Draft
Eighteenmile Creek
Powdered Activated Carbon (PAC)
Pilot Study Report

December 2012

Prepared for:

NIAGARA COUNTY SOILD AND WATER CONSERVATION DISTRICT
Lockport, New York

Prepared by:

ECOLOGY AND ENVIRONMENT, INC.
368 Pleasant View Drive
Lancaster, New York 14086

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List of Abbreviations and Acronyms

AOC	area of concern
E & E	Ecology and Environment, Inc.
BSAF	Biota-sediment accumulation factors
BUI	beneficial use impairment
EPA	United States Environmental Protection Agency
GLRI	Great Lakes Restoration Initiative
IJC	International Joint Commission
NCSWCD	Niagara County Soil and Water Conservation District
OC	organic carbon
PAC	powdered activated carbon
PCB	polychlorinated biphenyl
RAP	Remedial Action Plan
RI	Remedial Investigation
TOC	total organic carbon

Executive Summary

A laboratory pilot study was undertaken in 2012 to evaluate the efficacy of using powdered activated carbon (PAC) to reduce the bioavailability of polychlorinated biphenyls (PCBs) in Eighteenmile Creek sediment. The pilot study consisted of a laboratory bench-top experiment with sediment from three locations in the creek: (1) downstream from Burt Dam; (2) between Burt and Newfane dams; and (3) upstream from Newfane Dam. Sediment from each area was augmented with PAC concentrations of 6%, 3%, and 1%. Bioaccumulation was evaluated with United States Environmental Protection Agency (EPA) Test Method 100.3 (28-day *Lumbriculus variegatus* bioaccumulation test for sediments). For comparison, bioaccumulation in untreated (control) creek sediment from each location was also evaluated. The sediment samples used in the study were analyzed for PCB Aroclors and congeners and total organic carbon (TOC). At the end of the bioaccumulation tests, *Lumbriculus* biomass was analyzed for PCB Aroclors and congeners and lipids. The following results are noteworthy:

- Amending Eighteenmile Creek sediment with PAC was highly effective in reducing PCB levels in *Lumbriculus*. The sum of PCB congeners (micrograms per gram [µg/g] lipid) in *Lumbriculus* in the 6%, 3%, and 1% PAC treatments was on average reduced by 99%, 97%, and 84%, respectively, compared with *Lumbriculus* exposed to untreated Eighteenmile Creek sediment.

- Biota-sediment accumulation factors (BSAFs) were estimated using data for total PCBs and TOC in sediment and total PCBs and lipids in *Lumbriculus*. BSAFs were greatest for untreated Eighteenmile Creek sediment (1.4 to 2.7) and decreased with increasing PAC dose, decreasing to less than 0.2 at the greatest PAC treatment concentration (6%).

Overall, the results of the pilot study indicate that PAC was highly effective in reducing bioaccumulation of PCBs from Eighteenmile Creek sediment to benthic organisms. From the perspective of beneficial use impairment (BUI) delisting, the pilot study results are encouraging because they suggest that it may be possible to reduce exposure and risk to people and wildlife from PCBs at Eighteenmile Creek using a remedial approach less costly and disruptive than sediment dredging and/or capping. We recommend that small-scale in situ testing in one or more areas of the Eighteenmile Creek be considered as a logical extension of the current study.

1 Introduction

This report describes the results of a laboratory pilot study undertaken in 2012 to evaluate the efficacy of using powdered activated carbon (PAC) to reduce the bioavailability of polychlorinated biphenyls (PCBs) in Eighteenmile Creek sediment. Several studies have shown that adding carbonaceous sorbents to sediment is effective in reducing the bioavailability of hydrophobic organic contaminants. In laboratory studies, Zimmerman et al. (2005) found that adding activated carbon to marine sediment contaminated with PCBs reduced sediment porewater concentrations of PCBs, reduced the flux of PCBs from sediment to overlying water, and reduced bioaccumulation of PCBs into benthic organisms. In laboratory and field studies, Alcoa (2010) found that adding activated carbon to freshwater sediment contaminated with PCBs reduced PCB tissue residues in oligochaetes by approximately 90% compared with oligochaetes grown in untreated sediment.

Beneficial use impairments (BUIs) at Eighteenmile Creek are largely the result of PCBs in sediment and their subsequent bioaccumulation in the aquatic food web of the creek (E & E 2011). Therefore, any technique that limits PCB bioaccumulation is expected to be useful in ameliorating the BUIs. It is expected that the results from the PAC pilot study will be considered in the Eighteenmile Creek Feasibility Study (expected to be initiated in 2013). Sediment treatment with PAC may be useful in Eighteenmile Creek as a polishing step in areas where sediment dredging is implemented and/or as the principal means of sediment remediation in areas that are difficult or infeasible to access for dredging.

The study described in this report was first identified in the *Eighteenmile Creek Area of Concern (AOC) Strategic Plan for Beneficial Use Impairment (BUI) Delisting* (E & E 2011) and described in detail in the *Quality Assurance Project Plan* (QAPP) (E & E 2012a) prepared to guide the work. This work was supported by a grant from the United States Environmental Protection Agency (EPA) Great Lakes Restoration Initiative (GLRI) to the Niagara County Soil and Water Conservation District (NCSWCD).

This remainder of this report is organized as follows:

- Section 2 describes field and laboratory methods used for the PAC pilot study;
- Section 3 describes the study results;

- Section 4 provides a summary and recommendations;
- Section 5 provides references; and

Appendix A contains a copy of the project QAPP and the complete analytical results from the laboratories that supported the project are located in Appendices B, C, and D.

1.1 Background on Eighteenmile Creek AOC Status and BUIs

In 1987, the International Joint Commission (IJC) identified 43 AOCs in the Great Lakes Basin where the beneficial uses of the water body were considered impaired. Eighteenmile Creek was identified as one of the 29 United States AOCs. The creek has been polluted by past industrial and municipal discharges, the disposal of waste, and the use of pesticides. Currently, there are five documented BUIs at the Eighteenmile Creek AOC: (1) restrictions on fish and wildlife consumption; (2) degradation of fish and wildlife populations; (3) bird or animal deformities or reproductive problems; (4) degradation of benthos; and (5) restrictions on dredging activities (USEPA 2010). These five BUIs are largely driven by elevated levels of PCBs in sediment and fish (E & E 2011). Table 1-1 lists the site-specific BUI delisting criteria developed by the NCSWCD for the Eighteenmile Creek system.

Both human and ecological receptors using the Eighteenmile Creek system may be at risk from PCBs and perhaps other chemicals in fish based on recent investigations (E & E 2009a) and current fish consumption advisories (NYSDOH 2011). Elevated levels of PCBs in fish in Eighteenmile Creek appear to be the result of bioaccumulation from sediment (USACE 2004a, b; von Stackelberg and Gustavson 2012). Recent sediment data from the Remedial Investigation (RI) for Eighteenmile Creek show that surface sediment PCB levels are greater in the portion of the creek near the source areas in Lockport, New York, compared with downstream reaches (E & E 2012b). Source areas along the creek in Lockport were characterized by the New York State Department of Environmental Conservation (NYSDEC 2006) and E & E (2009b). Remediation of upstream sources areas and contaminated sediment throughout the creek will be necessary to eliminate BUIs in the Eighteenmile Creek system and eventually delist this Great Lakes AOC (E & E 2011).

1.2 Site Location and Description

The Eighteenmile Creek AOC is located in Niagara County, New York (see Figure 1-1). The creek flows generally north through central Niagara County and discharges via Olcott Harbor into Lake Ontario, approximately 18 miles east of the mouth of the Niagara River. The AOC includes Olcott Harbor and extends upstream to the farthest point at which backwater conditions exist during Lake Ontario's highest monthly average lake level (see Figure 1-1). This point is located just downstream of Burt Dam, approximately 2 miles south of Olcott Harbor.

This portion of the watershed is a unique gorge habitat that attracts recreational boaters, anglers, birders, and waterfowl hunters.

Only a small portion of the Eighteenmile Creek basin was originally designated an AOC by the IJC. However, for two reasons, since the Eighteenmile Creek Remedial Action Plan (RAP) process began, the AOC has been considered to include the impact area and the upper watershed as the source area (NYSDEC 1997). First, except for potential impacts from agricultural operations adjacent to the current AOC boundary, there are no documented sources or source areas of contamination within the AOC. Second, various investigations conducted over the past 35 years have suggested that contaminants may enter the AOC from upstream areas. Specifically, PCBs, copper, lead, and other metals have been found in creek sediment and bank fill in Lockport, New York, at concentrations well above applicable New York State Department of Environmental Conservation standards, indicating that contaminant sources exist in this area (NYSDEC 2006; E & E 2009b, 2012b). Other contaminant source areas may exist along the creek between Lockport and the AOC (NYSDEC 2001).

Additional information regarding the characteristics of the Eighteenmile Creek AOC and watershed are available in the *Eighteenmile Creek State of the Basin Report* (E & E 2007), *Beneficial Use Impairment (BUI) Investigation Report for Eighteenmile Creek* (E & E 2009a), *Sediment Remedial Investigation Report* (E & E 2012b), and additional publications and factsheets available from the Eighteenmile Creek RAP Web site (www.eighteenmilerap.com).

Table 1-1 Beneficial Use Impairments and Delisting Criteria for the Eighteenmile Creek AOC

BUI	BUI Status	Delisting Criteria
1. Restrictions on Fish and Wildlife Consumption	Impaired	There are no AOC-specific fish and wildlife consumption advisories issued by New York State; **AND**
		Contaminant levels in fish and wildlife must not be due to contaminant input from the watershed upstream of Burt Dam
3. Degradation of Fish and Wildlife Populations	Impaired	Fish and wildlife diversity, abundance and condition are statistically similar to diversity, abundance and condition of populations at non-AOC control sites; **AND**
		PCB levels in bottom-dwelling fish do not exceed the critical PCB tissue concentration for effects on fish (440 micrograms per kilogram of weight; Dyer et al. 2000)
5. Bird or Animal Deformities or Reproduction Problems	Impaired	No reports of wildlife population deformities or reproductive problems from wildlife officials above expected natural background levels; **AND**
		Contaminant levels in bottom-dwelling fish do not exceed the level established for the protection of fish-eating wildlife (NYSDEC Fish Flesh Criteria); **OR**
		In the absence of fish data, the toxicity of sediment-associated contaminants does not exceed levels associated with adverse effects on wildlife (NYSDEC Fish & Wildlife Bioaccumulation Sediment Criteria)
6. Degradation of Benthos	Impaired	Benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices; **OR**
		In the absence of NYSDEC data, riffle habitats require benthic macroinvertebrate communities with a species richness higher than 20, EPT richness greater than 6, a biotic index value greater than 4.51, and a percent model affinity greater than 50; **OR**
		In the absence of benthic community data, this use will be considered restored when the level of toxic contaminants in sediments is not significantly higher than controls.
7. Restrictions on Dredging Activities	Impaired	When contaminants in AOC sediments (located within the actual or potential dredging areas identified for the improvement of ship navigation) do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities.

Source: USEPA 2010

Key:

AOC = Area of Concern
BUI = Beneficial Use Impairment
EPT = Ephemeroptera, Plecoptera, and Trichoptera
NYSDEC = New York State Department of Environmental Conservation
PCB = Polychlorinated Biphenyl

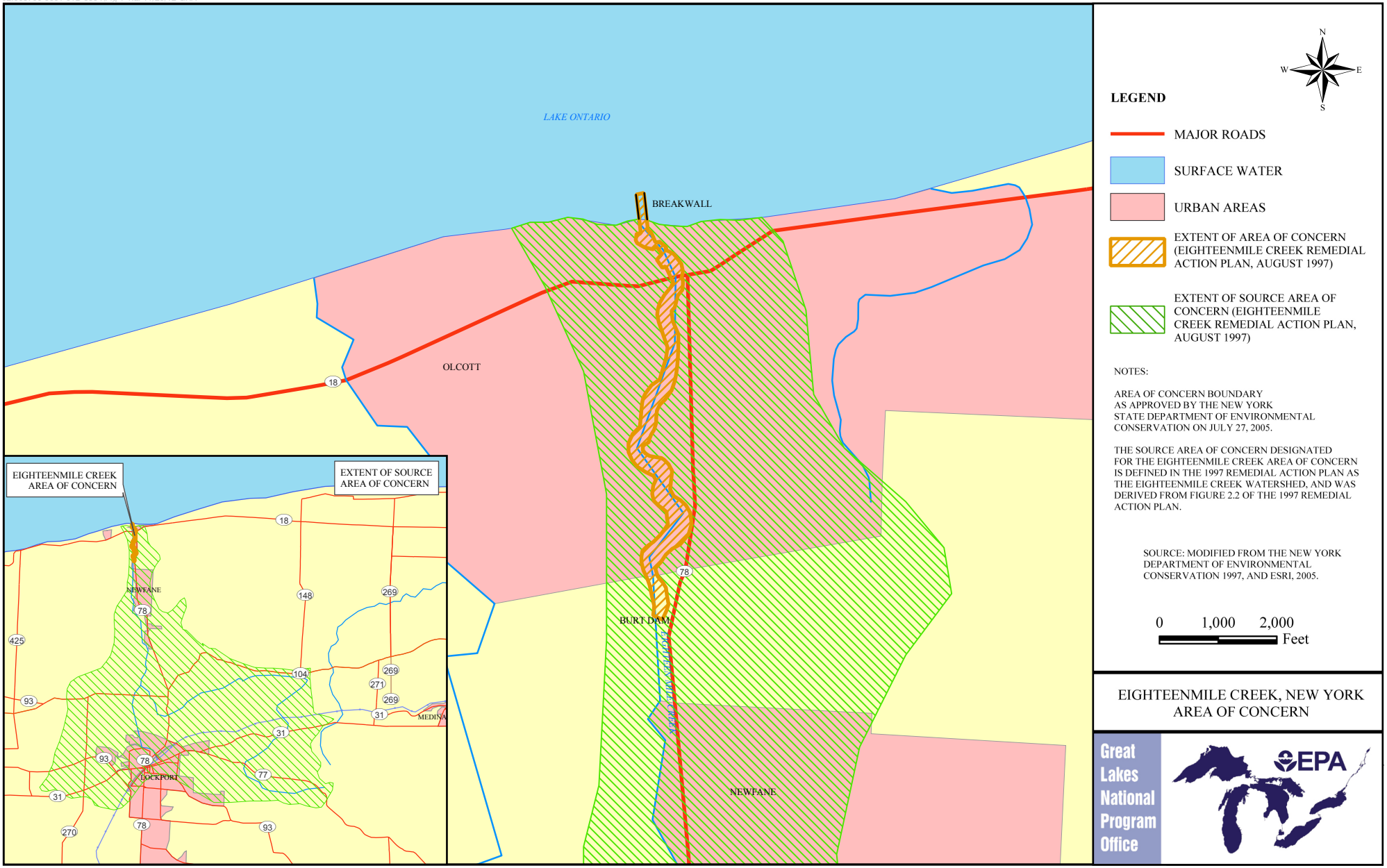

Figure 1-1 Eighteenmile Creek Area of Concern

2 Methods

The PAC pilot study consisted of a laboratory bench-top experiment with sediment from three locations in Eighteenmile Creek. Sediment samples representing a range of PCB concentrations were collected and augmented with a range of PAC concentrations. Bioaccumulation in each PAC treatment was evaluated with EPA (2000) Test Method 100.3 (28-day *Lumbriculus variegatus* Bioaccumulation test for Sediments). For comparison, bioaccumulation in untreated (control) creek sediment also was evaluated. Sediment was analyzed for PCB Aroclors and congeners and total organic carbon (TOC) and *Lumbriculus* biomass was analyzed for PCB Aroclors and congeners and lipids. Details are provided below and in E & E (2012a).

2.1 Field and Laboratory Methodology

Sediment samples for the PAC pilot study were collected in August 2012. Sampling areas are listed in Table 2-1 and shown in Figures 2-1 to 2-3. One sampling area was selected in each of the three main reaches of the creek: (1) below Burt Dam (PAC-1); (2) between Newfane and Burt dams (PAC-2); and (3) upstream from Newfane Dam (PAC-3). The areas were selected to span a range of sediment PCB concentrations based on historical data (see Table 2-1). Within each area, three 3.5-gallon pre-cleaned plastic buckets were filled with surface sediment (0 to 6 inches below the sediment water interface) by taking multiple grabs with a petite Ponar dredge from a small Jon boat. Surface sediment only was included in the samples. Between sampling areas, the dredge was thoroughly cleaned with an Alconox detergent solution and rinsed. Samples were cooled to 4°C and shipped in coolers under chain-of-custody by overnight courier to Aquatec Biological Sciences (Aquatec) of Williston, Vermont, for bioaccumulation testing. Further mixing of the sediment in the three buckets from each sampling area to create a single composite sample for each area was conducted at Aquatec. Aquatec sent subsamples of each composite sediment sample to ALS Environmental of Kelso, Washington, for chemical analysis. Table 2-2 lists analytical parameters, laboratory methods, and sample-handling details for the PAC pilot study.

2.2 Experimental Design

At the laboratory, each composite sediment sample was divided into a four aliquots that received PAC treatments on a dry weight basis of 6%, 3%, 1%, or 0% (control) (see Table 2-3). The weight of PAC that was added to each treatment was estimated from sample bulk density and percent solids (see Table 2-4). Figure

2-4 provides a flowchart showing the order of sediment mixing, subsampling for chemical analysis, PAC addition, and bioaccumulation testing. There was a one-week equilibration period between the time when PAC was added and *Lumbriculus* biomass was added to start the bioaccumulation tests. The bioaccumulation tests were started in mid-September and ended in mid-October 2012.

The PAC used for this study was purchased from Carbon Activated Corporation of Blasdell, New York (http://www.activatedcarbon.com). It was a 325 standard mesh size (0.045 mm particle size), bituminous coal-based activated carbon.

Table 2-1 PAC Study Sediment Sampling Locations

Reach	Sample Area Description	Feet Mark[a]		Total PCB Concentration (mg/kg)[b]		
		Downstream	Upstream	n	Range	Average
1	Between Burt Dam and Lake Ontario	75500	73677	6	0.17 - 1.96	0.9
3	Upstream end of Burt Dam pool	60756.9	60734.2	8	0.11 - 8.3	2.9
5	Newfane Dam Pool	52060.8	51122.4	11[c]	0.01 - 0.25	0.1

Notes:
[a] Feet downstream from Erie Canal, Lockport, New York.
[b] Sum of Aroclors (E & E 2012b).
[c] Excluding one outlier from 1994, which does not reflect current conditions.

Key: PCB = polychlorinated biphenyl
mg/kg = milligrams per kilogram

Table 2-2 Analytical Methods, Sample Containers, Preservatives, and Holding Times for PAC Pilot Study Samples, Eighteenmile Creek, Niagara County, New York

Sample Type	Preparation/Analysis	Method	Number of Samples	Sample Container	Preservation	Maximum Holding Time
Bioaccumulation Testing[a]	4-day screening test with *Lumbriculus variegatus*	EPA 100.3	3	Three pre-cleaned 3.5-gallon plastic buckets from each of three (3) sample sites.	4°C	8 weeks
	28-day bioaccumulation test with *Lumbriculus variegatus*	EPA 100.3	12			
Lumbriculus tissue	Lipids	See note b.	12	Amber 4-oz glass jar	4°C	14 days to extraction; 35 days from extraction to analysis
	PCB Congeners and Aroclors (8082 list)	EPA 8082	12	Amber 4-oz glass jar	4°C	14 days to extraction; 35 days from extraction to analysis
Sediment	Total Organic Carbon	See note b.	12	Amber 4-oz glass jar	4°C	28 days
	PCB Congeners and Aroclors (8082 list)	EPA 8082	12	Amber 4-oz glass jar	4°C	14 days to extraction; 35 days from extraction to analysis
	Density, wet	ASTM D854	12	Amber 4-oz glass jar	4°C	na
	Percent Solids	ASTM D2216	12	Amber 4-oz glass jar	4°C	na

Notes:

[a] Four (4) PAC treatments (6%, 3%, 1%, and 0% [control]) were prepared from each of the three sediment samples. See Section 2 for further detail.

[d] Laboratory standard operating procedure (SOP) provided in E & E (2012a).

Key:

AOC = Area of Concern
ASTM = American Society of Testing and Materials
AVS = acid volatile sulfide
na = not applicable
PAC = powdered activated carbon
PCB = polychlorinated biphenyls
SEM = simultaneously extracted metals
TAL = target analyte list

Table 2-3 Experimental Design for Eighteenmile Creek Powdered Activated Carbon (PAC) Pilot Study

Sediment Sample	Location	Treatment	Possible PAC Treatment Concentration
PAC-1	Downstream from Burt Dam	High PAC	6%
		Medium PAC	3%
		Low PAC	1%
		No PAC	0%
PAC-2	Between Burt and Newfane Dams	High PAC	6%
		Medium PAC	3%
		Low PAC	1%
		No PAC	0%
PAC-3	Upstream from Newfane Dam	High PAC	6%
		Medium PAC	3%
		Low PAC	1%
		No PAC	0%

Key:
PAC = Powdered activated carbon

Table 2-4 Powdered Activated Carbon (PAC) Weight Requirements for Pilot Study with Eighteenmile Creek Sediment.

Sample and Aliquot	PAC Treatment (dry weight)	TOC (%)	Ratio of PAC to Native TOC	Sediment Volume per Replicate (L) (wet)	Bulk Density (Kg/L)[a]	Sediment Sample Wet Wt. (Kg)	% solids (wet)[a]	Sediment Sample Dry Weight (Kg)	Sediment Sample Dry Weight (g)	PAC Dose (Fraction dry weight)	PAC Weight per Replicate (g)	Number of Replicates[b]	PAC Weight per Treatment (g)
PAC-1 (Below Burt Dam)													
1	6%	4.05%	1.48	1.5	1.320	1.98	0.386	0.764	764.3	0.06	45.9	3	137.6
2	3%	4.08%	0.74	1.5	1.365	2.05	0.412	0.844	843.6	0.03	25.3	3	75.9
3	1%	3.46%	0.29	1.5	1.269	1.90	0.400	0.761	761.4	0.01	7.6	3	22.8
4	0%	3.69%	0.00	1.5	1.236	1.85	0.379	0.703	702.7	0	0.0	3	0.0
PAC-2 (Between Burt and Newfane Dams)													
1	6%	5.84%	1.03	1.5	1.291	1.94	0.433	0.839	838.5	0.06	50.3	3	150.9
2	3%	5.53%	0.54	1.5	1.374	2.06	0.404	0.833	832.6	0.03	25.0	3	74.9
3	1%	3.87%	0.26	1.5	1.373	2.06	0.387	0.797	797.0	0.01	8.0	3	23.9
4	0%	6.25%	0.00	1.5	1.311	1.97	0.439	0.863	863.3	0	0.0	3	0.0
PAC-3 (Above Newfane Dam)													
1	6%	5.95%	1.01	1.5	1.165	1.75	0.251	0.439	438.6	0.06	26.3	3	79.0
2	3%	5.97%	0.50	1.5	1.258	1.89	0.252	0.476	475.5	0.03	14.3	3	42.8
3	1%	5.86%	0.17	1.5	1.242	1.86	0.231	0.430	430.4	0.01	4.3	3	12.9
4	0%	6.15%	0.00	1.5	1.121	1.68	0.251	0.422	422.1	0	0.0	3	0.0

Notes:

[a] Bulk density, % solids, and TOC were determined prior to testing. Final PAC weigh per replicate was based on sample-specific bulk density and % solids data.
[b] Five (5) replicates per treatment are recommended (USEPA 2000, Table 13.1), but Aquatec used three (3) replicates per treatment based on experience and for logistical reasons.

Key:
PAC = powdered activated carbon
TOC = total organic carbon

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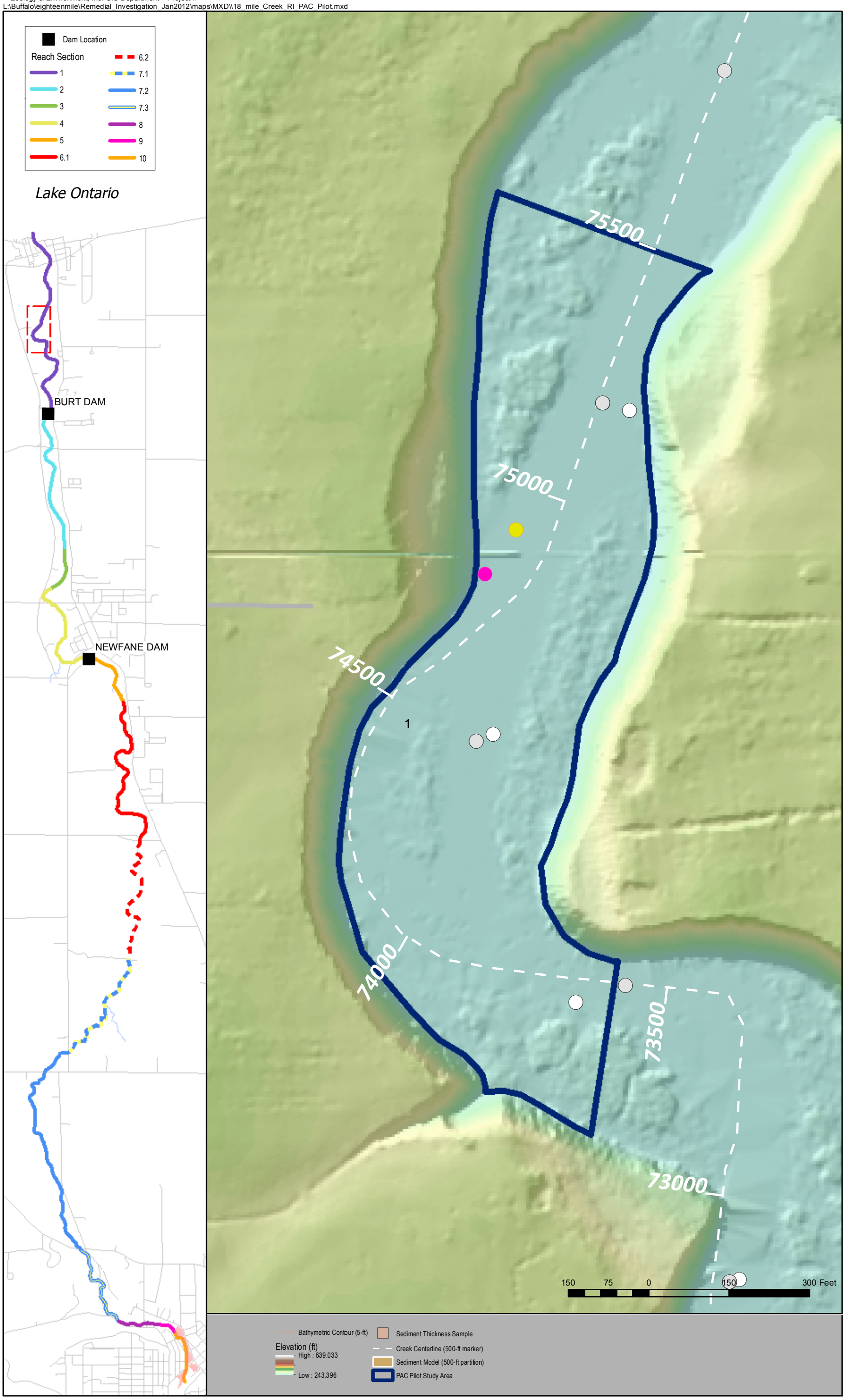

Figure 2-1. PAC Pilot Study Sample Area 1

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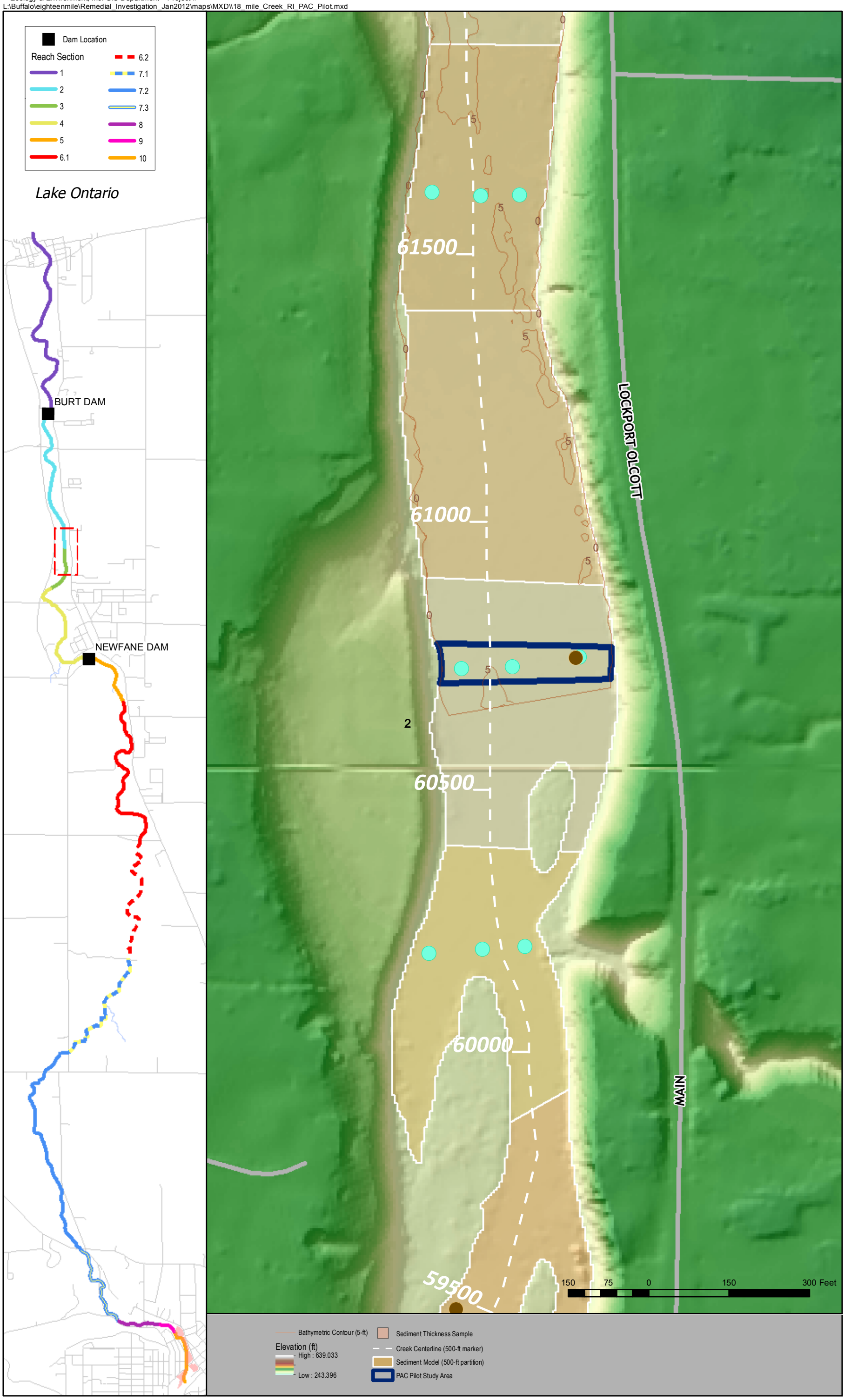

Figure 2-2. PAC Pilot Study Sample Area 2

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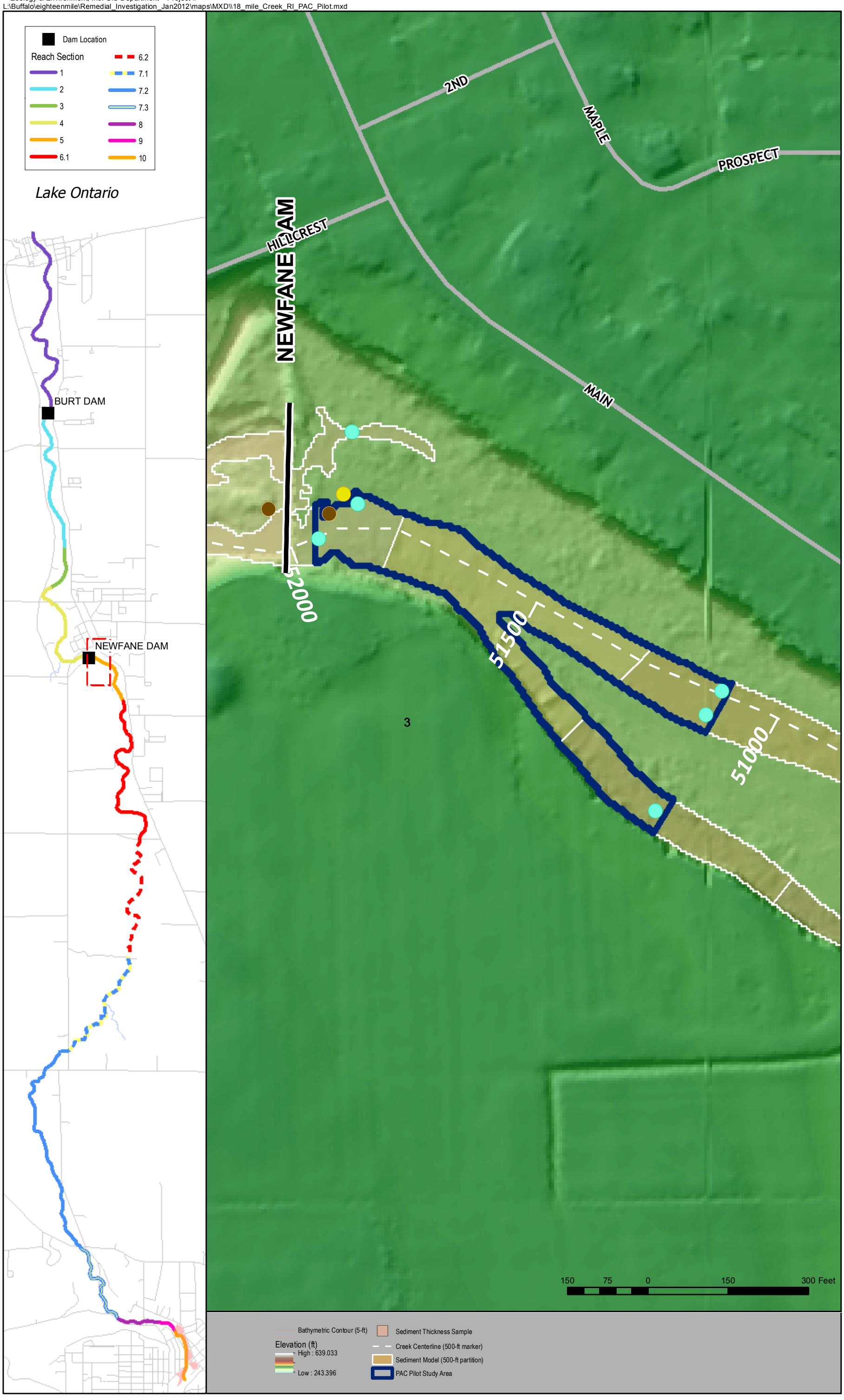
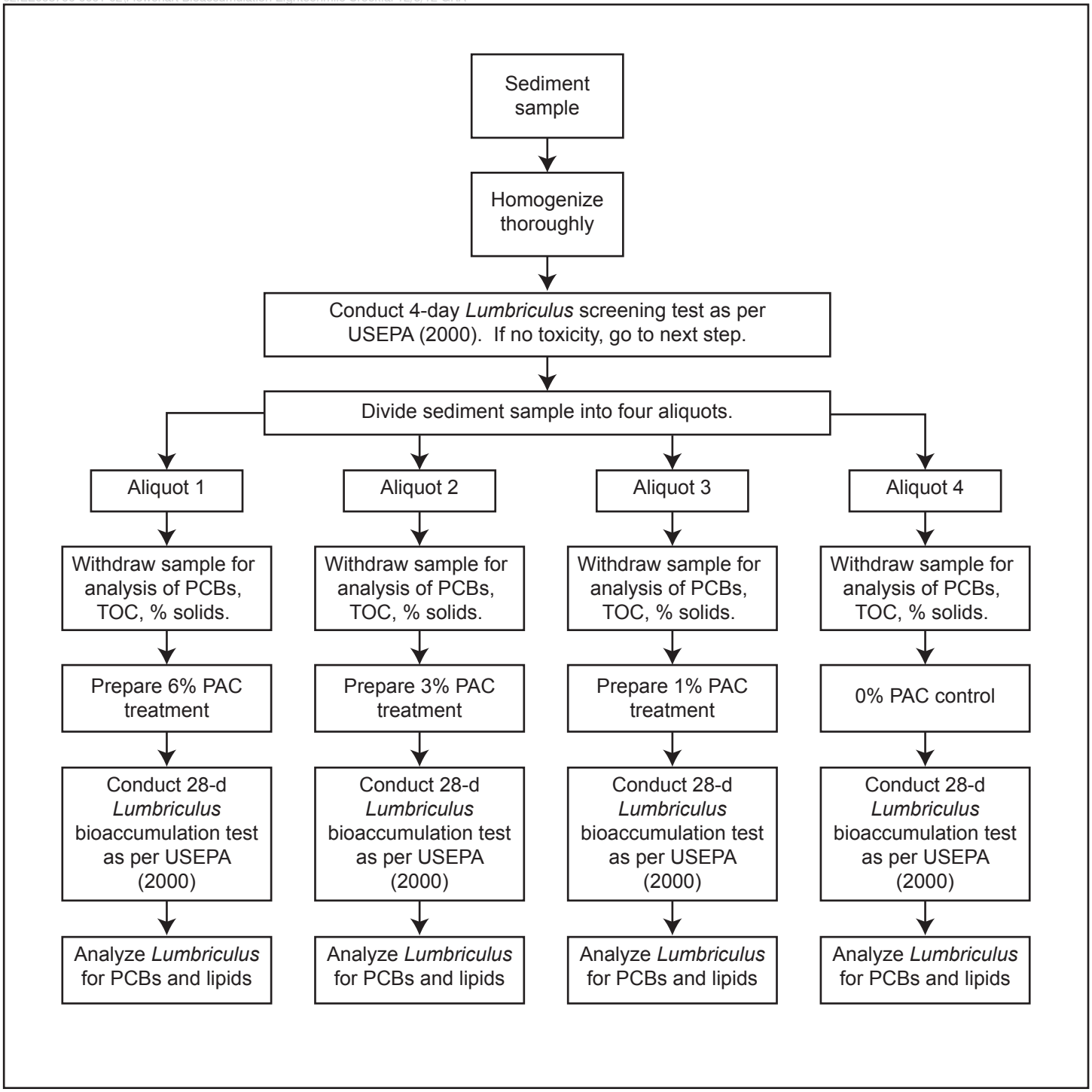


Figure 2-3. PAC Pilot Study Sample Area 3



SOURCE: Ecology and Environment, Inc. 2012

Figure 2-4 Flowchart for Bioaccumulation Testing with Eighteenmile Creek Sediment Amended with Powdered Activated Carbon (PAC)

3 Results and Discussion

3.1 Sediment PCB Concentrations and TOC Content

Concentrations of total PCBs and organic carbon (OC) in the sediment samples used in the PAC pilot study are shown in Table 3-1. The total PCB concentration was calculated based on the sum or Aroclors (EPA Method 8082 list) and sum of congeners (EPA Method 8082 list) and using both zero and 0.5 times the method detection limit for non-detected analytes. Hence, four total PCB concentrations are reported for each sample in Table 3-1. Seven Aroclors (1016, 1221, 1232, 1242, 1248, 1254, and 1260) are included in the EPA Method 8082 list. Aroclors 1254 and 1248 were the predominant Aroclors in the samples (see Appendix B), consistent with historical results for Eighteenmile Creek (E & E 2012b). Eighteen PCB congeners are included in the EPA Method 8082 list (see Appendix B for congener list). Fourteen to 17 of these congeners were routinely detected in the samples (see Appendix B).

The total PCB concentration (dry weight basis) in the samples from above Newfane Dam (PAC-3) and between Burt and Newfane dams (PAC-2) were comparable and roughly three times greater than the concentration in the sample from below Burt Dam (PAC-1) (see Table 3-1). In all samples, the total PCB concentration (dry weight basis) based on the sum of Aroclors was approximately three times greater than the total PCB concentration (dry weight basis) based on the sum of congeners (see Table 3-1). This result is not unexpected given that the congeners quantified by EPA Method 8082 are only a subset of the 209 possible congeners that may be present in the environment.

The total PCB concentration (sum of Aroclors, dry weight basis) in samples PAC-1 and PAC-2 were comparable to concentrations measured historically at these locations (compare Tables 3-1 and 2-1). In contrast, the total PCB concentration (sum of Aroclors, dry weight basis) in sample PAC-3 was an order of magnitude greater than historical results for this location (compare Tables 3-1 and 2-1). The reason for this difference is unclear.

Table 3-1 also lists total PCB concentrations normalized to sediment OC. Because PAC is a form of OC, the sum of the native total organic carbon (TOC) and added PAC (nominal dose) was used to normalize the sediment PCB results. As would be expected, the OC-normalized total PCB concentration decreased with increasing PAC dose (see Table 3-1).

3.2 Lumbriculus Testing Results, PCB Concentrations, and Lipid Content

As shown in Figure 2-4, a four-day *Lumbriculus* screening test was conducted with a subsample of the three PAC study samples to test for the presence or absence of acute toxic effects. *Lumbriculus* survival in each sample was near 100% and no different than *Lumbriculus* survival in clean (control) sediment (see Appendix D). Because no acute toxicity was observed, the three PAC study samples were deemed to be suitable for 28-day bioaccumulation testing.

At the end of the 28-day bioaccumulation tests, the *Lumbriculus* organisms in each PAC treatment were separated from the sediment matrix by sieving, allowed to depurate in clean water, and placed in amber glass vials for overnight shipment to ALS-Kelso for analysis of PCB Aroclors and congeners and lipids. Analytical results are provided in Table 3-2.

Amending Eighteenmile Creek sediment with PAC was highly effective in reducing PCB levels in *Lumbriculus* (see Table 3-2 and Figure 3-1). In addition, an inverse dose-response relationship was evident. For example, the sum of PCB congeners (µg/g lipid) in *Lumbriculus* in the 6%, 3%, and 1% PAC treatments were on average reduced by 99%, 97%, and 84% , respectively compared with *Lumbriculus* exposed to untreated (control) Eighteenmile Creek sediment (see Table 3-3, last column).

3.3 Biota Sediment Accumulation Factors (BSAFs)

Biota sediment accumulation factors (BSAFs) were calculated using data for total PCBs and TOC in sediment and total PCBs and lipids in *Lumbriculus*. The following equation from USEPA (2009) was used:

$$BSAF = (C_o/f_l)/(C_s/f_{soc}) = C_l/C_{soc}$$

Where:

C_o = chemical concentration in organism (micrograms per kilogram [µg/kg] wet weight);
f_l = lipid fraction of organism (g lipid/g wet weight);
Cs = chemical concentration in surficial sediment (µg/kg dry weight);
f_{soc} = fraction OC in sediment (g OC/g dry weight);
C_l = chemical concentration in organism on a lipid basis (micrograms per gram [µg/g] OC); and
C_{soc} = chemical concentration in sediment on an OC basis (µg/g OC).

The calculated BSAF are provided in Table 3-4. BSAFs were greatest for untreated Eighteenmile Creek sediment and decreased with increasing PAC dose. BSAFs calculated from the sum of Aroclors and sum of congeners were generally similar for any given treatment.

Table 3-1 Sediment PCB and Organic Carbon Concentrations, Eighteenmile Creek PAC Pilot Study

Sample and Aliquot	PAC Treatment (% dry wt.)	Native TOC		Native TOC + PAC		Sum of Aroclors (µg/kg dry weight)		Sum of Congeners (µg/kg dry weight)		Sum of Aroclors (µg/g OC)[c]		Sum of Congeners (µg/g OC)[c]	
		% dry weight	mg/kg dry weight	% dry weight	mg/kg dry weight	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]
PAC-1 (Below Burt Dam)													
1	6	4.05	40500	10.1	100500	570	577	201	208	5.7	5.7	2.0	2.1
2	3	4.08	40800	7.1	70800	640	647	201	208	9.0	9.1	2.8	2.9
3	1	3.46	34600	4.5	44600	480	487	167	173	10.8	10.9	3.7	3.9
4	0 (Control)	3.69	36900	3.7	36900	590	597	209	216	16.0	16.2	5.7	5.9
PAC-2 (Between Burt and Newfane Dams)													
1	6	5.84	58400	11.8	118400	1420	1453	374	378	12.0	12.3	3.2	3.2
2	3	5.53	55300	8.5	85300	1240	1273	307	311	14.5	14.9	3.6	3.6
3	1	3.87	38700	4.9	48700	3500	3568	781	789	71.9	73.3	16.0	16.2
4	0 (Control)	6.25	62500	6.3	62500	1980	2040	509	512	31.7	32.6	8.1	8.2
PAC-3 (Above Newfane Dam)													
1	6	5.95	59500	12.0	119500	1590	1643	409	415	13.3	13.7	3.4	3.5
2	3	5.97	59700	9.0	89700	1800	1853	480	486	20.1	20.7	5.4	5.4
3	1	5.86	58600	6.9	68600	1990	2048	491	498	29.0	29.8	7.2	7.3
4	0 (Control)	6.15	61500	6.2	61500	1800	1853	465	471	29.3	30.1	7.6	7.7

Note:
[a] non-detected analytes set equal to zero when calculating sum.
[b] non-detected analytes set equal to 0.5 times method detection limit when calculating sum.
[c] normalized to native TOC + PAC.

Key:
DL = detection limit
ND = non detect
OC = organic carbon
PAC = powdered activated carbon
PCBs = polychlorinated biphenyls
TOC = total organic carbon

Table 3-2 *Lumbriculus* PCB Concentrations and Lipid Content, Eighteenmile Creek PAC Pilot Study

Sample and Aliquot	PAC Treatment (% dry wt.)	Lipid Content		Sum of Aroclors (µg/kg wet weight)		Sum of Congeners (µg/kg wet weight)		Sum of Aroclors (µg/g lipid)		Sum of Congeners (µg/g lipid)	
		% wet weight	mg/kg wet weight	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]	ND = 0[a]	ND = 0.5DL[b]
PAC-1 (Below Burt Dam)											
1	6	0.98	9800	0	13	0.8	4.6	0.0	1.4	0.1	0.5
2	3	0.86	8600	0	11	1.4	4.2	0.0	1.2	0.2	0.5
3	1	0.87	8700	16	35	9.5	10.9	1.8	4.0	1.1	1.3
4	0 (Control)	1.1	11000	480	487	119.1	123.1	43.6	44.3	10.8	11.2
PAC-2 (Between Burt and Newfane Dams)											
1	6	0.82	8200	12	19	1.7	4.3	1.4	2.4	0.2	0.5
2	3	0.87	8700	17	27	3.4	5.5	2.0	3.1	0.4	0.6
3	1	0.83	8300	37	61	13.4	15.8	4.5	7.4	1.6	1.9
4	0 (Control)	1.2	12000	530	539	203.3	205.4	44.2	44.9	16.9	17.1
PAC-3 (Above Newfane Dam)											
1	6	0.84	8400	8	17	1.5	4.7	1.0	2.1	0.2	0.6
2	3	1.3	13000	27	40	7.8	9.9	2.1	3.0	0.6	0.8
3	1	0.84	8400	86	94	36.0	39.6	10.2	11.2	4.3	4.7
4	0 (Control)	1.1	11000	510	580	114.0	115.6	46.4	52.7	10.4	10.5

Note:
[a] non-detected analytes set equal to zero when calculating sum.
[b] non-detected analytes set equal to 0.5 times method detection limit when calculating sum.

Key:
DL = detection limit
ND = non detect
PAC = powdered activated carbon
PCBs = polychlorinated biphenyls

Table 3-3 Effectiveness of Powdered Activated Carbon in Reducing Total PCB Levels in *Lumbriculus*

Sample and Aliquot	PAC Treatment (% dry wt.)	Sum of Aroclors[a] in *Lumbriculus* (ug/kg wet)	% Reduction Compared with Control	Sum of Congeners[a] in *Lumbriculus* (ug/kg wet)	% Reduction Compared with Control	Sum of Aroclors[a] in *Lumbriculus* (ug/g lipid)	% Reduction Compared with Control	Sum of Congeners[a] in *Lumbriculus* (ug/g lipid)	% Reduction Compared with Control
PAC-1 (Below Burt Dam)									
1	6	13.4	-97%	4.6	-96%	1.4	-97%	0.1	-99%
2	3	10.6	-98%	4.2	-97%	1.2	-97%	0.2	-98%
3	1	35.0	-93%	10.9	-91%	4.0	-91%	1.1	-90%
4	0 (Control)	487	--	123	--	44.3	--	10.8	--
PAC-2 (Between Burt and Newfane Dams)									
1	6	19.4	-96%	4.3	-98%	2.4	-95%	0.2	-99%
2	3	27.3	-95%	5.5	-97%	3.1	-93%	0.4	-98%
3	1	61.25	-89%	15.8	-92%	7.4	-84%	1.6	-90%
4	0 (Control)	539	--	205	--	44.9	--	16.9	--
PAC-3 (Above Newfane Dam)									
1	6	17.45	-97%	4.7	-96%	2.1	-96%	0.2	-98%
2	3	39.5	-93%	9.9	-91%	3.0	-94%	0.6	-94%
3	1	94.4	-84%	39.6	-66%	11.2	-79%	4.3	-59%
4	0 (Control)	580	--	116	--	52.7	--	10.4	--

Note:
[a] One-half method detection limit used for non-detected analytes (see Table 3-2).

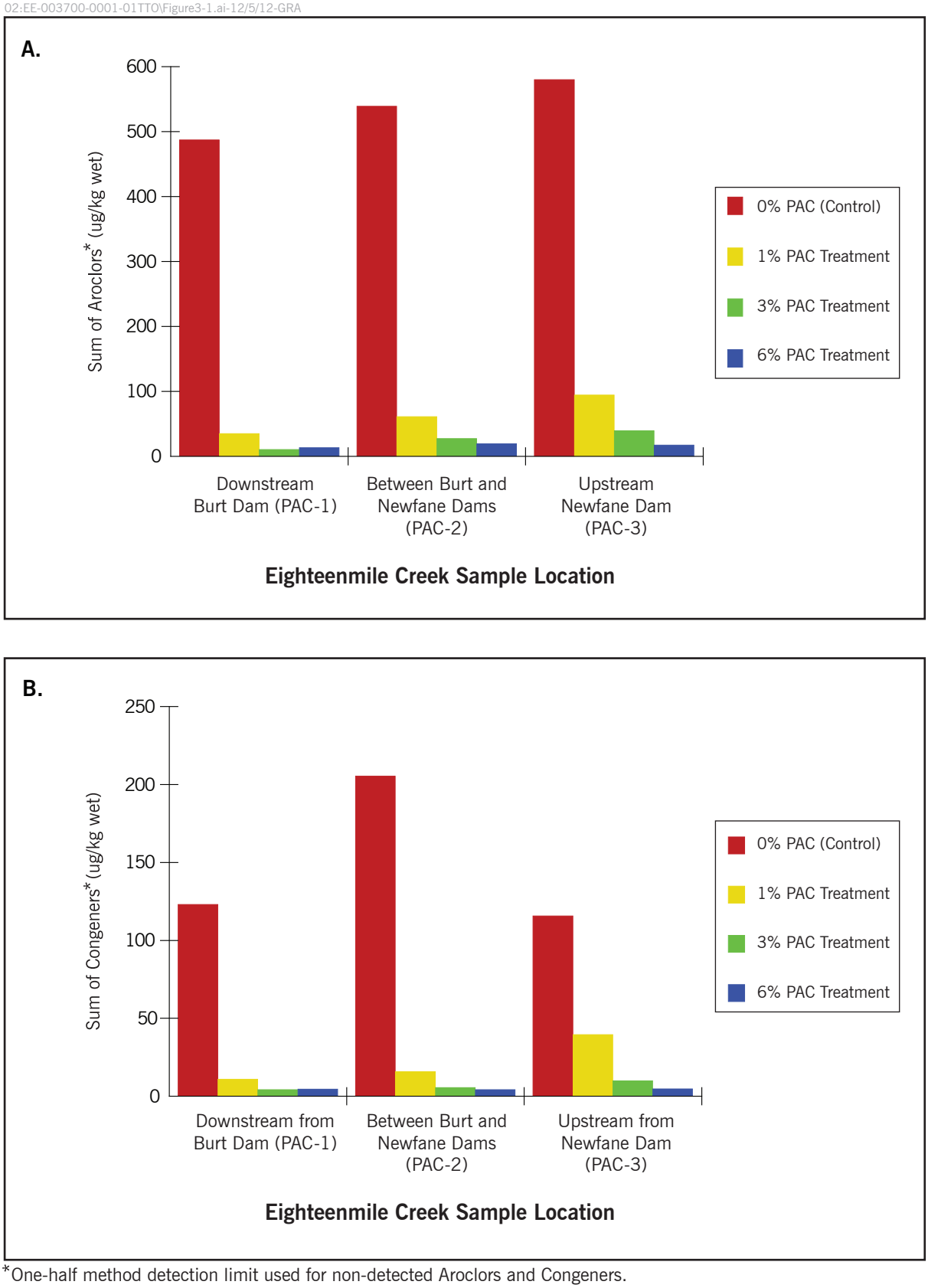
Key:
-- = not applicable
PAC = powdered activated carbon
PCBs = polychlorinated biphenyls

Table 3-4 Biota Sediment Accumulation Factors (BSAFs) for Eighteenmile Creek Estimated from PAC Study Results.

Sample and Aliquot	PAC Treatment (% dry wt.)	BSAF[a] Based on Sum of Aroclors		BSAF[a] Based on Sum of Congeners	
		ND = 0[b]	ND = 0.5DL[c]	ND = 0[b]	ND = 0.5DL[c]
PAC-1 (Below Burt Dam)					
1	6	0.00	0.24	0.04	0.23
2	3	0.00	0.13	0.06	0.16
3	1	0.17	0.37	0.29	0.32
4	0 (Control)	2.73	2.74	1.91	1.91
PAC-2 (Between Burt and Newfane Dams)					
1	6	0.12	0.19	0.07	0.16
2	3	0.14	0.21	0.11	0.17
3	1	0.06	0.10	0.10	0.12
4	0 (Control)	1.39	1.38	2.08	2.09
PAC-3 (Above Newfane Dam)					
1	6	0.07	0.15	0.05	0.16
2	3	0.10	0.15	0.11	0.14
3	1	0.35	0.38	0.60	0.65
4	0 (Control)	1.58	1.75	1.37	1.37

Note:
[a] See Section 3.3 for method of calculation.
[b] Non-detected analytes set equal to zero when calculating sum.
[c] Non-detected analytes set equal to 0.5 x DL when calculating sum.

Key:
BSAF = biota sediment accumulation factor
DL = detection limit
ND = non detect
PAC = powdered activated carbon
PCBs = polychlorinated biphenyls



*One-half method detection limit used for non-detected Aroclors and Congeners.

Figure 3-1 Total PCBs in Lumbriculus Exposed to Eighteenmile Creek Sediment Amended with Powered Activated Carbon (PAC): (A) Sum of Aroclors and (B) Sum of Congeners

4 Summary and Recommendations

The following results of the PAC pilot study are noteworthy:

- Amending Eighteenmile Creek sediment with PAC was highly effective in reducing PCB levels in *Lumbriculus*. The sum of PCB congeners (µg/g lipid) in *Lumbriculus* in the 6%, 3%, and 1% PAC treatments was on average reduced by 99%, 97%, and 84%, respectively compared with *Lumbriculus* exposed to untreated Eighteenmile Creek sediment.

- Sediment-to-benthic organism BSAFs were greatest for untreated Eighteenmile Creek sediment (1.4 to 2.7) and decreased with increasing PAC dose, decreasing to less than 0.2 at the greatest PAC treatment concentration (6%).

Overall, the results of the pilot study indicate that PAC was highly effective in reducing bioaccumulation of PCBs from Eighteenmile Creek sediment to benthic organisms. From the perspective of BUI delisting, the pilot study results are encouraging because they suggest that it may be possible to reduce exposure and risk to people and wildlife at Eighteenmile Creek from PCBs using a remedial approach less costly and disruptive than sediment dredging and/or capping. We recommend that small-scale in situ testing in one or more areas of the Eighteenmile Creek be considered as a logical extension of the current study.

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