedances are noted in the table by single underline .

Station 2-JMS074.85 exhibited exceedances of the ER-L or TEC for aluminum, chromium, copper, lead, manganese, mercury, nickel, and zinc. This station is located in Bailey's Bay near the east bank and approximately in an old channel extending south toward but not into Bailey Creek. At the other station in Bailey's Bay (2-JMS076.42), a TEC exceedance was noted for copper and an ER-L exceedance for zinc. Station 2-JMS093.28, located at the upstream end of the Jones Neck Cutoff, exhibited exceedances of the ER-L or TEC for aluminum, lead, manganese, mercury, and zinc. Station 2-JMS104.46 exhibited exceedances of the ER-L or TEC for aluminum, chromium, copper, lead, manganese, nickel, and zinc. Two of these stations are near significant industrial activity in the Richmond stratum.

The acid volatile sulfide concentration ranged from 5.3 $\mu\text{mole/g}$ wet weight of sediment to 19.2 $\mu\text{mole/g}$ wet weight (Table 3.5). The highest sulfide concentrations were found at stations 2-JMS074.85, 2-JMS093.28, 2-JMS102.20, and 2-JMS104.46. These are perhaps coincidentally, the stations at which there were exceedances of the ER-L for some metals in the bulk sediment analyses. At all stations, the SEM/AVS ratio was <1.0 , suggesting excess capacity to bind metals.

In AVS-SEM analyses, only copper, lead, and zinc occurred at concentrations above the detection limits. Cadmium, mercury and nickel were all found below the detection limit. Copper, lead, and zinc concentrations were consistently high ($\text{Cu} > 0.2 \mu\text{mole/g}$ wet weight, $\text{Pb} > 0.1 \mu\text{mole/g}$ wet weight, and $\text{Zn} > 1.2 \mu\text{mole/g}$ wet weight) at stations 2-JMS074.85, 2-JMS076.42, 2-JMS093.28, and 2-JMS104.46. Concentrations at the remaining stations were consistently low ($\text{Cu} < 0.13 \mu\text{mole/g}$ wet weight, $\text{Pb} < 0.07 \mu\text{mole/g}$ wet weight, and $\text{Zn} 0.09 \mu\text{mole/g}$ wet weight). Station 2-JMS093.28 had the highest concentrations of all three metals.

3.3.2 Semi-Volatile organic compounds (SVOC) – This compound group consisted largely low and high molecular weight PAH (Table 3.6) although there were also other compounds present, notably a variety of phthalates. Only two of the phthalates (di-N-butylphthalate and bis[2-ethylhexyl]phthalate) exhibited concentrations much above the detection limit. In the absence of (SQGs) for these compounds, one cannot really evaluate their toxic potential.

ER-L and ER-M values do exist for some PAH and for the sum of low molecular weight PAH and the sum of high molecular PAH. The only case in which was there a slight exceedance of an ER-M was station 2-APP005.38 for indeno(1,2,3-cd)pyrene. While there were several exceedances of ER-L values, only stations 2-APP005.38, 2-JMS076.42 (field duplicate), and 2-JMS096.93 exhibited any large proportion of exceedances. At station 2-APP005.38, there were exceedances of the ER-L or ER-M for 9 of 13 compounds for which an SQG is defined, including about equal numbers of high and low molecular weight PAH. At station 2-JMS096.93, there were exceedances of the ER-L in 4 of 7 low molecular weight PAH and 1 of 6 high molecular weight PAH. At these stations, the aggregate concentrations of high and low molecular weight PAH exceeded the appropriate total PAH ER-L values. In addition, at stations 2-JMS076.42 (field duplicate) and 2-JMS104.46, the total high molecular weight PAH concentration exceeded the ER-L.

3.3.3 Pesticides (Organophosphate and Organochloride) – For organophosphate (Table 3.7) and organochlorine pesticides excluding Kepone (Table 3.8), all measurements were below the detection limits. The timing of this study made it less likely that one would detect current use pesticides such as organophosphates, which are likely to be released primarily in the spring period. One would expect the more persistent organochlorines to be present in the sediments as relicts of historical usage.

Kepone at three stations in Stratum 3 near Hopewell exceeded the detection limit. Two of these stations are in Bailey Bay that receives discharge from Bailey Creek, site of the 1975 discharges of Kepone. The third is located just upstream of the confluence with the Appomatox.

Curiously, Kepone concentrations were measured at the detection limit at Stations 2-JMS102.20 and 2-JMS104.46, located in Stratum 1 outside the known area of release of Kepone. These detections may reflect releases during shipment of Kepone during the late 1960's and early 1970's. This region of the river is dominated by freshwater flow and characterized by a progressive tidal wave, not characteristics suggesting upstream transport of Kepone. Further, the lack of any samples with Kepone at stations between Hopewell and the Richmond Terminal suggests no upstream transport.

3.3.4 PCB – PCB congener concentrations were below detection limits at all stations except 2-JMS109.27, the most upstream station in Stratum 1 (Table 3.9). Concentrations above detection limit were not very significant from a toxicological perspective.

3.3.5 Herbicides – Herbicide concentrations were below detection limits at all stations without exception (Table 3.10).

Table 3.4. Bulk metal concentrations ($\mu\text{g/g}$) in sediment samples collected from the James River in October 2001.

Station	Al	Sb	As	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Th	Zn
2-APP005.38	7,050	< 5	< 5	< 5	< 1	12.7	9.7	12,700	13.2	485	< 0.1	7.1	< 1	< 1	< 5	40
2-JMS074.85	<u>26,400</u>	< 5	5.4	< 5	< 1	<u>40.1</u>	<u>49.7</u>	40,300	<u>36.9</u>	<u>909</u>	<u>0.18</u>	<u>27.3</u>	< 1	< 1	< 5	<u>173</u>
2-JMS076.42	11,500	< 5	< 5	< 5	< 1	22.8	<u>33.9</u>	25,600	21.4	530	0.12	15.6	< 1	< 1	< 5	<u>111</u>
2-JMS076.42 FD	11,700	< 5	< 5	< 5	< 1	23.1	27.4	25,700	21.7	532	0.12	16.0	< 1	< 1	< 5	107
2-JMS078.09	8,000	< 5	< 5	< 5	< 1	15.0	10.7	16,800	15.3	410	< 0.1	9.4	< 1	< 1	< 5	59
2-JMS093.28	<u>16,400</u>	< 5	< 5	< 5	< 1	35.9	31.6	32,500	<u>53.4</u>	<u>771</u>	<u>0.17</u>	17.5	< 1	< 1	< 5	<u>320</u>
2-JMS096.93	10,700	< 5	< 5	< 5	< 1	20.5	17.5	21,700	14.8	449	< 0.1	13.0	< 1	< 1	< 5	84
2-JMS102.20	<u>16,300</u>	< 5	< 5	< 5	< 1	31.8	28.4	34,900	26.1	<u>1,000</u>	< 0.1	20.4	< 1	< 1	< 5	<u>133</u>
2-JMS104.46	<u>25,700</u>	< 5	5.5	< 5	< 1	<u>45.1</u>	<u>35.6</u>	43,100	<u>38.0</u>	<u>1,390</u>	< 0.1	<u>30.0</u>	1.1	< 1	< 5	<u>173</u>
2-JMS109.27	3,230	< 5	< 5	< 5	< 1	16.1	5.2	11,000	11.4	170	< 0.1	5.0	< 1	< 1	< 5	39
Detection Limit	5	5.0	5.0	5.0	1.0	5.0	5.0	5	5.0	5	0.10	5.0	1.0	1.0	5.0	5
ER-L ^a			8.2		1.2	81	34		46.7		0.15	20.9		1.7		271
ER-M ^a			70.0		9.6	370	270		218		0.71	51.6		3.7		410
ER-L ^b	14,000		13		0.7	39	41	200,000	55	730		24				110
ER-M ^b	58,000		50		3.9	270	190	280,000	99	1,700		45				550
TEC ^c			9.79		0.99	43.4	31.6		35.8		0.18	22.7				121
PEC ^c			33		4.98	111	149		128		1.06	48.6				459

Underlined values exceed the relevant ER-L or TEC.

^a Long, E.R. *et al.* 1995.

^b Ingersoll, C.G. *et al.* 1996.

^c MacDonald, DD, CG Ingersoll and TA Berger. 2000

Table 3.5. Sediment acid volatile sulfide and simultaneously extracted metals (expressed as $\mu\text{mole/g}$ wet weight) for sediments collected from the James River in October 2001.

Station	AVS	Cadmium	Copper	Lead	Mercury	Nickel	Zinc	Sum SEM	SEM/AVS RATIO
2-APP005.38	5.5660	< 0.0218	< 0.0770	0.0236	< 0.000024	< 0.1667	0.3892	0.4128	0.0742
2-JMS074.85	19.1980	< 0.0331	0.2106	0.1076	< 0.000037	< 0.2533	1.6491	1.9673	0.1025
2-JMS076.42	6.3680	< 0.0199	0.1691	0.0670	< 0.000022	< 0.1525	1.1508	1.3869	0.2178
2-JMS076.42 FD	5.4380	< 0.0204	0.2018	0.0641	< 0.000023	< 0.1560	1.4501	1.7160	0.3156
2-JMS078.09	6.8840	< 0.0178	0.0755	0.0289	< 0.000020	< 0.1362	0.5261	0.6305	0.0916
2-JMS093.28	11.0290	< 0.0222	0.2516	0.1977	< 0.000025	< 0.1702	4.5006	4.9499	0.4645
2-JMS096.93	8.3880	< 0.0188	0.1398	0.0408	< 0.000021	< 0.1441	0.7957	0.9763	0.1261
2-JMS102.20	12.0430	< 0.0254	0.1349	0.0441	< 0.000028	< 0.1946	0.8739	1.0529	0.0874
2-JMS104.46	14.1760	< 0.0351	0.2236	0.0952	< 0.000039	< 0.2688	1.4003	1.7191	0.1213
2-JMS109.27	5.3520	< 0.0153	< 0.0540	0.0398	< 0.000017	< 0.1169	0.3622	0.4020	0.0751

FD = Field Duplicate

Table 3.6. Semi-Volatile Organic Compound (SVOC) concentrations (ng/g) in sediment samples collected from the James River in October 2001.

Analyte	Sediment Quality Guidelines													
	ER-L	ER-M	TEC	PEC	2-APP005.38	2-JMS074.85	2-JMS076.42	2-JMS076.42	2-JMS078.09	2-JMS093.28	2-JMS096.93	2-JMS102.20	2-JMS104.46	2-JMS109.27
								Field Dup.						
1,4-Dichlorobenzene	Not Available				< 25	< 25	< 25	5	< 25	< 25	5	< 25	< 25	10
1,2,4-Trichlorobenzene	Not Available				< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	25	< 25
2,4-Dinitrotoluene	Not Available				< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	15	< 25
Isophorone	Not Available				20	5	< 25	15	< 25	20	80	10	15	10
Carbazole	Not Available				< 25	< 25	10	15	< 25	< 25	25	< 25	25	< 25
Dimethyl phthalate	Not Available				< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25
Dibenzofuran	Not Available				10	< 25	10	< 25	< 25	< 25	15	< 25	< 25	< 25
Diethyl phthalate	Not Available				20	30	15	30	10	15	< 25	30	55	10
N-Nitrosodiphenylamine	Not Available				< 25	15	10	25	< 25	< 25	< 25	< 25	< 25	< 25
Di-N-butylphthalate	Not Available				170	190	65	190	80	10	130	130	240	15
Butylbenzylphthalate	Not Available				< 25	< 25	< 25	< 25	< 25	< 25	< 25	< 25	30	< 25
Bis[2-ethylhexyl]phthalate	Not Available				340	190	95	210	100	100	100	140	380	110
Di-N-octylphthalate	Not Available				< 25	< 25	5	25	< 25	< 25	25	< 25	20	< 25
<i>Low Molecular PAHs</i>														
2-Methylnaphthalene	70	670			15	40	35	40	15	30	<u>140</u>	20	30	10
Acenaphthalene	44	160			30	15	5	<u>130</u>	15	10	10	20	20	< 25
Acenaphthene	16	500			<u>30</u>	< 25	10	10	5	15	<u>20</u>	10	<u>35</u>	10
Anthracene	85.3	1,100	57.2	845	<u>140</u>	40	45	45	30	30	50	25	40	15
Fluorene	19	540	77.4	536	<u>20</u>	15	<u>20</u>	15	10	10	<u>20</u>	10	15	5
Naphthalene	160	2,100	176	561	55	60	40	75	35	40	<u>240</u>	45	75	40
Phenanthrene	240	1,500	204	1,170	<u>320</u>	110	110	170	120	90	180	140	180	110
Total LM PAHs	552	3,160			<u>610</u>	280	265	485	230	225	<u>660</u>	270	395	190

Table 3.6 (Cont.). Semi-Volatile Organic Compound (SVOC) concentrations (ng/g) in sediment samples collected from the James River in October 2001.

Analyte	Sediment Quality Guidelines				2-	2-	2-	2-	2-	2-	2-	2-	2-	2-
	ER-L	ER-M	TEC	PEC	APP005.38	JMS074.85	JMS076.42	JMS076.42 Field Dup.	JMS078.09	JMS093.28	JMS096.93	JMS102.20	JMS104.46	JMS109.27
<i>High Molecular PAHs</i>														
Benzo[a]anthracene	261	1600			<u>670</u>	120	85	<u>280</u>	190	75	230	140	170	70
Benzo[b]fluoranthene					560	140	100	270	210	80	260	190	250	110
Benzo[k]fluoranthene					180	70	55	150	140	35	140	100	90	35
Benzo[e]pyrene					310	80	60	180	130	60	190	120	140	60
Benzo[a]pyrene	430	1600	150	1450	<u>510</u>	90	75	<u>210</u>	<u>190</u>	80	<u>180</u>	120	<u>160</u>	60
Benzo[g,h,i]perylene					110	10	< 25	10	10	25	10	10	10	5
Chrysene	384	2,800	166	1,290	<u>440</u>	95	90	<u>210</u>	130	65	160	110	<u>190</u>	70
Dibenz[a,h]anthracene			33	NA	<u>85</u>	15	10	25	20	10	30	15	28	10
Fluoranthene	600	5,100	423	2,230	<u>830</u>	200	120	<u>480</u>	190	80	300	210	370	160
Indeno[1,2,3-cd]pyrene	63.4	260			<u>270</u>	55	35	<u>120</u>	<u>100</u>	45	<u>110</u>	65	<u>130</u>	40
Perylene					550	350	180	410	110	170	95	40	100	15
Pyrene	665	2,600	195	1,520	<u>660</u>	<u>240</u>	120	<u>490</u>	<u>220</u>	140	<u>260</u>	<u>220</u>	<u>320</u>	130
Total HM PAHs	1,700	9,600	NA	NA	<u>5,175</u>	1,465	930	<u>2,835</u>	1,640	865	<u>1,965</u>	1,340	<u>1,958</u>	765
Total PAHs	4,022	44,792	1,610	22,800	<u>5,785</u>	<u>1,745</u>	1,195	<u>3,320</u>	<u>1,870</u>	1,090	<u>2,625</u>	1,610	<u>2,353</u>	955

Reporting Limits = 25 ng/g (dry weight)

Compounds reported 5-25 ng/g are estimated concentrations

Underlined values exceed the relevant ER-L

Table 3.7. Organophosphate pesticides in sediment samples (ng/g dry weight) collected from the James River in October 2001.

Compound		2-APP005.38	074.85	076.42	076.42	078.09	093.28	096.93	102.20	104.46	0109.27
					Field Dup.						
Dichlorvos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Mevinphos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
TEPP	BQL	<10	<13	<9	<9	<8	<7	<8	<12	<17	<7
Thionazon	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Demeton	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Ethoprop	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Naled	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Dicrotophos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Sulfotep + Phorate	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Monocrotophos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Dimethoate	BQL	<6	<8	<5	<5	<5	<4	<5	<7	<10	<4
Terbufos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Monophos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Diazinon	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Disulfoton+Phosphamidon											
+Dichlorofenthion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Chlorpyrifos(methyl)	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Parathion(methyl)	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Ronnel	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Fenitrothion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Malithion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Chlorpyrifos+Aspon	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Fenthion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Parathion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Trichlornate	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Chlorfenvinphos	BQL	<6	<8	<5	<5	<5	<4	<5	<7	<10	<4
Crotoxyphos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Tetrachlorvinphos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Tokuthion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Folex	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Fensulfothion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Ethion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Carbophenothion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Bolstar	BQL	<6	<8	<5	<5	<5	<4	<5	<7	<10	<4
Famfur	BQL	<6	<8	<5	<5	<5	<4	<5	<7	<10	<4
Triphenylphosphate SS	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Phosmet	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
EPN	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Leptophos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Guthion(methyl)	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Guthion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Coumaphos	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3
Dioxathion	BQL	<4	<5	<3	<4	<3	<3	<3	<5	<7	<3

All results are reported in ng/g (dry weight)

The QLs have been adjusted for each sample based on % moisture.

Table 3.8. Organochlorine pesticides in sediment samples (ng/g dry weight) collected from the James River in October 2001.

Analyte	Blank 1	ER-L	ER-M	TEC	PEC	2-APP005.38	074.85	076.42	076.42	078.09	093.28	096.93	102.20	104.46	109.27
									Field Dup.						
HCCP	3					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
a-BHC & HCB & Diallyate	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
b-BHC & g-BHC	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
d-BHC	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Heptachlor	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Aldrin	5					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Isodrin	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Heptachlor Epoxide	BQL			2.5	16	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
g-Chlordane	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Endosulfan I & a-Chlordane	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Dieldrin & DDE	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Endrin	BQL			2	207	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Endosulfan II & DDD						< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Chlorbenzylate	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
DDD	BQL	2	20	5	28	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Endosulfan Sulfate	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
DDT	BQL	1	7	4	63	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Endrin Ketone	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Methoxychlor	BQL					< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
Kepone						< 10	50	180	20	< 10	< 10	< 10	10	10	< 10

The QLs have been adjusted for each sample based on % moisture.

DL Kepone \leq 10 ng/g

Table 3.9. Polychlorinated Biphenyls in sediment samples (ng/g dry weight) collected from the James River in October 2001.

Compound		2-APP005.38	074.85	076.42	076.42	078.09	093.28	096.93	102.20	104.46	109.27
					Field Dup						
PCB-001	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-005+008	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-018	BQL	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	< 3
PCB-028+031	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-52	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-44	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-66	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-101	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	5
PCB-81+77	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-87	BQL	< 4	< 5	< 3	< 4	< 3	< 3	< 3	< 5	< 7	4
PCB-110	BQL	< 6	< 8	< 5	< 5	< 5	< 4	< 5	< 7	< 10	< 1
PCB-151	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-118	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-105	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	5
PCB-153	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-141	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-138	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	9
PCB-126	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-187	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-183	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-128	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-156	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-169	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	< 1
PCB-180	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	1
PCB-170	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-195	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D
PCB-206	BQL	< 2	< 3	< 2	< 2	< 2	< 1	< 2	< 2	< 3	D

D = Detected with mass spectral confirmation but < 1 ng/g.

The QLs have been adjusted for each sample based on % moisture.

Table 3.10. Herbicide concentrations in sediment samples (ng/g, dry weight basis) collected from the James River in October 2001.

Compound	2-APP005.38	074.85	076.42	076.42	078.09	093.28	096.93	102.20	104.46	109.27
				Field Dup						
Dalapon	< 30	< 38	< 26	< 26	< 23	< 21	< 24	< 36	< 51	< 19
3,5-DBCA	< 40	< 50	< 34	< 35	< 30	< 28	< 32	< 48	< 68	< 26
4-Nitrophenol	< 30	< 38	< 26	< 26	< 23	< 21	< 24	< 36	< 51	< 19
Dicamba	< 10	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
MCPP	< 800	< 1000	< 680	< 700	< 600	< 560	< 640	< 960	< 1360	< 512
MCPA	< 1200	< 1500	< 1020	< 1050	< 900	< 840	< 960	< 1440	< 2040	< 768
Dichlorprop	< 20	< 25	< 17	< 18	< 15	< 14	< 16	< 24	< 34	< 13
2,4-D	< 10	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
Pentachlorophenol	< 10	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
2,4,5-TP	< 10	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
Chloramben	< 50	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
2,4,5-T	< 10	< 13	< 9	< 9	< 8	< 7	< 8	< 12	< 17	< 6
2,4-DB & Dinoseb	< 20	< 25	< 17	< 18	< 15	< 14	< 16	< 24	< 34	< 13
Bentazon	< 20	< 25	< 17	< 18	< 15	< 14	< 16	< 24	< 34	< 13
Picloram	< 40	< 50	< 34	< 35	< 30	< 28	< 32	< 48	< 68	< 26
Acifluorfen	< 30	< 38	< 26	< 26	< 23	< 21	< 24	< 36	< 51	< 19

3.4 Toxicity Characterization

3.4.1 Amphipod Test: Test acceptability criteria based on control responses were met for both survival and growth (Table 3.11). Mean dry weight increased by 0.030 mg/individual for control animals, a 44% increase. Dissolved oxygen concentrations, temperatures, pH values and ammonia concentrations in the water column for all treatments were within acceptable ranges throughout the test (Appendix A, Table A1). The 96-h LC50 value for the concurrent reference toxicant test fell within the 95% confidence limits of values for tests previously conducted with this species in the Coastal Bioanalysts, Inc. laboratory (Table 3.12).

Survival in individual laboratory replicates ranged from 70% to 100%. Overall survival among field replicates was 90.3% (6.7% C.V.). No significant differences in survival between control and field replicates or among stations were identified with the Kruskal-Wallis test (Appendix A, Table A3).

Amphipods exposed to sediment from station 2-JMS078.09 were larger than amphipods exposed to any other sediment in the test, and significantly larger than amphipods exposed to sediment from stations 2-JMS093.28, 2-JMS096.93, 2-JMS102.20 or 2-JMS104.46. The total range in final amphipod weight among all station replicates was 0.067 to 0.128

The number of emergent animals observed is sometimes considered an indicator of sediment avoidance. Although no significant differences were identified when comparing individual samples and the laboratory control, emergence did differ significantly ($p = 0.03$) among stations. Hypothesis tests using a nested design (Tukey's test) failed to identify significant pair-wise differences. A qualitative examination of the data suggests that emergence may have been greater among amphipods exposed to sediment from stations 2-JMS074.85, 2-JMS093.28 and 2-JMS096.93. The field replicate with the highest emergence rate (2-JMS093.28C) was that observed to have a PAH-like odor (although PAH content of composited sediment from this station was not elevated; see Table 3.6). The elevated emergence rate for amphipods exposed to sediment from this station is consistent with the low survival and final weight among these amphipods.

3.4.2 Chironomid Test: Test acceptability criteria were met for both survival and growth (Table 3.13). Mean ash-free dry weight increased 1.01 mg/individual for control animals. Final control growth well exceeded the EPA (2000) criterion of 0.48 mg ash-free dry weight. Dissolved oxygen concentrations, temperatures, pH values and ammonia concentrations in the water column for all treatments were within acceptable ranges throughout the test (Appendix A, Table A2). The 96-h LC50 value for the concurrent reference toxicant test fell within the 95% confidence limits of values for tests previously conducted with this species in the Coastal Bioanalysts, Inc. laboratory (Table 3.12).

Survival in all other laboratory replicates except those for station 2-JMS093.28B was 70% to 100%. The lowest three survival rates occurred in the laboratory replicates of sediment from 2-JMS093.28B (25% to 60%). Overall survival among field replicates was 91.1% (9.8% C.V.). Survival in field replicate 2-JMS093.28B was significantly less than that of laboratory controls (Table 3.13). Survival in sediment from Station 2-JMS093.28 was significantly less than that of

animals exposed to sediment from stations 2-JMS078.09, 2-JMS096.93 and 2-JMS102.20. These differences at the station level appear to be due solely to the performance of animals in field replicate 2-JMS093.28B.

Average ash-free dry weight for individual laboratory replicates ranged from 0.711 mg to 1.683 mg. Overall the average ash-free dry weight among field replicates was 1.073 mg (10.7% C.V.). Ash-free dry weight did not differ significantly among stations or between control and field replicates.

Emergence rates were low for most stations and lab replicates. However, field replicate 2-JMS109.27C had a significantly higher emergence rate than did control animals and the overall emergence rate for station 2-JMS109.27 was significantly greater than that of all other stations except 2-JMS078.09 and 2-JMS096.93. The emergence values for field replicate 2-JMS109.27C are probably responsible for the overall significance at this station.

3.4.3 Fathead Minnow Test: A few fish embryos hatched on test day 3, or 5 days post fertilization. The majority of the fish embryos hatched on test days 4 and 5, or 6-7 days after fertilization. The time to hatching is typical for fathead minnows at 24° C. Previous tests conducted on sediments from the same system had a slightly shorter incubation period (5-6 days) but the test temperature was slightly higher (25° C) and the fish may have been slightly more developed at test initiation. Obvious fungal or bacterial growth was not observed on any eggs or sediment surfaces. Mean hatch rate and survival for control fish (96.7%) greatly exceeded the minimum test acceptability criterion of 80% and post-hatch survival was 100% (Tables 3.14 and 3.15). Dissolved oxygen concentrations, temperatures, pH values and ammonia concentrations in the water column for all treatments were within acceptable ranges throughout the test (Appendix A, Table A3). The 96-h LC50 value for the concurrent reference toxicant test fell within the 95% confidence limits of values for tests previously conducted with this species in the Coastal Bioanalysts, Inc. laboratory (Table 3.12). Therefore, the criteria for test acceptability were all met.

Although total (i.e. embryo and fry stages) exposure time is the same for all fish, exposure times for fish fry vary depending upon the time of hatch of individual eggs. In addition, one cannot discriminate unequivocally whether dead fish occurring in the chambers since the previous 24-h check result from an unsuccessful hatch or post-hatch fish that died subsequent to the previous observation time. Therefore interpretation of the percent hatch and survival data is somewhat confounded.

Most mortality appears to be associated with the embryonic period. Post-hatch survival rates generally exceeded cumulative hatch rates and cumulative hatch rates were similar to total survival rates. This indicates that most mortality was associated with hatch failures. Cumulative hatch of laboratory control and treatment embryos plateaued between test days 5 and 6 (Table 3.14). Embryos that did not hatch by day 5 or 6 were unlikely to hatch, even in treatments with moderately good hatch rates. In addition, many fish that hatched on test day 3 (when only 6.7% of the lab control fish had hatched) appeared to have hatched prematurely and were found dead in a curled, embryo-like state.

Mortality appeared to be replicate specific (Table 3.15). Within some field replicates (e.g. 2-APP005.38A, 2-JMS074.85B), survival varied among laboratory replicates by as much as 90% (Table 3.15). These observed replicate-specific differences preclude one arguing that replicate 2-APP005.38A and 2-APP005.38B (or replicates 2-JMS074.85B and 2-JMS074.85C) differ in ability to support fish embryos. Of the 83 treatment replicates (86 if one includes the control replicates), there were 10 cases in which excessive replicate-specific mortality was clearly demonstrable. Because of these replicate-specific effects, no valid statistical analysis was possible using post-hatch or total survival for the test.

Numerous studies have correlated replicate-specific mortality in larval fathead minnow tests with the presence of fish pathogens in ambient water samples. Frequently, treatment with UV irradiation, antibiotics or filtration (0.2 um), eliminated replicate-specific mortality (Grothe and Johnson, 1996; Kszos *et al.*, 1997; Guinn, 1998; Downey *et al.*, 2000). Pathogens to fathead minnows may occur in natural water samples at a relatively high frequency. The Wisconsin Department of Natural Resources has reported that several laboratories conducting larval fathead minnow tests (n=1496) showed sporadic mortality in 26% of the ambient water control groups compared with 2.9% of the laboratory water controls (Downey *et al.*, 2000). Seasonal effects have also been noted. Ambient water samples collected in warm months appear to exhibit lower incidences of replicate-specific mortality than those collected at other times of the year (Kszos *et al.* 1997; unpublished data of CBI).

The published studies report pathogen interference in fathead larval tests, not embryo-larval tests. It is suggestive nevertheless that replicate-specific mortality has been consistently noted to start on or about test day 4, which corresponds to the time of elevated mortality in the current study. In contrast, survival of laboratory control animals was consistently high, and no similar mortality (embryo, larval or adult) was noted in the laboratory cultures from which test animals were obtained. The hatch rate for several hundred embryos retained for the reference toxicant test was high (near 100%). Thus circumstantially, infective agents would have had to originate from the sediment samples.

To prove definitively that fish pathogens from the sediments caused the observed mortality would require detailed studies that go beyond the normal and reasonable procedures for sediment toxicity tests.

Table 3.11. Survival and final weight of *Hyallorella azteca* exposed to sediment. (Shaded cells in bold significantly different from shaded non-bold cells; p = 0.05)

Station	Survival (%)		Dry Wt. (mg)		Total No. Emergent
	Mean	S.D.	Mean	S.D.	
005.38A	92	7.8	0.102	0.005	9
005.38B	88	12.2	0.087	0.010	5
005.38C	90	3.3	0.070	0.011	8
074.85A	92	7.8	0.082	0.015	14
074.85B	90	3.3	0.091	0.017	8
074.85C	90	6.7	0.080	0.016	4
076.42A	97	2.2	0.095	0.006	7
076.42B	92	2.2	0.094	0.014	5
076.42C	93	4.4	0.092	0.010	5
078.09A	100	0.0	0.101	0.016	8
078.09B	95	3.3	0.121	0.017	8
078.09C	88	4.4	0.128	0.039	1
093.28A	73	7.8	0.073	0.007	4
093.28B	90	6.7	0.085	0.002	7
093.28C	80	3.3	0.067	0.005	19
096.93A	87	11.1	0.083	0.011	15
096.93B	92	5.6	0.068	0.009	9
096.93C	97	4.4	0.089	0.016	6
102.20A	90	0.0	0.069	0.010	7
102.20B	98	2.2	0.083	0.004	1
102.20C	83	2.2	0.084	0.011	0
104.46A	82	7.8	0.081	0.021	1
104.46B	83	4.4	0.080	0.003	3
104.46C	95	3.3	0.070	0.009	2
109.27A	97	4.4	0.096	0.011	3
109.27B	88	8.9	0.100	0.013	0
109.27C	95	6.7	0.080	0.005	7
Lab Control	92	4.4	0.098	0.015	5

Table 3.12. Reference toxicant test results for species used in aqueous toxicity tests (Reference toxicant: KCl, Sigma “Ultra” lot #29H00321; values in mg/l).

	<i>H. azteca</i>	<i>C. tentans</i>	<i>P. promelas</i>
Ref. Test Dates	10/23/01 to 10/27/01	10/26/01 to 10/30/01	10/29/01 to 10/31/01
LC50 (95% C.L.)	439.2 (415.8-463.7)	5200 (4500-5900)	936.6 (874.0-1003.7)
Control Chart LC50 (95% C.L.)	468.4 (387.1-549.6)	4900 (3300-6400)	829.3 (648.6-1018.9)

Table 3.13. Survival, final weight, and emergence of *Chironomus tentans* exposed to sediment. (Shaded cells in bold significantly different from shaded non-bold cells. Values noted with asterisk significantly different from laboratory control group (p = 0.05)).

Station	Survival (%)		Ash Free Dry Wt (mg)		Total No. Emergent
	Mean	S.D.	Mean	S.D.	
005.38A	98	2.2	1.058	0.143	1
005.38B	93	2.2	0.970	0.132	0
005.38C	83	15.6	0.836	0.118	0
074.85A	95	3.3	1.097	0.183	0
074.85B	92	7.8	1.093	0.087	0
074.85C	88	4.4	1.114	0.095	0
076.42A	90	3.3	1.230	0.074	0
076.42B	95	3.3	0.880	0.067	0
076.42C	92	5.6	0.979	0.148	0
078.09A	100	0.0	1.097	0.105	0
078.09B	93	8.9	1.120	0.214	3
078.09C	90	0.0	1.095	0.098	0
093.28A	92	5.6	0.897	0.124	1
093.28B	50*	16.7	1.208	0.201	0
093.28C	85	6.7	0.874	0.058	0
096.93A	98	2.2	1.060	0.191	0
096.93B	93	5.6	1.057	0.081	1
096.93C	93	8.9	1.145	0.070	3
102.20A	92	5.6	1.233	0.300	0
102.20B	97	2.2	0.980	0.044	0
102.20C	98	2.2	1.062	0.199	0
104.46A	87	2.2	1.096	0.101	1
104.46B	95	3.3	1.097	0.136	0
104.46C	93	5.6	1.312	0.042	0
109.27A	90	3.3	1.222	0.086	3
109.27B	90	6.7	1.045	0.152	2
109.27C	93	8.9	1.092	0.230	9*
Lab Control	95	6.7	1.090	0.010	0

Table 3.14. Percent hatch percent for *Pimephales promelas* exposed to sediment.

Station	Cumulative % Hatch							
	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
005.38A	0.0	0.0	0.0	40.0	40.0	46.7	56.7	56.7
005.38B	0.0	3.3	10.0	16.7	23.3	23.3	23.3	23.3
005.38C	0.0	0.0	0.0	70.0	80.0	80.0	80.0	80.0
074.85A	0.0	0.0	0.0	16.7	43.3	43.3	43.3	43.3
074.85B	0.0	0.0	0.0	3.3	26.7	36.7	36.7	36.7
074.85C	0.0	0.0	0.0	3.3	3.3	3.3	3.3	3.3
076.42A	0.0	3.3	3.3	10.0	36.7	46.7	53.3	53.3
076.42B	0.0	3.3	3.3	46.7	73.3	76.7	80.0	80.0
076.42C	0.0	0.0	3.3	40.0	63.3	66.7	73.3	73.3
078.09A	0.0	0.0	0.0	23.3	33.3	33.3	33.3	33.3
078.09B	0.0	0.0	0.0	33.3	70.0	70.0	70.0	70.0
078.09C	0.0	0.0	13.3	26.7	36.7	40.0	43.3	43.3
093.28A	0.0	0.0	3.3	26.7	63.3	80.0	80.0	80.0
093.28B	0.0	3.3	10.0	76.7	80.0	83.3	83.3	83.3
093.28C	0.0	6.7	6.7	13.3	50.0	60.0	76.7	76.7
096.93A	0.0	13.3	20.0	43.3	60.0	63.3	63.3	63.3
096.93B	0.0	0.0	16.7	40.0	60.0	63.3	66.7	66.7
096.93C	0.0	0.0	6.7	46.7	50.0	50.0	50.0	50.0
102.20A	0.0	3.3	6.7	6.7	30.0	36.7	43.3	43.3
102.20B	0.0	3.3	10.0	33.3	50.0	56.7	56.7	56.7
102.20C	0.0	10.0	30.0	30.0	36.7	36.7	40.0	40.0
104.46A	0.0	3.3	3.3	36.7	46.7	53.3	53.3	53.3
104.46B	0.0	6.7	6.7	10.0	23.3	23.3	26.7	26.7
104.46C	0.0	0.0	0.0	20.0	26.7	33.3	33.3	33.3
109.27A	0.0	10.0	20.0	50.0	60.0	63.3	66.7	66.7
109.27B	0.0	0.0	0.0	43.3	66.7	66.7	66.7	66.7
109.27C	0.0	0.0	0.0	40.0	60.0	63.3	63.3	63.3
Lab Control	0.0	0.0	6.7	56.7	90.0	96.7	96.7	96.7

Table 3.15. Percent post hatch survival and percent total survival for *Pimephales promelas* exposed to sediment. Total percent survival by replicate is included to illuminate the lack of significant differences among locations.

Station	Mean % Survival		% Total Survival by Replicate		
	Post Hatch	Total	Repl. #1	Repl. #2	Repl. #3
005.38A	66.7	53.3	90.0	70.0	0.0
005.38B	30.0	10.0	20.0	0.0	10.0
005.38C	90.5	73.3	100.0	50.0	70.0
074.85A	100.0	43.3	40.0	10.0	80.0
074.85B	66.7	36.7	0.0	90.0	20.0
074.85C	0.0	0.0	0.0	0.0	0.0
076.42A	100.0	53.3	10.0	70.0	80.0
076.42B	95.8	76.7	80.0	70.0	80.0
076.42C	100.0	73.3	100.0	60.0	60.0
078.09A	66.7	33.3	20.0	80.0	0.0
078.09B	100.0	70.0	90.0	40.0	80.0
078.09C	83.3	40.0	80.0	10.0	30.0
093.28A	100.0	80.0	80.0	70.0	90.0
093.28B	96.3	80.0	80.0	90.0	70.0
093.28C	100.0	76.7	70.0	100.0	60.0
096.93A	85.7	53.3	40.0	60.0	60.0
096.93B	89.2	60.0	70.0	40.0	70.0
096.93C	66.7	46.7	80.0	60.0	0.0
102.20A	66.7	40.0	90.0	0.0	30.0
102.20B	95.2	53.3	40.0	60.0	60.0
102.20C	85.2	26.7	50.0	10.0	20.0
104.46A	60.0	46.7	80.0	0.0	60.0
104.46B	66.7	20.0	0.0	40.0	20.0
104.46C	83.3	26.7	30.0	30.0	20.0
109.27A	95.8	63.3	60.0	60.0	70.0
109.27B	63.3	50.0	90.0	0.0	60.0
109.27C	66.7	63.3	90.0	100.0	0.0
Lab Control	100.0	96.7	90.0	100.0	100.0

3.5 Benthic Community Analysis

The salinity was virtually 0 at every station. The temperature was uniform across all strata. Sediment texture (Table 3.16) was generally similar to that of samples collected for chemical and toxicological analysis, though there were some clear differences. The TOC was uniformly higher than in the chemical and toxicological samples analyzed by DCLS and by the VIMS Analytical Services Laboratory with greater interstation differences (Tables 3.2 and 3.3). In a general way, the samples did contain similar sand content.

Important community level parameters for the samples are the species composition in each grab sample, abundance (number of individuals per m²), and biomass (ash-free dry weight per m² (with and without bivalves)). These and other scored community parameters result in the values of the Benthic Index of Biotic Integrity and the condition of each site (Table 3.17). Samples from all but one station (2-JMS096.93) had a B-IBI below 3.0, which indicates a benthic community with a degraded condition (Alden *et al.* 2002). Four of the stations had B-IBI values below 2.0 indicating a severely degraded condition (Alden *op cit.*). These stations were located, one downstream of Falling Creek near Richmond, the 2 stations nearest Hopewell, and one in the Appomatox. The one non-degraded station was located in the oxbow around Hatcher Island.

The numbers of individuals and their AFDW biomass are listed in Table 3.18. The 8 stations with degraded benthic communities were all dominated by oligochaetes, most notably *Limnodrilus* sp. as well as pollution indicative insects (chironomids). In contrast, the non-degraded community consisted of pollution-sensitive insect species exclusively and was totally lacking in oligochaete species. There was a notable lack of amphipod species at almost every station except 2-APP005.38. The pollution sensitive isopod *Cyathura polita* was found in stratum 2 (downstream station), stratum 3 and stratum 4 (2-APP005.38, the most degraded station).

Table 3.19 lists the individual metric scores for each station and the resultant B-IBI. The metrics used, a more comprehensive list than that in Weisberg *et al.* (1997), are described and justified in Scott *et al.* (in preparation as cited in Alden *et al.* 2002). Scores cannot be given for some metrics, and these are designated with a “-“ in the table and are omitted from the calculation of the B-IBI.

Table 3.16 Sediment Texture for 9 James River stations upstream of Jordan Point.

Station	% sand	% silt-clay	%TOC (w/w * 100)
2-JMS109.27	96.17	3.83	2.08
2-JMS104.46	1.57	98.43	12.21
2-JMS102.20	46.26	53.74	9.77
2-JMS096.93	38.54	61.46	3.24
2-JMS093.29	8.83	91.17	10.44
2-JMS078.09	88.33	11.67	2.30
2-JMS076.42	71.17	28.83	8.41
2-JMS074.85	8.86	91.14	9.73
2-APP005.38	96.77	3.23	1.17

Table 3.17 Benthic Community Parameters for 9 James River stations upstream of Jordan Point.

Station	Total Species	Ind./sq.m	Total AFDW Biomass (g/sq.m)	BIBI Score	Community Condition
2-JMS109.27	3	340.2	0.227	2.0	Degraded
2-JMS104.46	9	975.2	0.726	2.5	Degraded
2-JMS102.20	7	771.1	0.181	1.5	Severely Degraded
2-JMS096.93	7	2268.0	0.318	4.5	Healthy
2-JMS093.29	11	5307.1	1.452	2.5	Degraded
2-JMS078.09	11	10296.7	0.975	1.7	Severely Degraded
2-JMS076.42	10	3810.2	0.408	1.7	Severely Degraded
2-JMS047.85	9	6191.6	0.522	2.3	Degraded
2-APP005.38	13	6826.7	0.408	1.3	Severely Degraded

Table 3.18 Benthic species abundance list with ash-free dry weight biomass (AFDW in mg).

Phylum	Class	Taxon Genus species	Stratum 1				Stratum 2					
			2-JMS109.27		2-JMS104.46		2-JMS102.20		2-JMS096.93		2-JMS093.27	
			Abundance	AFDW								
Annelida	Oligochaeta	<i>Limnodrilus hoffmeisteri</i>	8	8	10	11	13	2			78	39
Annelida	Oligochaeta	<i>Limnodrilus cervix</i>									2	1
Annelida	Oligochaeta	<i>Limnodrilus</i> spp (juv)	4	1	19	10	10	1			131	16
Annelida	Oligochaeta	<i>Branchiura sowerbyi</i>			1	4						
Annelida	Oligochaeta	<i>Dero</i> spp			3	1					3	1
Annelida	Oligochaeta	<i>Ilyodrilus templetoni</i>			4	1					6	1
Annelida	Oligochaeta	<i>Isochaetides freyi</i>			2	2					2	1
Annelida	Oligochaeta	<i>Marenzelleria viridis</i>										
Annelida	Oligochaeta	<i>Tasserkidrilus harmani</i>										
Annelida	Polychaeta	Pilargidae spp			2	1						
Arthropoda	Isopoda	<i>Cyathura polita</i>									3	1
Arthropoda	Amphipoda	<i>Gammarus daiberi</i>										
Arthropoda	Amphipoda	<i>Melita nitida</i>										
Arthropoda	Cumacea	<i>Almyracuma proximoculi</i>									1	1
Arthropoda	Insecta	<i>Caeniss</i> spp										
Arthropoda	Insecta	Chironomini spp							41	4		
Arthropoda	Insecta	<i>Chironomus</i> spp										
Arthropoda	Insecta	<i>Dicrotendipes nervosus</i>							32	3		
Arthropoda	Insecta	<i>Glyptotendipes</i> spp.							12	1		
Arthropoda	Insecta	<i>Hexagonia</i> spp.							1	2		
Arthropoda	Insecta	<i>Clinotanypus pinguis</i>										
Arthropoda	Insecta	<i>Coelotanypus</i> spp	3	1			1	1				
Arthropoda	Insecta	<i>Tanypus</i> spp										
Arthropoda	Insecta	<i>Cryptochironomus fulvus</i>			1	1	3	1			4	1
Arthropoda	Insecta	<i>Polypedilum convictum</i>					1	1			1	1
Arthropoda	Insecta	<i>Procladius sublettei</i>			1	1	5	1	2	1		
Arthropoda	Insecta	<i>Trichoptera</i> sp.							2	1		
Arthropoda	Insecta	<i>Xenochironomus</i> spp.							10	2		
Mollusca	Bivalvia	Sphaeriidae spp.					1	1				
Totals			15	10	43	32	34	8	100	14	231	63

Table 3.18 (con't.) Benthic species abundance list with ash-free dry weight biomass (AFDW in mg).

Phylum	Class	Taxon Genus species	Stratum 3				Stratum 4			
			2-JMS078.09		2-JMS076.42		2-APP0005.38			
			Abundance	AFDW	Abundance	AFDW	Abundance	AFDW		
Annelida	Oligochaeta	<i>Limnodrilus hoffmeisteri</i>	122	14	26	2	32	2	41	2
Annelida	Oligochaeta	<i>Limnodrilus cervix</i>	2	1			3	1		
Annelida	Oligochaeta	<i>Limnodrilus</i> spp (juv)	265	16	69	2	145	6	140	4
Annelida	Oligochaeta	<i>Branchiura sowerbyi</i>			4	1				
Annelida	Oligochaeta	<i>Dero</i> spp			8	1	5	1		
Annelida	Oligochaeta	<i>Ilyodrilus templetoni</i>	31	1			62	1	2	1
Annelida	Oligochaeta	<i>Isochaetides freyi</i>	5	3					65	2
Annelida	Oligochaeta	<i>Marenzelleria viridis</i>	2	3						
Annelida	Oligochaeta	<i>Tasserkidrilus harmani</i>							1	1
Annelida	Polychaeta	Pilargidae spp								
Arthropoda	Isopoda	<i>Cyathura polita</i>	5	1	7	1			1	1
Arthropoda	Amphipoda	<i>Gammarus daiberi</i>							10	1
Arthropoda	Amphipoda	<i>Melita nitida</i>							10	1
Arthropoda	Cumacea	<i>Almyracuma proximoculi</i>							3	1
Arthropoda	Insecta	<i>Caenis</i> spp							7	1
Arthropoda	Insecta	Chironomini spp								
Arthropoda	Insecta	<i>Chironomus</i> spp	9	1	15	5	4	3		
Arthropoda	Insecta	<i>Dicrotendipes nervosus</i>								
Arthropoda	Insecta	<i>Glyptotendipes</i> spp.								
Arthropoda	Insecta	<i>Hexagonia</i> spp.								
Arthropoda	Insecta	<i>Clinotanypus pinguis</i>					20	7		
Arthropoda	Insecta	<i>Coelotanypus</i> spp	4	1	31	3				
Arthropoda	Insecta	<i>Tanypus</i> spp			2	1			5	1
Arthropoda	Insecta	<i>Cryptochironomus fulvus</i>	7	1					13	1
Arthropoda	Insecta	<i>Polypedilum convictum</i>			3	1			3	1
Arthropoda	Insecta	<i>Procladius sublettei</i>	2	1			1	1		
Arthropoda	Insecta	<i>Trichoptera</i> sp.								
Arthropoda	Insecta	<i>Xenochironomus</i> spp.								
Mollusca	Bivalvia	Sphaeriidae spp.			3	1	1	1		
Totals			454	43	168	18	273	23	301	18

Table 3.19. Individual metric scores and calculated B-IBI for each station.

Station	Abundance	Carnivore/ Omnivore Ratio	Deep Deposit Feeders	Tolerance Score	Pollution Indicative Species	Pollution Sensitive Species	Tanypodinae/ Chironomidae Ratio	B-IBI Score
2-JMS109.27	1	-	1	3	3	-	-	2.0
2-JMS104.46	3	-	3	1	3	-	-	2.5
2-JMS102.20	1	-	1	1	3	-	-	1.5
2-JMS096.93	5	-	5	3	5	-	-	4.5
2-JMS093.28	1	-	3	3	5	-	-	2.5
2-JMS078.09	1	1	-	1	1	1	5	1.7
2-JMS076.42	1	1	-	1	1	3	3	1.7
2-JMS074.85	3	3	-	3	3	1	1	2.3
2-APP005.38	1	1	-	1	3	1	1	1.3

4.0 DISCUSSION

Four strata were defined for this study based on obvious differences in adjacent land use and river morphology. Nevertheless, the sediment texture was similar throughout the region. All but two stations had substantial sand present. Both stations with low sand content were in industrialized areas, but neither exhibited substantially elevated concentrations of any analyte reported.

The two non-sandy stations both contained measurable amounts of Kepone, but a sandy station in the Hopewell region exhibited a higher concentration of Kepone. No other pesticide and no SVOCs were present in concentrations suggesting possible toxic effects. Similarly, metals were not sufficiently abundant to suggest toxicity of sediments.

One might expect elevated chemical concentrations for some compounds in the vicinity of Hopewell and Richmond. There is limited evidence of such a trend, based on exceedance of the ER-L for some PAHs. However, if one plots the total sedimentary PAH for the stations sampled in this study with that data for the study of the region extending downstream to Jamestown Island (Roberts *et al.*, 2002), there is a clear indication of the industrial impact stemming from Richmond and Hopewell (Figure 4.1). Total PAHs exceeded 1000 at nearly all stations from Station 2-JMS052.52 (Sandy Point) to Station 2-JMS109.27 (Richmond) with peaks at Station 2-JMS074.25 (Jordan Point near Hopewell) and 2-JMS068.49 (near Windmill Point). Most stations were predominantly sand and total organic carbon concentrations were typically in the range 1.6 to 2.7, with no clear correlation with PAH concentrations. For other analytes, such as PCB or pesticides, the occurrence of the analytes at or below the detection limit precludes evaluation in this manner.

More compelling evidence suggests elevated chemical concentrations can be found for some chemicals derived from independent studies of fish tissue. The Water Quality Standards and Biological Programs within the Office of Water Quality Programs of the DEQ has sampled fish tissues at a series of stations in the upper tidal freshwater James River from 1995 to 2002. Fishes sampled include various species of catfish, centrarchids, bass, eel, and alosids. Some carp and blue catfish captured in the James during 2002 exceeded the Virginia Department of Health (VDH) criterion for PCB in fish tissue at two stations (mile 110 in Richmond and mile 73.5 in Hopewell (Bailey Bay), Table 4.1). Consistently high concentrations were observed at the mouth of Bailey Creek in the same species as well as gizzard shad. As a result, the VDH published an advisory for the river from Richmond downstream to Windmill Point.

Sediment samples collected in 1997 under the Water Quality Standards and Biological Programs study indicate severe PCB contamination (total PCB >5 times the ERM) within the Bailey Creek complex and the nearby Poythress Creek (Table 4.2). Sediment samples from only two stations within the James (both within Bailey Bay) were contaminated (Total PCB >ERM). A sample

from mile 59.24 was slightly contaminated (Total PCB>ERL). Elsewhere total PCB in sediment was less than the ERL but quantifiable.

Five stations within the present study were near five of the DEQ monitoring stations and therefore likely to have comparable sedimentary PCB concentrations. These stations were 2-JMS074.85, 2-JMS076.42, 2-JMS078.09, 2-JMS109.27, and 2-APP005.38. Only Station 2-JMS109.27 exhibited a quantifiable concentration of total PCB (sum of isomer concentrations exceeding the quantitation limit). In contrast, all but one of the corresponding stations in the Water Quality Standards and Biological Programs study had at least one quantifiable isomer. Only in the case of Station 2-JMS076.42 was the station near an area previously found to have a high concentration of PCB (Station 2-JMS076.18 sampled in 1997).

This difference in findings between the studies may be explained by 1) real changes in concentration resulting from sediment movement or burial during the four years intervening between the two sampling activities, 2) differences in analytes sought, and 3) the different laboratories performing the analyses in the two studies. The first possibility is very plausible since there is considerable water flow, both gravity and wind driven. The difference in the number of congeners sought is also very plausible. Of the total 208 PCB congeners possible, only 30 were sought in the present study, whereas the full complement was sought in the previous sediment analyses.

The lack of measurable effect in toxicity tests with these sediments is consistent with the low chemical concentrations within these sediments. Neither acute nor subacute endpoints for the amphipod, *Hyaella azteca*, or the insect, *Chironomus tentans*, showed any adverse effect of exposure to these sediments. The results with the fish embryo/larval test superficially suggest a possible effect throughout the region, but these effects are concluded to result from a biological infection rather than toxicity because the average effect is strictly the result of the effect at a single replicate at a station.

The data from Roberts *et al.* (2002) for the reach of the James River from Jamestown Island to the Jordan Point Bridge and that of McGee *et al.* (2001) for the James River area near the mouth of the Chickahominy River, coupled with the data from this study extending the observations to the fall line at Richmond, provide coverage of the entire tidal freshwater reach of the river. All three studies failed to produce any chemical or toxicological evidence of substantial adverse impacts in this region that could be attributed to the presence of toxic materials.

This conclusion is reached despite concerns about the high level of industrial activity in two areas in particular; Hopewell and Richmond. Hopewell in particular has a history of contaminant release, most notably Kepone. Almost three decades after the last known release, we observed only a small amount of Kepone in sediment from the three stations nearest Hopewell (20-180 ng/g dry wt). No other contaminant was observed at these stations in amounts likely to produce an adverse effect.

Kepone in water is not acutely toxic to freshwater fish (Roberts, *et al.*, 1982), though it is accumulated in substantial amounts by freshwater and saltwater fish as well as crustaceans (Fisher *et al.*, 1983; Fisher *et al.*, 1986; Roberts and Fisher, 1985; Van Veld, *et al.*, 1984). The

aqueous exposure concentrations used in these studies were all orders of magnitude above those observed in the sediment samples. No data has been identified to suggest that amphipods or chironomids would be any more sensitive to Kepone than fish.

These data represent two legs of the Sediment Triad, now widely used to evaluate sediment for toxic responses. These results suggest that degradation of the benthic community, the third leg of the triad, would be unlikely but as discussed below, the benthic community was in fact degraded.

Concern was expressed previously (Roberts *et al.* 2002) that the tests used to evaluate toxicity in ambient sediment samples might not be sensitive enough to detect effects of the low concentrations of contaminants observed in this study. A chemical toxic enough to produce an acute lethal response at low concentrations would need to be as or more toxic than dioxin-like compounds or TBT that are toxic in the parts per trillion range for some test species.

Though no contaminant was detected chemically in toxicologically significant concentrations, the total number of analytes is much below the number of potential contaminants. Although it seems unlikely that one could, even with a very sensitive biological test, detect acute lethal toxicity of a mixture in the absence of a measurable amount of any single analyte, observation of a sublethal toxic effect resulting from the occurrence of a material not on the analyte list could well occur even with the existing tests. The lack of any observable toxic response suggests strongly the absence of such a material.

In contrast to the lack of substantial concentrations of chemicals or apparent toxic responses, the B-IBI indicates degradation, sometimes extreme degradation, at all but one station. There are several points, however, that suggest that such lack of concordance does not imply the presence of a non-detected toxic chemical or response by the limited array of test species.

1. Uncertainty is high for B-IBI values in oligohaline and tidal freshwater systems and (Weisberg, *et al.*, 1997; Alden *et al.* 2002).
2. The B-IBI, as presently developed, does not directly relate to any specific stressor such as toxic chemicals or reduced oxygen tension, and there is no reliable method at this time to demonstrate an association between a specific stressor and the index (Dauer, personal communication).
3. Interestingly, the median B-IBIs calculated for samples from both reference and degraded sites in tidal freshwater and oligohaline regions are higher than those for mesohaline and polyhaline habitats (Alden, *et al.* 2002).
4. Confidence limits around the median B-IBI for clean versus degraded sites do not overlap for mesohaline and polyhaline habitats whereas there is substantial overlap for oligohaline and tidal freshwater habitats (Alden, *et al.* 2002). This is perhaps not surprising because with an upper domain limit of 5, as the median B-IBIs for tidal freshwater and oligohaline systems increases relative to that for more saline environments, the scope for difference decreases. Further, confidence limits calculated for B-IBIs the tidal freshwater habitat seem broader than for most other habitats. Both factors would contribute to the observed substantial overlap.
5. Stresses leading to community degradation might include toxic materials (natural or anthropogenic), reduced oxygen concentrations, generalized stress related to the ecotonal

nature of tidal freshwater environments, or physical stress associated with the narrowness of such systems.

The extreme low B-IBI for several stations in the region makes it unlikely that the degraded designation is an artifact of the method, small sample size, or other procedural matter. The reduced ability to distinguish slightly degraded from non-degraded regions does likely relate to procedural issues alluded to above.

A major factor leading to the degraded nature of the benthic community throughout much of the study region is likely physical stress. Between Richmond and Hopewell, the channel is naturally deep (30 ft or so) and the river is narrow. There are few locations prone to deposition of fine sediment, which suggests strong water flow and sheer stress on the bottom. The strong water flow and sheer stress would impact on benthic community development, as reflected in the absence of some species, notably *C. polita*, and depressed B-IBI.

The physical stress argument is more compelling than the ecotonal stress argument. If ecotonal stress was important, degradation based on B-IBI should be apparent from Jamestown Island to Richmond (Roberts, *et al.*, 2002 and the present study), and that was not the case.

Table 4.1. Total PCB concentrations in fish tissue from surveys of the Fish Tissue Monitoring Program of the Virginia DEQ (ng/g wet on a weight basis).

Stream	Bailey Creek			Appomattox			James							
Mile	5.72	0.55	0.65	4.12	1.53		66.88	73.48	74.44		86.22	97.77	98.64	110.00
Date	10/97	10/97	5/01	10/97	6/95	5/01	10/97	5/01	6/95	10/97	10/97	5/01	10/97	5/01
Bass, Largemouth		49.8	<u>61.9</u>	<u>55.0</u>	<u>72.2</u>	<u>53.1</u>	<u>80.2</u>				<u>96.8</u>	<u>154.8</u>	<u>99.4</u>	
Bass, Striped				173.4		282.5	194.7		165.2	175.2	341.3			
Carp, Common		<u>394.5</u>	699.0	<u>486.3</u>	<u>230.9</u>	<u>268.0</u>	<u>598.8</u>	936.8	<u>151.1</u>	<u>354.3</u>	<u>539.5</u>	<u>275.1</u>	<u>468.0</u>	808.6
Catfish, Blue Md			<u>395.5</u>											
Catfish, Blue Lg			778.1					3212.3		<u>181.8</u>				1197.4
Catfish, Channel		<u>215.2</u>		<u>220.3</u>			<u>260.4</u>				<u>169.1</u>	<u>120.7</u>	<u>114.0</u>	
Catfish, White		<u>305.3</u>												
Catfish, Yellow Bullhead	<u>57.4</u>													
Chub	<u>69.0</u>													
	<u>50.9</u>													
Crappie, Black		<u>22.4</u>						<u>23.5</u>		<u>31.8</u>				
Eel, American	<u>169.6</u>													
Perch, White		<u>78.0</u>	<u>78.5</u>					<u>69.6</u>				<u>69.1</u>	<u>27.8</u>	
Shad, Gizzard		667.3	<u>391.1</u>	<u>166.6</u>	<u>289.3</u>	<u>182.1</u>	<u>315.8</u>	<u>335.5</u>	<u>206.3</u>	<u>216.6</u>	<u>219.6</u>	<u>298.7</u>	<u>303.4</u>	<u>135.6</u>
		1008.3												
Sucker, Torrent	<u>96.3</u>													
Sunfish, Bluegill	8.72	50.0		13.7		33.4	8.1			15.4	9.6	50.9	26.0	51.2
Sunfish, Pumpkinseed		28.2												
Sunfish, Redbreast														42.6

Exceeds DEQ Screening Level
Exceeds VA Department of Health Criterion

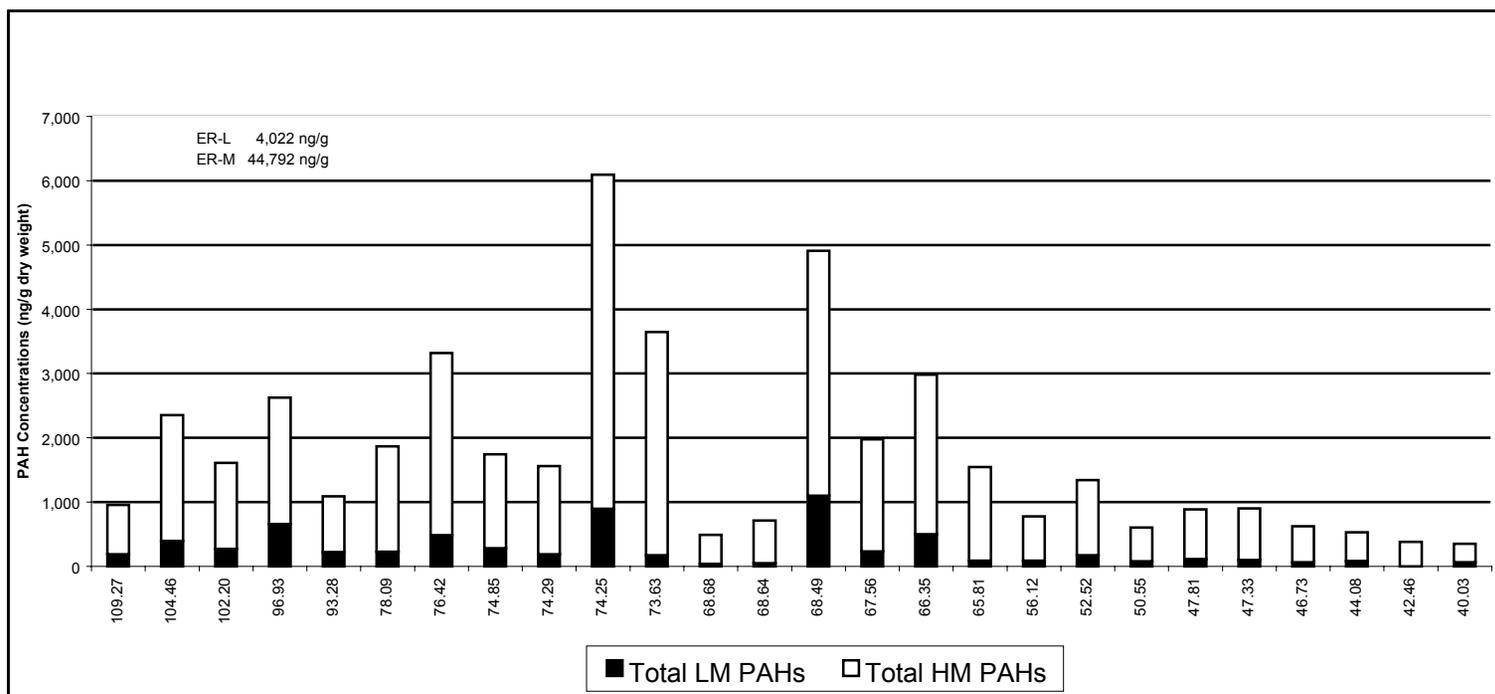
54
600

Table 4.2 Total PCB Concentrations in sediment collected at stations selected to evaluate possible sources of these compounds in fish tissues (ng/g on a dry weight basis).

Stream	Mile	Date				
		6/95	6/96	6/97	10/97	5/01
Cattail Creek	0.02				1895.7	
Bailey Creek	0.20				<u>976.2</u>	
	0.55				1836.6	
	0.65					<u>273.8</u>
	2.40				13.8	
Gravelly Run	0.01				<u>36.6</u>	
	0.57				<u>99.9</u>	
Poythress Creek	0.23				3669.5	
Appomattox	1.53					<u>230.4</u>
	5.19			4.8		
James River	53.35			13.9		
	59.24			<u>59.6</u>		
	68.87		13.3			
	74.44	4.13				
	75.81				<u>370.8</u>	
	76.18				<u>194.2</u>	
	76.94				17.8	
	81.19			4.0		
	84.34		0.3			
	97.77					7.83
	100.16		16.1			

Exceeds ERL 22.7
 Exceeds ERM 180
 Exceeds 5 x ERM **1427**

Figure 4.1 Total PAHs in the James River from Richmond (river mile 109.27) to Jamestown Island (rm 40.03). Exceedances of the ER-L for total PAH occurred at Jordan Point (rm 74.25), just downstream from Hopewell, and near Windmill Point (rm 68.49).



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Appendix A

Table A1. Summary Water Quality – *Hyalella azteca* Sediment Test

Station	Temperature (C)		Diss. Oxygen (mg/l)		pH (S.U.)		Conductivity (µS/cm)		Hardness (mg/l as CaCO3)		Alkalinity (mg/l as CaCO3)		NH3-N (mg/l)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
005.38A	23.4	0.6	8.3	0.1	7.77	0.21	285	25.0	106.5	7.5	53.0	0.0	0.3	0.1
005.38B	23.5	0.5	8.4	0.1	7.64	0.04	244	13.0	86.0	0.0	50.0	4.0	0.9	0.7
005.38C	23.2	0.4	8.4	0.1	7.55	0.19	243	14.0	84.0	3.0	53.0	5.0	0.3	0.1
074.85A	23.2	0.4	8.4	0.1	7.79	0.04	305	18.5	86.5	2.5	57.5	3.5	0.2	0.0
074.85B	23.5	0.5	8.4	0.1	7.73	0.05	312	22.0	84.5	0.5	56.5	0.5	0.5	0.3
074.85C	23.5	0.6	8.4	0.1	7.80	0.12	313	24.0	95.5	13.5	51.5	3.5	0.5	0.3
076.42A	23.5	0.6	8.4	0.1	7.92	0.16	334	27.5	107.5	17.5	54.0	3.0	0.3	0.1
076.42B	23.4	0.5	8.4	0.1	7.84	0.16	304	28.5	97.5	13.5	50.0	6.0	0.3	0.1
076.42C	23.5	0.6	8.3	0.1	7.83	0.13	316	23.5	105.5	8.5	52.0	3.0	0.3	0.1
078.09A	23.5	0.5	8.4	0.1	7.87	0.14	289	15.5	97.0	8.0	58.5	2.5	0.5	0.3
078.09B	23.5	0.5	8.4	0.1	7.95	0.26	302	22.0	103.0	11.0	58.5	1.5	1.1	0.9
078.09C	23.4	0.5	8.3	0.1	7.94	0.16	319	30.0	113.5	18.5	59.0	2.0	1.1	0.9
093.28A	23.4	0.5	8.4	0.1	7.74	0.01	284	9.5	94.0	2.0	54.5	2.5	1.3	1.1
093.28B	23.4	0.6	8.3	0.1	7.60	0.17	279	2.5	88.5	4.5	46.0	6.0	1.1	0.9
093.28C	23.2	0.4	8.4	0.1	7.75	0.04	277	0.5	97.0	8.0	53.0	4.0	0.5	0.3
096.93A	23.5	0.5	8.4	0.1	7.83	0.18	277	10.0	99.0	3.0	51.0	4.0	0.9	0.7
096.93B	23.4	0.6	8.3	0.2	7.66	0.09	263	8.0	88.0	4.0	52.0	4.0	0.7	0.5
096.93C	23.4	0.6	8.4	0.1	7.89	0.19	305	35.0	94.5	11.5	54.0	2.0	0.2	0.0
102.20A	23.5	0.5	8.3	0.1	7.68	0.00	243	3.5	80.5	3.5	56.5	1.5	0.5	0.3
102.20B	23.5	0.5	8.3	0.1	7.90	0.06	294	5.5	92.5	6.5	62.0	3.0	1.3	1.1
102.20C	23.4	0.6	8.4	0.1	7.83	0.01	302	19.0	102.0	2.0	59.0	6.0	4.4	4.0
104.46A	23.5	0.5	8.3	0.1	7.92	0.28	321	25.5	102.5	8.5	67.5	5.5	2.1	1.9
104.46B	23.3	0.5	8.2	0.1	7.91	0.13	287	2.5	107.0	3.0	60.0	3.0	1.1	0.9
104.46C	23.3	0.5	8.4	0.1	7.92	0.21	296	10.5	97.5	5.5	59.5	6.5	1.3	1.1
109.27A	23.5	0.5	8.4	0.1	8.00	0.38	302	28.5	102.5	14.5	50.0	4.0	0.5	0.3
109.27B	23.5	0.5	8.4	0.0	7.98	0.28	315	23.5	97.0	5.0	58.0	3.0	0.3	0.1
109.27C	23.4	0.6	8.3	0.1	7.86	0.11	283	16.5	99.5	4.5	58.0	1.0	0.3	0.1
LABCTRL	23.5	0.6	8.3	0.1	7.94	0.28	286	12.0	95.0	2.0	58.5	2.5	0.5	0.3

Table A2. Summary Water Quality – *C. tentans* Sediment Test

Station	Temperature (C)		Diss. Oxygen (mg/l)		pH (S.U.)		Conductivity (µS/cm)		Hardness (mg/l as CaCO3)		Alkalinity (mg/l as CaCO3)		NH3-N (mg/l)	
	Mean	S.D.	Mean	S.D.	Mean	S..D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
005.38A	23.0	0.4	8.4	0.1	7.79	0.13	303	9.0	98.5	9.5	51.0	0.0	0.3	0.1
005.38B	23.1	0.5	8.3	0.2	7.63	0.04	242	38.0	71.0	19.0	48.5	7.5	1.1	0.9
005.38C	23.0	0.4	8.5	0.1	7.28	0.86	247	19.5	84.0	10.0	47.5	14.5	0.5	0.3
074.85A	23.0	0.4	8.4	0.1	7.67	0.41	337	19.5	90.0	10.0	55.0	8.0	0.5	0.3
074.85B	23.1	0.3	8.2	0.3	7.65	0.40	328	17.5	89.5	9.5	50.0	7.0	0.5	0.3
074.85C	23.1	0.3	8.4	0.1	7.73	0.35	334	19.5	91.0	5.0	50.0	8.0	0.5	0.3
076.42A	23.0	0.4	8.3	0.1	7.98	0.04	371	44.5	98.0	4.0	59.0	4.0	0.3	0.1
076.42B	23.0	0.5	8.4	0.1	7.68	0.42	337	28.0	94.0	0.0	49.5	1.5	0.3	0.1
076.42C	23.2	0.4	8.3	0.1	7.69	0.17	345	33.0	99.0	7.0	58.0	1.0	0.3	0.1
078.09A	23.0	0.4	8.4	0.1	7.86	0.13	320	11.0	100.0	2.0	53.0	1.0	0.7	0.5
078.09B	23.0	0.5	8.4	0.1	7.78	0.16	334	11.5	111.5	16.5	61.0	0.0	1.1	0.9
078.09C	23.0	0.4	8.4	0.1	7.91	0.19	362	39.0	99.0	3.0	47.0	4.0	1.1	0.9
093.28A	23.1	0.5	8.2	0.3	7.40	0.45	303	0.5	84.0	0.0	50.0	8.0	1.3	1.1
093.28B	23.1	0.5	8.4	0.1	7.51	0.71	294	2.0	86.5	14.5	48.5	4.5	0.3	0.1
093.28C	23.1	0.3	8.2	0.2	7.59	0.32	298	11.5	91.0	11.0	44.0	12.0	0.7	0.5
096.93A	23.0	0.5	8.3	0.1	7.60	0.51	297	1.5	107.0	5.0	53.5	5.5	0.7	0.5
096.93B	23.2	0.4	8.3	0.1	7.42	0.40	282	8.0	75.0	7.0	38.0	16.0	0.9	0.7
096.93C	23.0	0.4	8.3	0.1	7.84	0.16	324	19.5	85.0	9.0	54.0	5.0	0.5	0.3
102.20A	23.1	0.3	8.3	0.1	7.57	0.52	255	25.5	79.5	23.5	48.5	6.5	0.5	0.3
102.20B	23.1	0.3	8.4	0.1	7.48	0.81	292	17.0	73.5	17.5	67.0	5.0	1.5	1.3
102.20C	23.1	0.5	8.4	0.1	7.22	0.38	302	16.5	92.0	10.0	51.5	7.5	2.5	2.3
104.46A	23.1	0.5	8.4	0.1	7.93	0.22	339	17.5	103.5	1.5	52.5	5.5	2.5	2.3
104.46B	23.1	0.5	8.4	0.1	7.78	0.33	294	18.0	89.0	17.0	49.5	10.5	1.5	1.3
104.46C	23.1	0.3	8.4	0.1	7.81	0.35	304	13.0	102.0	6.0	52.0	6.0	1.3	1.1
109.27A	23.1	0.5	8.4	0.1	7.86	0.12	311	15.5	104.0	8.0	60.0	6.0	0.5	0.3
109.27B	23.1	0.5	8.4	0.1	7.83	0.33	324	18.5	99.5	6.5	54.5	1.5	0.5	0.3
109.27C	23.1	0.5	8.5	0.1	7.80	0.35	306	18.5	104.5	0.5	47.5	7.5	0.5	0.3
LABCTRL	23.1	0.5	8.4	0.1	7.88	0.18	290	4.0	100.0	4.0	58.5	0.5	0.7	0.5

Table A3. Summary Water Quality – *P. promelas* Sediment Test

Station	Temperature (C)		Diss. Oxygen (mg/l)		pH (S.U.)		Conductivity (µS/cm)		Hardness (mg/l as CaCO3)		Alkalinity (mg/l as CaCO3)		NH3-N (mg/l)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
005.38A	24.1	0.0	8.1	0.1	7.73	0.13	277	10.1	95.0	2.0	52.5	5.5	1.1	0.9
005.38B	24.1	0.0	8.0	0.1	7.64	0.23	256	7.3	88.5	6.5	49.5	1.5	1.3	1.1
005.38C	24.1	0.0	8.1	0.1	7.64	0.11	260	7.8	85.5	5.5	50.0	3.0	0.5	0.3
074.85A	24.1	0.0	8.1	0.1	7.74	0.09	284	17.0	103.5	3.5	52.5	5.5	0.7	0.5
074.85B	24.1	0.0	8.1	0.1	7.70	0.10	284	15.9	90.5	1.5	51.0	5.0	0.5	0.3
074.85C	24.0	0.0	8.0	0.1	7.74	0.09	285	14.5	88.5	5.5	54.5	3.5	0.5	0.3
076.42A	24.1	0.0	8.0	0.1	7.78	0.12	291	18.9	104.5	4.5	50.5	1.5	0.3	0.1
076.42B	24.1	0.0	8.0	0.1	7.78	0.14	291	12.4	95.5	5.5	55.5	0.5	0.3	0.1
076.42C	24.1	0.0	8.0	0.1	7.84	0.13	286	16.5	93.0	12.0	49.5	3.5	0.5	0.3
078.09A	24.1	0.0	8.1	0.1	7.84	0.13	282	14.7	93.0	3.0	50.5	4.5	0.7	0.5
078.09B	24.1	0.0	8.0	0.1	7.81	0.17	284	13.8	107.5	9.5	57.5	4.5	1.4	1.0
078.09C	24.1	0.0	8.1	0.1	7.85	0.15	292	20.7	107.0	3.0	55.0	3.0	1.3	1.1
093.28A	24.1	0.0	8.0	0.1	7.70	0.16	279	9.2	91.5	7.5	52.5	0.5	2.1	1.9
093.28B	24.1	0.0	8.1	0.1	7.75	0.15	273	11.1	88.5	4.5	53.5	0.5	2.1	1.9
093.28C	24.1	0.0	8.0	0.1	7.69	0.13	273	9.9	95.5	6.5	49.0	3.0	0.7	0.5
096.93A	24.1	0.0	8.0	0.1	7.77	0.15	270	8.3	107.5	7.5	51.5	2.5	1.0	0.6
096.93B	24.1	0.0	8.0	0.1	7.73	0.14	267	7.5	103.5	1.5	53.5	4.5	1.1	0.9
096.93C	24.1	0.0	8.0	0.2	7.69	0.18	279	10.5	97.0	7.0	53.5	3.5	0.5	0.3
102.20A	24.1	0.0	8.0	0.1	7.69	0.16	256	6.5	90.0	8.0	52.5	6.5	0.7	0.5
102.20B	24.1	0.0	8.1	0.1	7.79	0.15	279	18.4	98.5	0.5	55.0	6.0	1.7	1.5
102.20C	24.1	0.0	8.0	0.1	7.82	0.19	312	29.4	94.5	0.5	63.5	5.5	4.7	4.1
104.46A	24.2	0.0	8.0	0.1	7.83	0.17	290	14.6	94.5	9.5	65.5	0.5	3.3	3.1
104.46B	24.1	0.0	8.1	0.1	7.78	0.18	277	15.6	92.5	2.5	57.5	3.5	1.3	1.1
104.46C	24.1	0.0	8.0	0.2	7.73	0.15	279	16.3	90.0	4.0	56.5	10.5	1.1	0.9
109.27A	24.1	0.0	8.0	0.1	7.82	0.15	276	6.6	96.0	4.0	53.5	0.5	0.7	0.5
109.27B	24.1	0.0	8.1	0.1	7.79	0.14	279	11.5	96.0	4.0	58.0	1.0	0.5	0.3
109.27C	24.1	0.0	8.0	0.1	7.77	0.13	273	9.2	96.5	1.5	53.0	5.0	0.3	0.1
LABCTRL	24.1	0.0	8.1	0.1	7.73	0.15	276	7.3	93.5	0.5	53.5	0.5	0.7	0.5