A Physical Habitat and Chemical Assessment of Pennsylvania Lake Erie Watershed Streams

Report to the Erie County Conservation District
Erie, Pennsylvania

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Abstract

A physicochemical assessment of the streams flowing directly into Lake Erie along the Pennsylvania shoreline was conducted as part of a comprehensive watershed assessment project. Streams flowing into Presque Isle Bay were not included in this report as they had been previously evaluated in a prior study.

Twenty-nine sites along Raccoon, Elk, Halls Run, Crooked, Little Elk, Walnut, McDaniels Run, 4 Mile, 6 Mile, 7 Mile, 12 Mile, 16 Mile, and Bakers Creek were evaluated using Habitat Assessment and Physicochemical Parameters section of the EPA's Rapid Bioassessment Protocol (Barbour et al., 1999). Selected water and sediment quality parameters were also measured using EPA-approved methods.

For the most part, these streams appear to be of high quality (with notable exceptions) and are worthy of protective efforts. The lesser quality streams are Baker's Creek, McDaniel's Run, and 16 Mile Creek, which ranked poorly for both physical habitat measures and sediment-associated heavy metals concentrations. Other sites also are of concern, such as 6 mile, 7 Mile, and 12 Mile (physical habitat scores) Creeks, and Hall's Run (heavy metals). While bacterial counts were not included in this study, organic pollution in general did not appear to be a problem for any of the sites studied.

Acknowledgment

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1. Introduction

The Lake Erie shoreline of Pennsylvania is home to Pennsylvania's (PA) only Great Lakes port (at Erie, the fourth largest city in PA), and is home to urban, suburban, agricultural, and forested regions. Most of this 47 mile shoreline consists of narrow beaches in front of steep bluffs cut into Pleistocene and early Holocene glacial and lacustrine sediments atop Devonian shale bedrock. Streams draining northwestern PA have eroded overlying sediments down to the shale bedrock creating the majority of breaks in the nearly uniform bluff-face shoreline (Shultz, 1999).

Major constituents of the upper bedrock are siltstones, sandstones and conglomerates. Four major glaciations dominated northwestern PA depositing what now overlays the bedrock in that area. Erie country is theorized to predominantly retain till of the late Wisconsin advance.

Shoreline erosion is widely variable as a function of weather patterns, lake levels and shoreline composition. Bluff erosion is dependent on wave activity and involves the removal of sediments within wave reach, acting to steepen the bluff face and leading to mass-movement and landslides.

Erie, PA is located in the approximately in the middle of the PA Lake Erie shoreline. It is centered on Presque Isle Bay, the Erie harbor, which is formed by the peninsula know as Presque Isle. Presque Isle is a compound recurved sandspit peninsula that lies in Lake Erie. It is attached at its southwest end to the shore at Erie, Pennsylvania and proceeds northeastward from the shore to its tip. From attachment to the tip, referred to as Gull Point, the peninsula is approximately 10.1 km (6.25 miles) in length, with width varying from several hundred meters at its neck to 2 km (1.25 miles) at its widest point (DCNR-1, 1991; Kormondy, 1969; Shultz, 1999).

The underlying geologic structure of the peninsula is mainly derived from a large deposit of glacial till left atop the shale bedrock of the area approximately 12,000 to 14,000 years ago by glaciers of the Pleistocene period. Presque Isle's topical nourishment is largely sand derived from the deposition of eroded rocks along the lakeshore west of the peninsula, and transported northeastward by long-shore lake and wind currents. The bulk of these eroded particles originated from the bluffs of Ashtabula, Ohio, approximately 50 miles west of Erie. Sediment deposition continues to accrue at Erie, helping to form and maintain Presque Isle (DCNR, 1991; Kormondy, 1969; Shultz, 1999). Additionally, there is an annual program of beach nourishment. Mass addition of sand to the beaches has been performed by the US Army Corps of Engineers for a number of years (DCNR, 1991; DCNR, 1999).

2. Background and Study Area

The streams flowing into Lake Erie along the Pennsylvania shoreline follow roughly parallel paths as they drain the relatively narrow Lake Erie watershed in this region. The lake level is roughly 60 to 100 feet lower than a narrow plateau created when the last glaciers retreated from this area about 12,000 years ago. Wave action over the last 12,000 years has created a cliff-like bluff along the shoreline in this region. Some of these streams flow southwest from their headwaters and all turn northwest as they cut their way through the Devonian shale bedrock of the region to drain into the Lake. The shale is easily eroded and each stream has more or less created a ravine as it descends through the bluff to the Lake level. These ravines are local foci for erosion and have resulted in steep unstable conditions for the unconsolidated material above the bedrock.

The watersheds along the Pennsylvania Lake Erie shoreline vary widely in their land use characteristics. The watersheds draining directly into Presque Isle Bay are mostly urban while, with some exceptions, the watersheds of streams draining directly into Lake Erie are mostly rural. However, there is extensive agricultural activity in these watersheds, with isolated population centers clustered in villages at various locations. It is not certain whether these small watersheds are important sources of non-point source pollution to Lake Erie and Presque Isle Bay.

The harbor formed by Presque Isle has been designated an Area of Concern in the Great Lakes National Program because of the presence of contaminated sediments and high incidence of fish tumors. The most likely sources of contamination now found in the Bay are pollutants released from activities along the Bayfront, many of which have subsequently been controlled. Today, it is likely that there continues to be a release of sediment and contamination from the watershed to the Bay, and that this transport of sediment and associated contamination is likely to have a deleterious impact on the streams of the watershed as well as on the Bay itself.

Pennsylvania's Lake Erie streams deserve protection. Many of these streams support valuable fisheries. In addition, a stream's quality reflects the overall environmental quality of its watershed. Therefore, it is important to monitor the water quality of these streams in order to identify potential threats to these valuable resources and to develop protection and intervention strategies where necessary. These streams also provide the opportunity to study the relative importance of urbanization and agriculture as determining factors influencing ecological quality and biodiversity.

3. Study Goals and Objectives

Most of the watersheds of these streams are non-urban, with notable exceptions (many of these streams flow through small towns and villages, the headwaters of Walnut Creek drain a highly developed area in the vicinity of a major shopping area, the 16 Mile Creek flows though the town of Northeast with some significant industrial activity). While the City of Erie and its surrounding townships (primarily Millcreek Township and Harbor Creek Township) are not growing rapidly in population, the phenomenon of urban sprawl has been occurring over the past several decades. Rural land is slowly being converted into higher density uses such as residential subdivisions and shopping centers. It is well established that such land use changes affect environmental quality in general, and water quality in particular. Therefore, the objectives of this study were:

- To document the general condition of streams in the LE watershed,
- To identify signs of stream habitat degradation through the use of the EPA’s Rapid Bioassessment Protocol – Habitat Assessment and Physicochemical Parameters,
- To collect and analyze stream sediments for the presence of heavy metals, and
- To provide habitat information to other researchers conducting coordinated studies at the same sites of the benthic and fish communities who also were following the EPA’s Rapid Bioassessment Protocol.

With the data gathered to accomplish the above listed objectives, it was also possible to rank sites according to their apparent level of impairment, based on both physical habitat and sediment quality characteristics.

4. Methods

4.1 Sampling Locations

The streams selected for this study were those which flow into Lake Erie directly along the PA shoreline. A previous similar assessment was conducted of streams which flow directly into Presque Isle Bay, and some of that data is included here by way of reference. Twenty-eight sites on thirteen named streams were included in this assessment. An aerial photograph (Figure 1) of the lake shore is provided to give a general impression of the study site locations relative to the City of Erie and Presque Isle Bay. All of these streams flow generally northwest into Lake Erie. Location information for the sampled sites is present in Table 1.

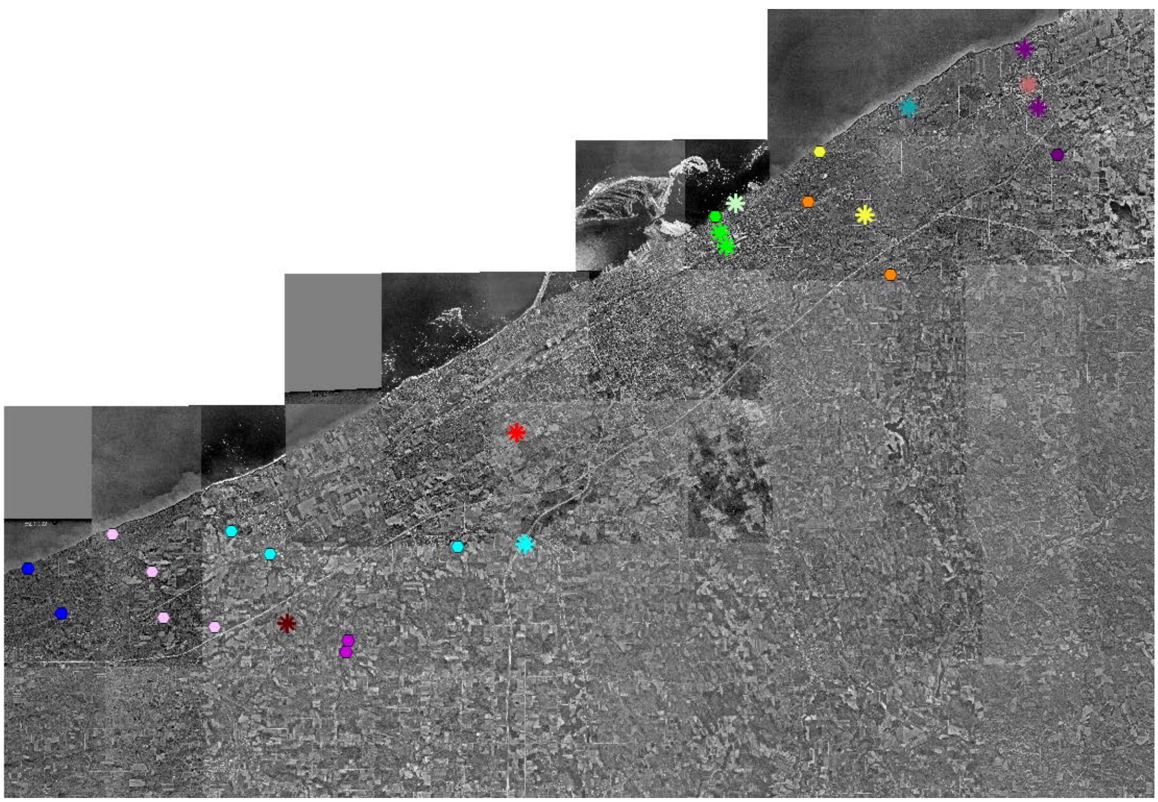

Figure 1. Aerial photo of the study area showing the approximate location of the stream assessment sites.

Table 1. Location information for stream sites assessed in this study.

		Latitude N		Longitude W	
Stream Name	**Site Designation**	**deg**	**min**	**deg**	**min**
Raccoon Creek	RC1a	41	59.333	80	28.860
	RC1b	41	59.336	80	28.836
	RC2	41	57.974	80	27.655
Crooked Creek	CrC1	42	0.137	80	25.686
	CrC2	41	59.087	80	24.326
	CrC3	41	57.909	80	23.473
	CrC4	41	57.518	80	21.828
Elk Creek	ELK1	42	0.405	80	21.178
	ELK2	41	59.646	80	19.558
	ELK3	41	59.642	80	13.002
	ELK4	41	59.841	80	10.023
Little Elk Creek	LE1	41	56.849	80	16.882
	LE2	41	56.689	80	16.704
Halls Run	HR	41	56.563	80	18.383
Walnut Creek	WC	42	3.107	80	10.010
McDaniels Run	MR1	42	9.074	80	2.469
	MR2	42	8.742	80	2.226
	MR3	42	8.247	80	1.880
4-Mile Creek	4Mile	42	9.528	80	1.641
6-Mile Creek	6Mile1	42	9.533	79	58.960
	6Mile2	42	7.421	79	55.678
7 Mile Creek	7Mile1	42	10.951	79	58.590
	7Mile2	42	9.280	79	56.570
12 Mile Creek	12Mile	42	12.242	79	54.762
16 Mile Creek	16Mile1	42	13.944	79	50.306
	16Mile2	42	12.338	79	50.078
	16Mile3	42	10.547	79	49.235
Baker's Creek	BC	42	12.917	79	50.023

note: streams are arranged generally from west to east along the PA shoreline of Lake Erie; streams flowing into Presque Isle Bay are not included in this study.

4.2 Field Activities

4.2.1 EPA Rapid Bioassessment Protocol

Habitat and physicochemical parameters were assessed at each site using the EPA Rapid Bioassessment Protocol (RBP). The purpose of the RBP is to characterize and rank impairments to a water resource by identifying and evaluating sources and causes (Barbour, et al., 1999). The RBP habitat assessment is divided into two parts: 1) physical characteristics and water quality, and 2) a visual habitat assessment scoring matrix. The physical characterization include such information as land use, stream origin and type, riparian and in-stream features along with in-situ measurements for water quality parameters. This physical characterization is done in order to assess the stream's ability to support an aquatic ecosystem. This information, coupled with analytical testing, can provide information on chemical and physical stressors present at the site. The physical habitat and water quality data sheets compiled for each site are found in the appendix.

The visual habitat assessment includes ten parameters scored on a range of 0-20 based on subjective judgment using guidance supplied by the protocol. Parameters differ depending on whether the stream has a high or low gradient. The 0-20 range for each parameter is sub-divided as "optimal, sub-optimal, marginal, and poor." Sites can be ranked using the habitat scores as a sum total or for selected individual parameters.

To compile a total habitat score, each parameter is weighted equally. The parameters included are as follows.

- <u>Epifaunal substrate or available cover</u>; evaluated for high and low gradient streams; overall evaluation of all structures present in the reach which could provide opportunity for fish and macroinvertebrates to feed and spawn; new fall, i.e., material recently deposited in the stream, is not a stable habitat and is not considered.
- <u>Embeddedness</u>; measured in high gradient sites where there is substantial flow; results from large-scale sediment movement within a stream; poor habitat results when gravel, cobbles, etc. are nearly or completely surrounded and covered by silt and mud; (for low gradient streams, the pool substrate is characterized).
- <u>Velocity/depth regime:</u> (slow deep, slow shallow, fast deep, fast shallow); only assessed for high gradient streams; in a stable situation, all four regimes will be present; pool variability is used for low gradient streams.
- <u>Sediment deposition</u>; evaluated for high and low gradient streams; a measure of the amount of sediment moved and deposited through a reach; islands and point bars are indicators of large volumes of sediment moving through the system, indicating an unstable condition.
- <u>Channel flow status;</u> the amount of water in the channel is estimated for both stream gradients; a measure of the exposure of the stable substrate or available habitat; few stable habitats exist in streams where the shape of the channel is changed or diverted.
- <u>Channel alteration</u>; urban and agricultural streams altered for flood control or irrigation purposes; measured in both high and low gradient streams.

- Frequency of riffles; in high gradient streams, stream community depends on riffles to provide high-quality habitat and otherwise enhance the aquatic community through diversity; in low gradient streams, the meandering or sinuosity of the stream is measured; numerous bends can better accommodate floodwaters, absorbing energy from the flow, reducing erosion and sedimentation.
- Bank stability; for both gradients, raw banks and undercutting are signs that the banks are unstable and erosion could be a problem; severely eroded banks can be strong indicators of sedimentation problems downstream.
- Vegetative protection; strong effect on the stability of a bank; a variety of vegetation as well as strong root systems can increase the stability of a bank by holding the soil together.
- Riparian vegetative zone width; scored by measuring the width of the natural vegetative zone along the stream bank; provides a buffer for the transport of pollutants from roadways and other sources of runoff.

4.2.2 *In-Situ* Measurements

On-site measurements of pH, dissolved oxygen (DO) and temperature were made at each site using Accumet portable pH and DO meters. Specific conductivity was measured with a Corning 311 portable conductivity meter and recorded in mS/cm. The surface velocity was taken at the thalweg of the stream with a hand-held velocity meter and recorded in ft/s, then converted to m/s.

4.2.3 Water and Sediment Sample Collection Procedures

Three water and sediment samples were collected within each sample reach, one upstream, one downstream, and one in the middle of the sample reach. A duplicate was collected at each site from one of the three sample locations, chosen randomly. Sample bottles were pre-washed using Alconox and rinsed with tap water. The bottles were then placed in a 0.1 N nitric acid bath for 24 hours and rinsed with deionized water and acetone. Bottles used in BOD analysis were not rinsed in acetone.

Water samples were collected in 1 L plastic bottles (for TSS and NPOC analysis) and in 250 mL small-neck plastic bottles (for turbidity analysis). One additional 1 L plastic bottle was used to collect a sample for BOD_5 testing. All water samples were collected with the bottle mouth facing downstream and were filled to the top so as to avoid headspace in the bottle.

Sediment samples were collected using a small garden shovel to scoop the sediment from the stream bed. The sediment was then passed through a VWR Scientific #10 U.S Standard Testing Sieve and transferred to the bottle with the shovel. The four samples collected at each site were placed in 250 mL wide-mouth plastic bottles for metals analysis.

4.3 Laboratory Procedures

4.3.1 Dissolved Organic Carbon (DOC)

Dissolved organic carbon was measured for four samples per site using the filtrate from the suspended solids samples. Dissolved organic carbon was measured in the sample by the non-purgeable organic carbon (NPOC) method using a Shimadzu 5050A Total Carbon Analyzer. Each sample was acidified with phosphoric acid to convert carbonate and bicarbonate ions to carbonic acid. The sample was then sparged with oxygen for 10 minutes to strip carbonic acid (as carbon dioxide) from the sample (this may also have removed volatile organics). Before and after each sample batch, a standard of known carbon content as well as a deionized water blank were analyzed for quality control purposes.

4.3.2 5-Day Biochemical Oxygen Demand (BOD_5)

The BOD_5 was determined at each site using the five-day test procedure as described by Standard Method 5210B (APHA et al., 1998). Initial and final DO concentrations were measured using a YSI 52 Dissolved Oxygen Meter. Samples were incubated in a Hach BOD Incubator at 20° C in the dark for the test period. When necessary, samples were diluted 1:10 with dilution water prepared in accordance with Section 4.a. of the procedure. To insure quality control, a dilution water blank was run with each batch of diluted samples. A deionized water blank was run with all batches when the sample was not diluted.

4.3.3 Acid Digestions for Metals Analysis

Acid digestions were performed on all plastic-bottle sediment samples. Samples (1-2 g wet wt) were digested with repeated additions of trace-metal grade nitric acid and 30% hydrogen peroxide according to EPA Method 3050B (EPA, 1990). Hydrochloric acid (trace-metal grade) was added to the digestate and refluxed for 15 minutes. This is an optional step to increase the solubility of certain metals. The final digestate was diluted to 100mL. A duplicate and matrix spike (1.5mg/L) of every tenth sample was included for quality control purposes.

4.3.4 Metals Analysis by Flame Atomic Absorption (FLAA)

Final digestates from acid digestions were analyzed for metal content using FLAA spectroscopy. The analysis was performed for five metals: cadmium, copper, lead, nickel, and zinc using a Perkin Elmer AAnalyst 100 Atomic Absorption Spectrometer. Calibration and setup followed the procedure in the instrument User's Guide. The machine was optimized for each metal using a standard made at the characteristic concentration of that particular metal (the concentration at which the instrument detects an absorbance of 0.20 units). Once calibrated, the instrument was checked using a standard of known concentration every ten samples to ensure accuracy. Metals standards were prepared using 1mg/mL Fisher Scientific stock solutions of each metal.

5. Results and Discussion

5.1 Physico-chemical Assessment

General information for the assessment sites is presented in Table 2, including the date the site was visited, the distance upstream (river mile), the catchment size above the sampling site, whether there was or was not precipitation within the seven days prior to the visit, and whether there were visible signs of non-point pollution and local erosion. Also provided is an estimate of the amount of large woody debris (LWD) in the sampled reach. The density of LWD is a good indicator of the availability of habitat and cover for fish. Because some of these streams experience fairly high water velocities during storm events and have bedrock stream beds, the abundance of LWD is low, ranging from none at many locations to a high of about 0.06 m^2 per m^2 of reach area at the mouth of McDaniel’s Run. The LWD area was estimated using a method provided in the RBP.

A judgment about the sources of non-point pollution near the sampling site was based simply on a visual examination of the area, and was rated as none (n), somewhat (s), or definitely present (y).

A judgment about local erosion was also made based on a visual examination of the stream reach, and was rated as none (n), moderate (m), or heavy (h).

Table 2. General information for assessment sites.

Stream Name	Site Designation	date sampled	river mile[a]	catchment area km^2	Recent Precip[b]	NPSP[c] N/S/Y	Erosion[d] N/M/H	LWD density[e] m^2/m^2
Raccoon Creek	RC1a	7/29/03	0.16	28.376	y	s	m	0.01
	RC1b	7/6/04	0.22	27.350	y	s	m	0.03
	RC2	7/30/03	2.91	22.725	y	s	h	0.02
Crooked Creek	CrC1	7/28/04	0.58	39.702	y	s	m	0.01
	CrC2	7/29/04	2.88	35.269	y	s	m	0.01
	CrC3	8/11/04	5.22	25.714	y	s	m	
	CrC4	7/29/04	7.39	14.362				
Elk Creek	ELK1	7/30/04	2.46	99.199	n	s	m	0.00
	ELK2	7/16/03	4.69	94.213	y	n	m	0.00
	ELK3	7/14/03	15.18	66.533	y	n	m	0.01
	ELK4	7/17/03	20.71	60.712	y	s	m	0.00
Little Elk Creek	LE1	7/27/04	4.77	53.870	y	s	m	0.01
	LE2	7/29/03	15.58	33.999	y	n	m	0.01
Halls Run	HR	7/30/04	2.34	9.661	n	s	m	0.04
Walnut Creek	WC	7/7/03	7.50	74.639	y	s	m	0.00
McDaniels Run	MR1	5/29/03	0.09	2.913	y	n	m	0.06
	MR2	5/29/03	0.60	2.842	y	s	m	0.00
	MR3	5/28/03	1.40	1.750	y	s	m	0.00
4-Mile Creek	4Mile	5/30/03	0.15	30.090	y	s	m	0.00
6-Mile Creek	6Mile1	6/11/03	1.75	52.924	y	s	h	0.00
	6Mile2	6/23/03	7.68	24.497	y	s	m	0.00
7 Mile Creek	7Mile1	6/6/03	0.25	22.279	y	n	h	0.00
	7Mile2	6/10/03	3.02	7.164	y	n	m	0.04
12 Mile Creek	12Mile	6/23/03	0.62	32.264	y	s	m	0.00
16 Mile Creek	16Mile1	6/11/03	0.71	43.796	y	s		0.00
	16Mile2	6/10/03	4.19	17.724	y	s	h	0.01
	16Mile3	6/16/03	8.24	1.591	y	n	n	0.01
Baker's Creek	BC	6/10/03	2.42	4.439	y	y	n	0.00

[a] miles from the mouth or confluence with a larger stream

[b] Recent Precip indicates rainfall within the previous 7 days

[c] NPSP:signs of non-point source pollution in the area near the sampling site: Non, Some, Yes

[d] Erosion evident in the vicinity of the sampling site: Non, Moderate, Heavy

[e] Large woody debris density as defined in the RBP

Water quality measurements made *in situ* during the visit to the assessment site are presented in Table 3. Several factors are of interest among these measurements. Water temperatures at most of the sites were at or below 20 ºC, except for Elk Creek, one location on Little Elk Creek, and Walnut Creek. Some measurements were taken later in the summer and thus explain the higher temperature to some extent, but even so, the waters of Elk Creek and Walnut Creek, the two largest streams along the PA shoreline, had higher temperatures than did smaller streams visited during the same time period. This undoubtedly is due to their wide expanse and lack of shading by overhanging trees.

Table 3. Water quality measurements made during site visits.

Stream Name	Site Designation	date sampled	river mile[a]	catchment area km^2	water temp C	sp cond mS/cm	DO mg/L	pH
Raccoon Creek	RC1a	7/29/03	0.16	28.376	19.4	0.5	6.9	6.5
	RC1b	7/6/04	0.22	27.350	20.5	0.7	9.0	7.8
	RC2	7/30/03	2.91	22.725	20.0	0.7	6.8	
Crooked Creek	CrC1	7/28/04	0.58	39.702	19.6	0.4	9.3	8.2
	CrC2	7/29/04	2.88	35.269	16.9	0.2	9.9	8.1
	CrC3	8/11/04	5.22	25.714	17.5	0.4	6.6	7.7
	CrC4	7/29/04	7.39	14.362				
Elk Creek	ELK1	7/30/04	2.46	99.199	20.8	0.4	9.6	8.1
	ELK2	7/16/03	4.69	94.213	25.3	0.7	6.3	8.0
	ELK3	7/14/03	15.18	66.533	24.5	0.7	8.0	8.6
	ELK4	7/17/03	20.71	60.712	24.2	0.7	6.8	7.9
Little Elk Creek	LE1	7/27/04	4.77	53.870	21.6	0.5	9.0	8.6
	LE2	7/29/03	15.58	33.999	19.9	0.5	6.0	7.1
Halls Run	HR	7/30/04	2.34	9.661	19.0	0.8	8.9	7.8
Walnut Creek	WC	7/7/03	7.50	74.639	23.8	0.8	6.1	8.2
McDaniels Run	MR1	5/29/03	0.09	2.913	15.0	1.3	9.0	8.1
	MR2	5/29/03	0.60	2.842	13.3	1.4	8.7	8.2
	MR3	5/28/03	1.40	1.750	15.3	1.4	13.0	8.4
4-Mile Creek	4Mile	5/30/03	0.15	30.090	16.6	0.9	9.6	7.9
6-Mile Creek	6Mile1	6/11/03	1.75	52.924	18.2	0.6	7.5	8.3
	6Mile2	6/23/03	7.68	24.497	19.6	0.6	8.3	8.8
7 Mile Creek	7Mile1	6/6/03	0.25	22.279	17.1	0.8	9.1	8.3
	7Mile2	6/10/03	3.02	7.164	16.6	0.8	7.7	8.0
12 Mile Creek	12Mile	6/23/03	0.62	32.264	16.2	0.7	7.0	8.1
16 Mile Creek	16Mile1	6/11/03	0.71	43.796	18.0	0.5	7.1	8.0
	16Mile2	6/10/03	4.19	17.724	15.9	0.6	8.1	7.5
	16Mile3	6/16/03	8.24	1.591	14.8	0.7	6.8	
Baker's Creek	BC	6/10/03	2.42	4.439	16.6	0.7	8.1	8.2

[a] miles from the mouth or confluence with a larger stream

The specific conductivity ranged from a low of 0.2 mS cm^{-1} in Crooked Creek to a high of 1.4 mS cm^{-1} in McDaniel's Run. Conductivity is an indirect measure of the saltiness (the concentration of dissolved ions) in the water. McDaniel's Run is a small stream with a highly industrial and high-density residential watershed. Thus, the high conductivity readings are not surprising, and are indicators of urban pollution.

McDaniel's Run was also the site of the highest dissolved oxygen (DO) readings. Normally, low DO readings are associated with organic pollution, but that notion applies to standing water rather than flowing water. In this case, it may be that an excess of nutrients are being delivered to the headwaters of McDaniel's Run by urban pollution sources, and these nutrients are supporting high densities of algal growth. The researchers did find drainage pipes and organic rich muck in various locations along McDaniel's Run supporting this speculation.

At no location were DO levels found to be below the typical standards for cold water streams, although there were several measurements at or close to 6.0 mg L^{-1}. Since most of these streams are well known for their high quality as trout fisheries, these DO levels approaching the minimum desirable levels should serve as a warning that these streams need protection.

The pH of the streams varied in the normal range.

5.2 Habitat Assessment Scores

The habitat assessment scores for all of the study sites are presented first for each parameter separately (tabular and individual score sheets for all sites appear in the appendix). Then sites are ranked using combined scores for all factors. The maximum possible score is 20 for each parameter, and 200 overall per site. The actual scores ranged from a high of 169 to a low of 87 for Baker's Creek in Northeast, the only site which had a score below 100. Overall results are reviewed in detail later in the report.

All of the stream sites evaluated for this study were judged to be high gradient streams as defined in the RBP: "natural high-gradient streams have substrates primarily composed of coarse sediment particles (i.e., gravel or larger) or frequent coarse particulate aggregations along stream reaches" rather than low gradient streams: "low-gradient streams have substrates of fine sediment or infrequent aggregations of more coarse (gravel or larger) sediment particles along stream reaches."

The categories established in the RBP are Poor (score of 5 or less), Marginal (score of 10 to 6), Suboptimal (score of 15 to 11), and Optimal (score of 16 to 20).

5.2.1 Epifaunal substrate/available cover

Sites CrC1, MR3, and BC received the scores in the poor range for this parameter, while eleven (11) sites had scores in the optimal category, having more than 70% of substrate available for suitable habitat (Figure 2). A poor condition indicates that a lack of habitat exists with less than about 20% being a stable substrate surface. Four of the sites fell into the marginal category (score 6-10), with the remainder of the sites scoring in the sub-optimal category (score 11-15). The average score was 13.0, well in the middle of the sub-optimal range, indicating that generally these stream sites have sufficient substrate for colonization by aquatic organisms.

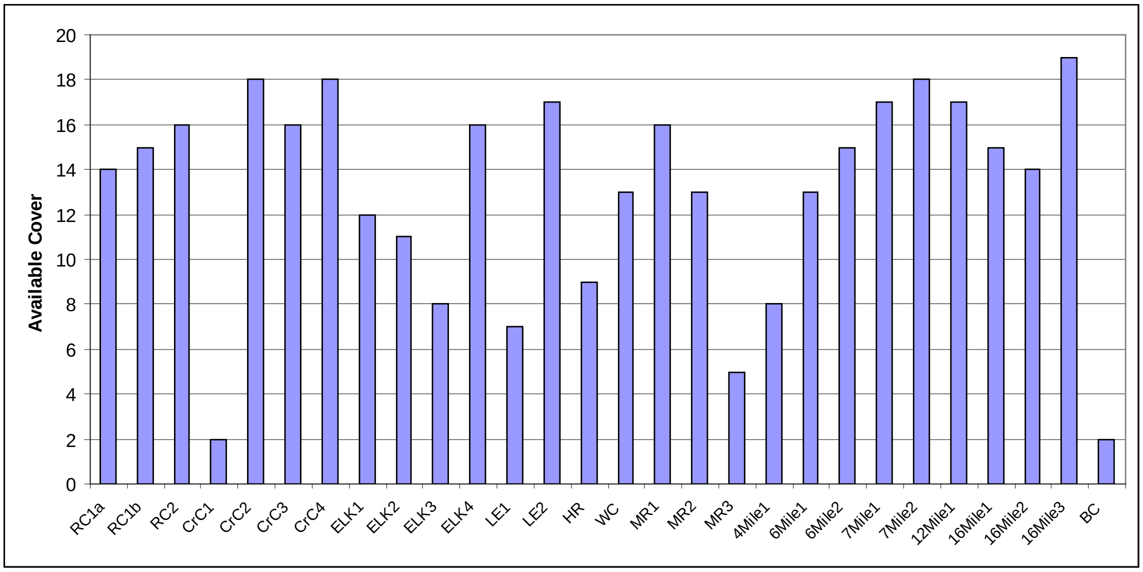

Figure 2. Scores for epifaunal substrate/available cover at each site.

5.2.2 Embeddedness

Embeddedness results from large-scale sediment movement within a stream. Poor habitat results when gravel, cobbles, etc. are nearly or completely surrounded and covered by silt and mud. None of the sites were scored in the poor range (Figure 3). Marginal scores for embeddedness were encountered only on two sites on Crooked Creek, while all of the other sites scored in the sub-optimal or optimal ranges. Optimal scores were achieved at fifteen of the sites.

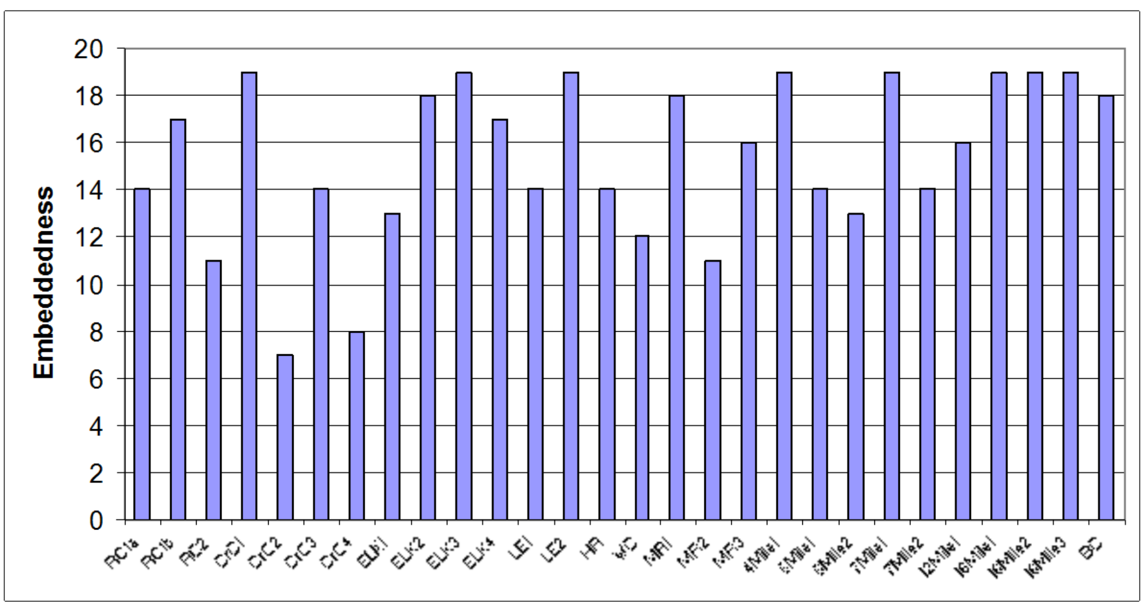

Figure 3. Scores for embeddedness.

5.2.3 Velocity/Depth Regime

Velocity/depth regime measurements the degree to which variability exists in a stream reach. Optimally, there will be all four of the following regimes present: slow-deep, slow-shallow, fast-deep, and fast-shallow, where slow is defined as less than 0.3 m/sec and deep is defined as greater than 0.5 meters.

Only one site (Baker's Creek) scored in the poor range. The reach studied is highly channelized and located within the city environment. The stream channel is rectangular, and flow is spread uniformly across the flat channel bottom, providing little variability for habitat for aquatic organisms. The one site on Hall Run scored in the marginal range as did the one site on 4Mile Creek. Other streams had occasional sites in the marginal range (Figure 4).

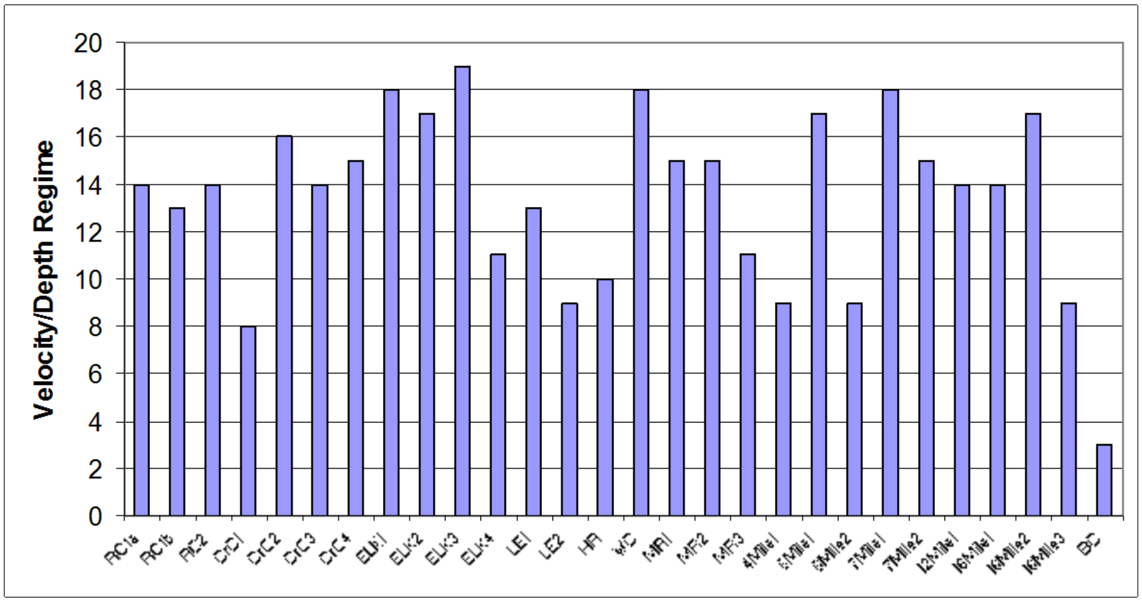

Figure 4. Habitat scores for velocity/depth regimes.

5.2.4 Sediment Deposition

Sediment deposition is an indication of the instability of the stream bottom, and results from a large amount of sediment moving through the reach as suggested by sediment "islands" and fine-grained point bars. A "poor" category has heavy sediment deposits and over 50% of the stream bottom changing on a regular basis. The "marginal" category, with scores ranging from 6-10 has moderate deposition with 30-50% of the stream bottom affected by sediment. The "sub-optimal" category reflects some new increase in sediment formations with 5-30% of the bottom affected by sediment.

This is the first factor which tends to show a geographical trend (Figure 5), with lower scores in the western-most end of the study area and higher scores in the eastern end of the area. This may relate to the typical slope of the streams or to the type of agriculture being practiced in their watersheds.

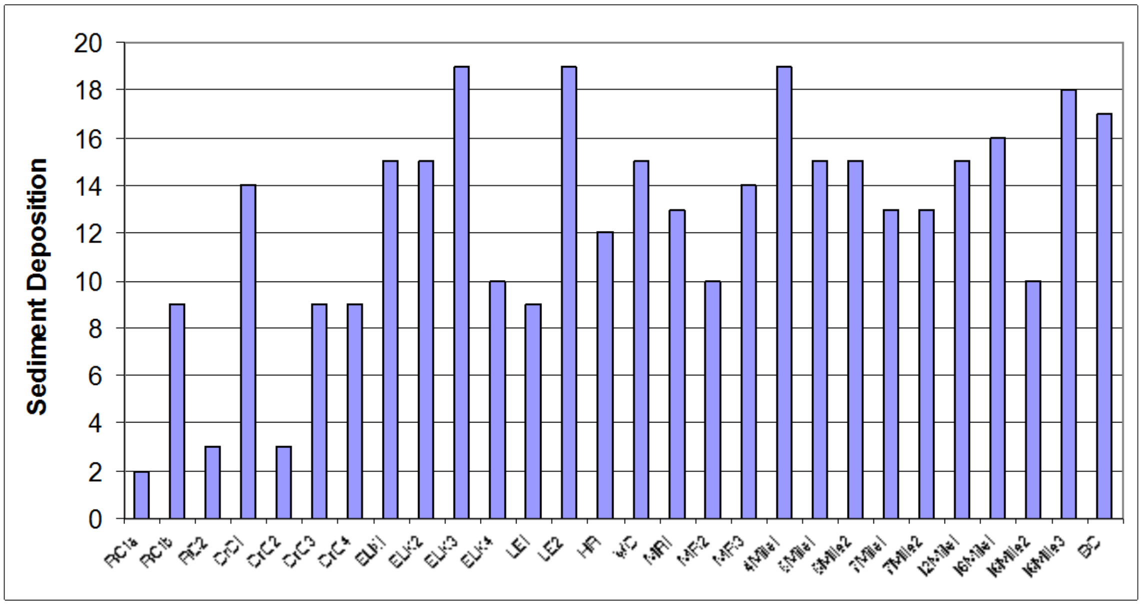

Figure 5. Scores for sediment deposition.

5.2.5 Channel Flow Status

Channel flow status is the degree to which the water reaches both banks of the reach. A poor score is awarded for a condition in which there is little water in the stream bed and is located mainly in standing pools. A high score is awarded for a stream bed in which water reaches both banks with minimal amounts of substrate exposed.

Few of the sites scored in the optimal range. With some exceptions, there appeared to be a trend for sites in the upper portions of the stream's watershed to be rated higher in this category (Figure 6).

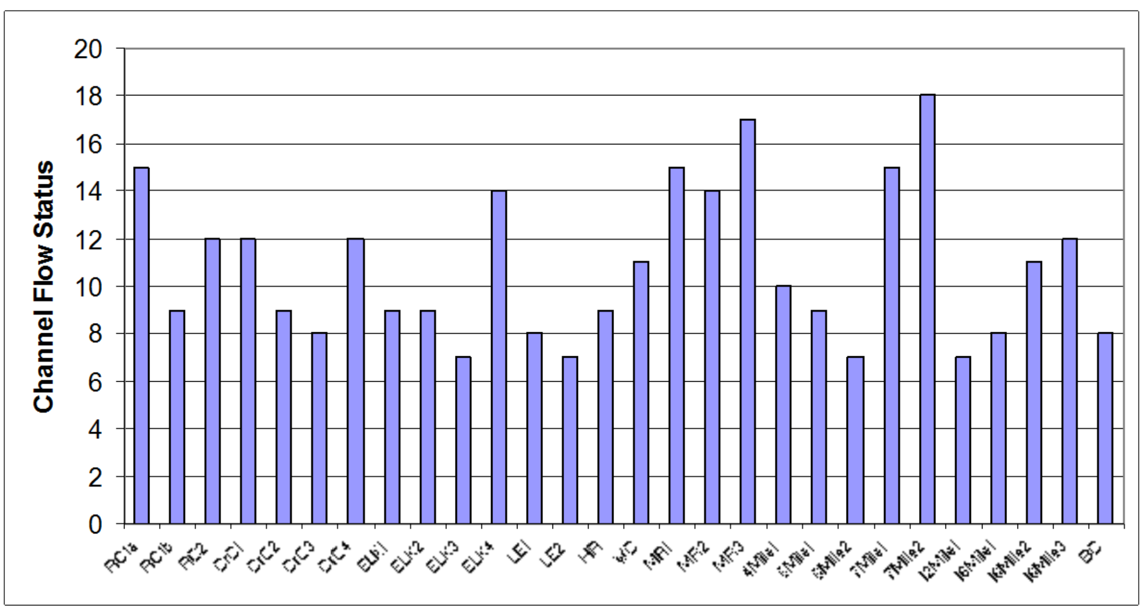

Figure 6. Channel flow status.

5.2.6 Channel Alteration

Channel alteration estimates the degree to which the stream channel has be altered by human construction and other activities. Thirteen of the sites were scored in the optimal range, with little or no human alteration (Figure 7). One of the sites (Baker's Creek in North East) scored a "0" for complete channelization at the study site. Other sites had scores in the marginal to sub-optimal ranges, but since many of our study sites were by necessity near bridges, these medium scores must be considered as an artifact of the site selection process.

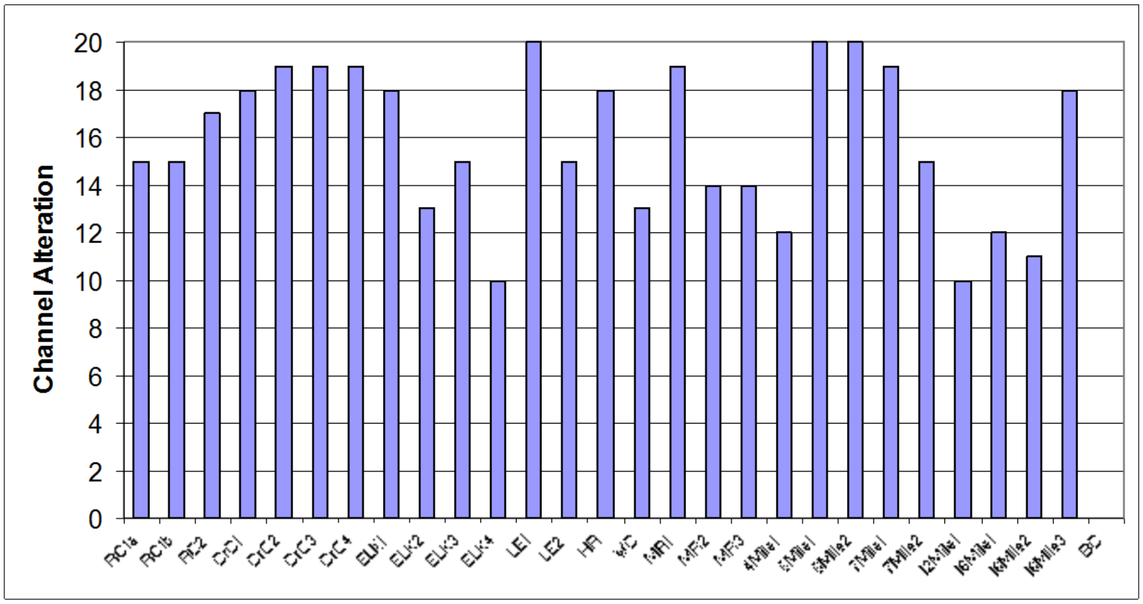

Figure 7 Channel alteration scores.

5.2.7 Frequency of Riffles

The frequency of riffles, shallow fast moving stretches of stream bed dominated by gravel and cobbles, is an important ecological feature, since many aquatic organisms make their home in these highly oxygenated stream beds and/or feed on benthic invertebrates which live there.

Riffle frequency is calculated by dividing the distance between riffle areas in a reach by the stream bed width, with a higher value being undesirable. Continuous riffles are also undesirable unless there are numerous boulders to disturb and obstruct the flow. A ratio of between 5 and 7 is optimal, while a ratio of greater than 25 indicates poor habitat.

One site (Little Elk Creek 1) scored in the marginal range, while all other sites scored in the sub-optimal or optimal ranges (Figure 8).

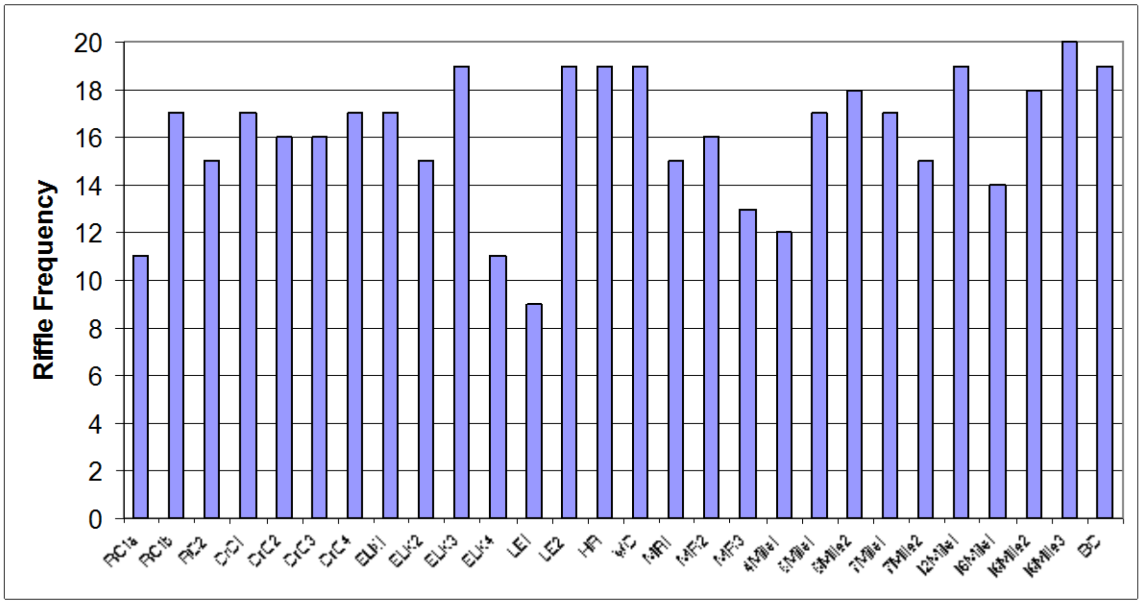

Figure 8. Reach scores for the frequency of riffles.

5.2.8 Bank Stability and Vegetative Protection

Bank stability, vegetative protection, and riparian zone width were assessed for each bank separately (left and right banks were assigned by facing downstream). The scores for bank stability and vegetative protection are presented in Figure 9 and Figure 10, respectively. Unstable banks are frequently found on the outside of meander bends, and are particularly present when the stream has a highly variable flow velocity during storm events. High velocity water during a storm event on the outside of a bend tends to scour away bank material and undermine vegetation, creating the instability. On the inside of the bend, where the water has a relatively lower velocity, sediment from upstream tends to be deposited creating meander point bars. Thus it is not unusual to find an unstable bank on one side of a stream and a stable bank on the other. Streams which have a well forested watershed tend to not experience such high velocities during storm events and thus have more stable banks with less exaggerated differences between left and right banks.

5.2.9 Riparian Zone Width

Scores were assigned to sites based on the width of the riparian zone on each side of the stream (Figure 11). Natural riparian zones are essential to stream systems. Scores were determined based on the width of the riparian zone containing natural vegetation. “Optimal” scores are for zones greater than 18 meters, “sub-optimal” is 12-18 meters, and “marginal” is 6-12 meters, and “poor” is less than six meters.

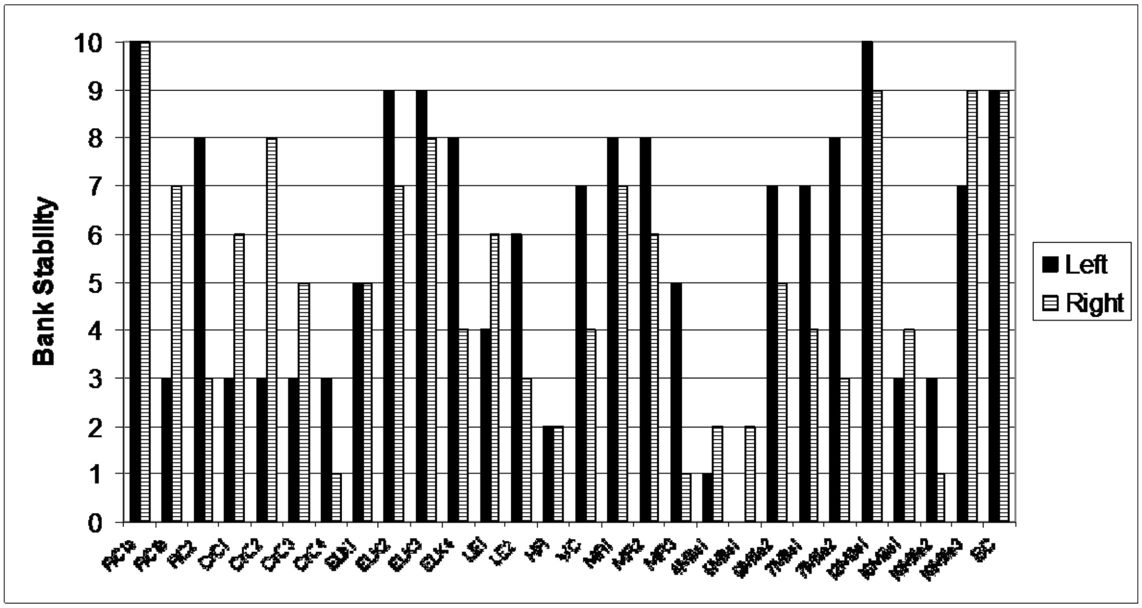

Figure 9. Assessment scores for bank stability.

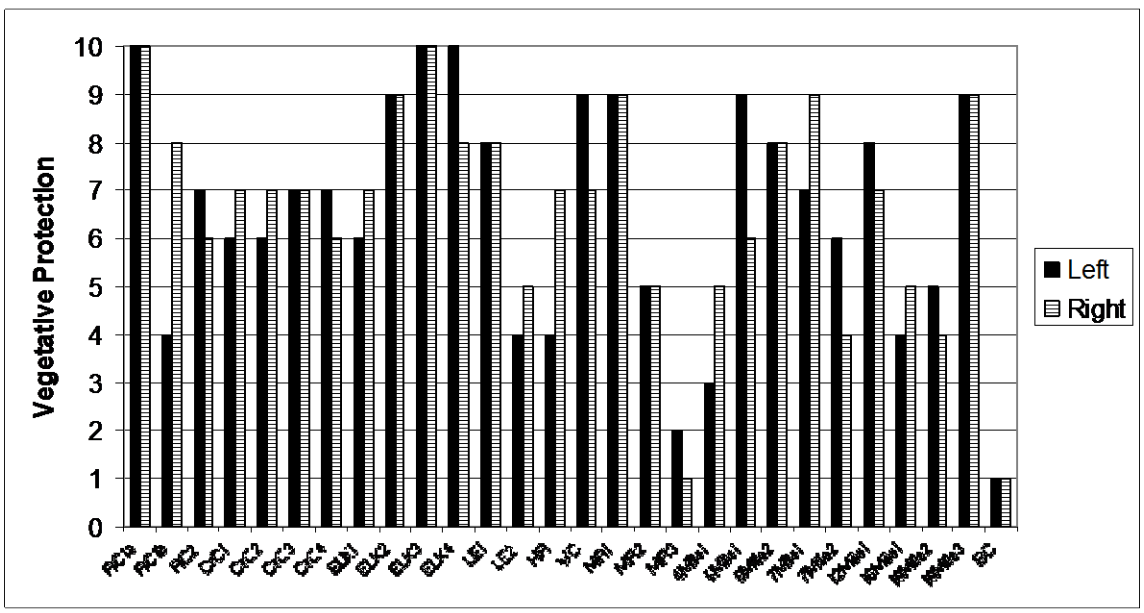

Figure 10. Vegetative protection scores for all study sites.

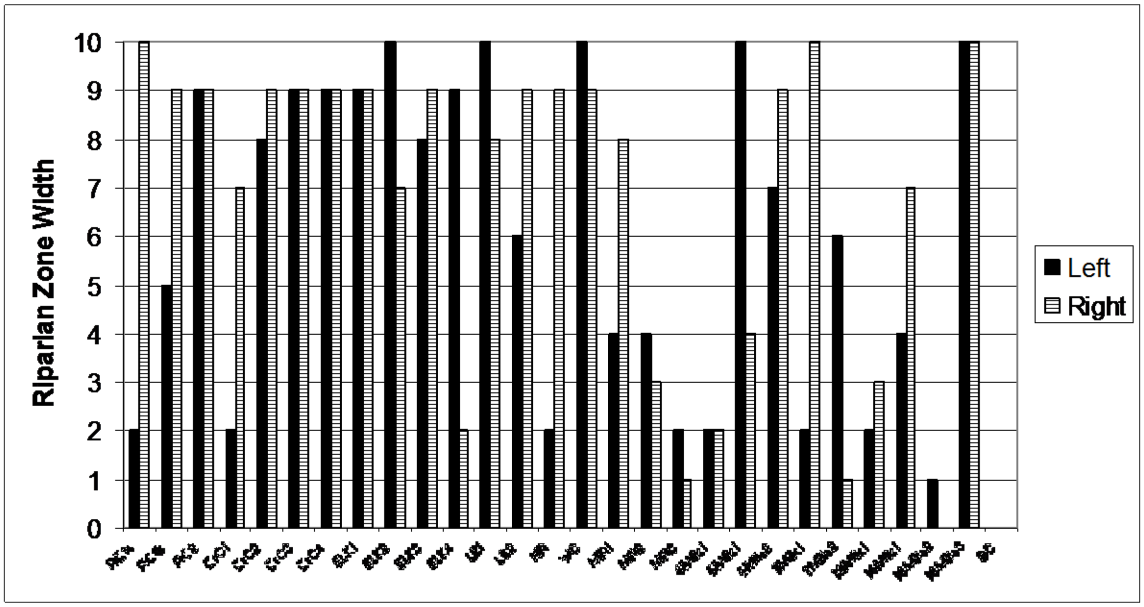

Figure 11. Riparian zone width scores for study sites.

5.2.10 Combined Habitat Assessment Scores for All Sites

There is no obvious trend in scores as one moves from west to east as presented in Figure 12. In several cases, the scores improve as one moves upstream (Crooked Creek, Elk Creek, Little Elk) but the reverse is true for other streams. The total scores for all sites are ranked by descending value in Table 4.

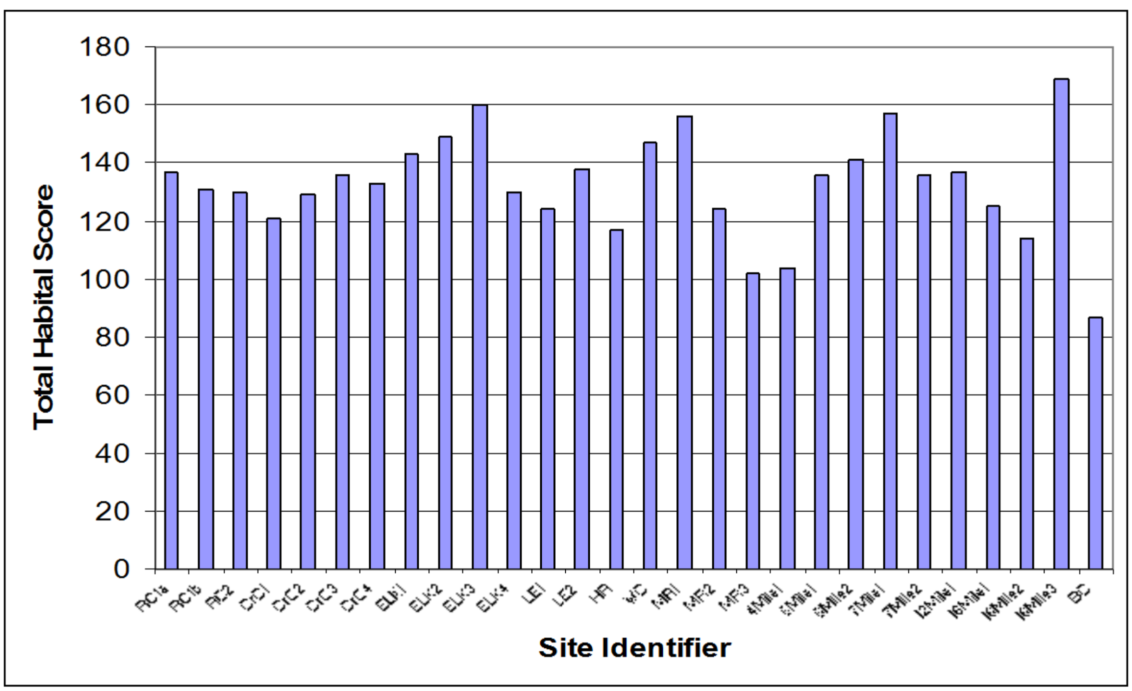

Figure 12. Consolidated scores for all parameters for all sites.

Table 4. Site rankings by total habitat score.

Site Identifier	Epifaunal Substrate Available Cover	Embeddedness	Velocity/Depth Regime	Sediment Deposition	Channel Flow Status	Channel Alteration	Frequency of Riffles or Bends	Bank Stability		Vegetative Protection		Riparian Zone Width		Total Score
								Left	Right	Left	Right	Left	Right	
16Mile3	19	19	9	18	12	18	20	7	9	9	9	10	10	169
ELK3	8	19	19	19	7	15	19	9	8	10	10	8	9	160
7Mile1	17	19	18	13	15	19	17	7	4	7	9	2	10	157
MR1	16	18	15	13	15	19	15	8	7	9	9	4	8	156
ELK2	11	18	17	15	9	13	15	9	7	9	9	10	7	149
WC	13	12	18	15	11	13	19	7	4	9	7	10	9	147
ELK1	12	13	18	15	9	18	17	5	5	6	7	9	9	143
6Mile2	15	13	9	15	7	20	18	7	5	8	8	7	9	141
LE2	17	19	9	19	7	15	19	6	3	4	5	6	9	138
RC1a	14	14	14	2	15	15	11	10	10	10	10	2	10	137
12Mile1	17	16	14	15	7	10	19	10	9	8	7	2	3	137
CrC3	16	14	14	9	8	19	16	3	5	7	7	9	9	136
6Mile1	13	14	17	15	9	20	17	0	2	9	6	10	4	136
7Mile2	18	14	15	13	18	15	15	8	3	6	4	6	1	136
CrC4	18	8	15	9	12	19	17	3	1	7	6	9	9	133
RC1b	15	17	13	9	9	15	17	3	7	4	8	5	9	131
RC2	16	11	14	3	12	17	15	8	3	7	6	9	9	130
ELK4	16	17	11	10	14	10	11	8	4	10	8	9	2	130
CrC2	18	7	16	3	9	19	16	3	8	6	7	8	9	129
16Mile1	15	19	14	16	8	12	14	3	4	4	5	4	7	125
LE1	7	14	13	9	8	20	9	4	6	8	8	10	8	124
MR2	13	11	15	10	14	14	16	8	6	5	5	4	3	124
CrC1	2	19	8	14	12	18	17	3	6	6	7	2	7	121
HR	9	14	10	12	9	18	19	2	2	4	7	2	9	117
16Mile2	14	19	17	10	11	11	18	3	1	5	4	1	0	114
4Mile1	8	19	9	19	10	12	12	1	2	3	5	2	2	104
MR3	5	16	11	14	17	14	13	5	1	2	1	2	1	102
BC	2	18	3	17	8	0	19	9	9	1	1	0	0	87

A correlation analysis was conducted to determine if certain of the ten habitat factors were more important than others. That is, did certain factors vary with the overall score more than did other factors. The correlation coefficients are given in Table 5 for the R value when each set of scores for all sites were compared to the total scores for all sites. The factor that was most closely correlated with the total score was the degree of vegetative protection on the stream banks (values for factors that had left and right bank scores were combined into one score for that factor for each site). The second most influential factor was riparian zone width. It should be noted that this only implies correlation, not causation. The regression coefficients shown in the table are also known as the coefficient of determination. This value indicates the amount of the variation in the total score explained by the variation in the particular factor. We see that vegetative protection on stream banks explains about two-thirds of the total score, while riparian zone width explains about half of the variation.

Table 5. Correlation of each habitat parameter with the total habitat score for the sites.

	Correlation r	Regression r^2
Epifaunal Substrate	0.581	0.33713
Embeddedness	0.033	0.00110
Velocity/Depth	0.532	0.28283
Sediment Deposition	0.096	0.00925
Flow Status	0.026	0.00068
Channel Alteration	0.518	0.26827
Riffles/Bends	0.257	0.06613
Bank Stability	0.366	0.13362
Veg Protection	0.816	0.66606
Riparian Width	0.696	0.48423

5.3 Organic Pollution

5.3.1 Biochemical Oxygen Demand (BOD_5)

The BOD_5 measurements presented in Table 6 are the mean values (n=4) for the samples collected and analyzed from each site. A BOD_5 value of about 10 mg/L or less is considered typical for unpolluted natural waters (USGS, 2001). All of the study sites had a BOD_5 value in this range. A value from 10-20 mg/L would be considered to be indicative of organic pollution.

Table 6. BOD_5 and DOC measurements for water from stream sites.

Stream Name	Site Designation	date sampled	river mile[a]	catchment area km^2	BOD5 mg/L	DOC mg/L
Raccoon Creek	RC1	7/31/03	0.16	28.376	4.5	7.8
	RC2	7/31/03	2.91	22.725	4.0	12.7
Crooked Creek	CrC1	7/31/03	0.58	39.702	5.1	6.6
	CrC2	7/31/03	2.88	35.269	4.5	5.7
	CrC3	7/31/03	5.22	25.714	3.1	6.6
	CrC4	8/13/03	7.39	14.362	3.0	7.7
Elk Creek	ELK1	8/9/04	2.46	99.199	2.4	6.1
	ELK2	8/9/04	4.69	94.213	2.1	4.3
	ELK3	8/9/04	15.18	66.533	3.0	5.1
	ELK4	8/9/04	20.71	60.712	2.5	5.7
Little Elk Creek	LE1	8/13/03	4.77	53.870	3.2	10.2
	LE2	8/13/03	15.58	33.999	1.8	8.1
Halls Run	HR	8/9/04	2.34	9.661	2.4	7.0
Walnut Creek	WC	8/9/04	7.50	74.639	1.7	7.2
McDaniels Run	MR1	5/29/03	0.09	2.913	3.5	4.4
	MR2	5/29/03	0.60	2.842	6.7	4.3
	MR3	5/29/03	1.40	1.750	6.8	6.4
4-Mile Creek	4Mile	5/30/03	0.15	30.090	4.3	4.8
6-Mile Creek	6Mile1	5/30/03	1.75	52.924	2.3	10.8
	6Mile2	8/13/03	7.68	24.497	5.8	6.4
7 Mile Creek	7Mile1	5/30/03	0.25	22.279	3.3	4.2
	7Mile2	5/30/03	3.02	7.164	2.3	7.9
12 Mile Creek	12Mile	6/20/03	0.62	32.264	3.5	3.4
16 Mile Creek	16Mile1	5/30/03	0.71	43.796	3.6	4.9
	16Mile2	6/20/03	4.19	17.724	2.7	4.3
	16Mile3	8/13/03	8.24	1.591	1.5	6.7
Baker's Creek	BC	6/20/03	2.42	4.439	3.5	4.9

[a] miles from the mouth or confluence with a larger stream

5.3.2 Dissolved Organic Carbon (DOC)

Not all organic carbon dissolved in water is biodegradable and thus a threat to oxygen levels in a stream. While the BOD_5 test relies upon microorganisms to feed on organic carbon in a sample over a five-day period and consume oxygen in the process, the NPOC test is a combustion procedure and will detect non-biodegradable carbon in the sample. The NPOC test does cause a loss of volatile organics. Also, the results are reported in different units: BOD_5 is reported in terms of oxygen while DOC is reported in terms of carbon.

For these study sites, there appeared to be no correlation ($R^2 = 0.02$) between BOD_5 and DOC. This suggests that in general the organic carbon measured in the samples was not indicative of non-point source pollution such as manure from agricultural sources or leaking from ineffective sewage treatment.

5.4 Sediment-Associated Heavy Metals

5.4.1 Toxicity of sediment-associated heavy metals

For the purpose of this study, the sediment criteria risk levels determined by the State of New York (NYDEC,1999) since the USEPA has not yet adopted guidance for contaminated sediments. NYDEC (1999) used the results from two studies to determine low-effect (LEL) and severe effect levels (SEL). The LEL is the lower of either the Persaud et al. (1992) LEL or the Long and Morgan (1990) Effect-Range Low. Similarly, the lower value of the two studies was used to determine the SEL. The LEL implies a contaminant level such that the majority of benthic organisms would be able to conduct a complete life cycle. As stated by Persaud et al. (1992), the SEL suggest the likelihood of pronounced disturbance of the sediment dwelling community. The NYDEC considers an area where the LEL is exceeded to be contaminated (NYDEC, 1999). Values for the metals studied here are presented in Table 7.

5.4.2 Heavy Metals Findings

The concentration of fine-grained bed sediments collected at the study sites was determined and is presented in Table 8. It should be emphasized that sediment-associated heavy metal concentration is directly related to particle size. Only very small particles with high surface area to volume ratios are capable of holding high levels of pollutant metals. In this study, a particle size distribution analysis was not conducted on the sediments collected. Therefore, it is conceivable that a site receiving high levels of metal pollution might not show up with high concentrations in the table if the stream bed is composed of scoured bedrock or cobbles, gravel, and sand.

In spite of the uncertainty associated with these metals values, it is informative to use the concentrations as rough indicators of potential metal pollution. When the sites are ranked based on total metal content (the sum of the individual concentrations), it is not surprising that certain locations occur at the top of the list (Table 9). They include Baker’s Creek (located in downtown North East) and McDaniel’s Run, which drains a highly industrialized area. Also of concern are locations along 16 Mile Creek. It is interesting to note that most of the sites with the lowest total metal concentrations are located to the west of the city of Erie.

Table 7. Effect levels for selected sediment-associated heavy metals as used by New York State for determining level of contamination.

Metal	Lowest Effect Level mg/kg (ppm)	Severe Effect Level mg/kg (ppm)
Cadmium	0.6 (P)	9.0 (L)
Copper	16.0 (P)	110.0 (P)
Lead	31.0 (P)	110.0 (L)
Nickel	16.0 (P)	50.0 (L)
Zinc	120 (P/L)	270.0 (L)

Persaud et al. 1992 (P); Long and Morgan 1990 (L)

Table 8. Concentration of selected heavy metals associated with stream-bed sediments at study sites.

Stream Name	Site	Cd mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Total mg/kg
Raccoon Creek	RC1	0.4	28.6	11.4	37.2	53	130.6
	RC2	0.5	19.5	5.8	17.0	42.6	85.4
Little Elk	LE1	0.8	24.3	24.2	38.2	75.1	162.6
	LE2	0.8	24.5	27.6	38.1	88.1	179.1
Crooked Creek	CrC1	2.4	17.8	16.2	45.3	63.6	145.3
	CrC2	1.4	19.8	10.6	42.5	53.9	128.2
	CrC3	2.3	16.9	13.9	56.4	57.4	146.9
	CrC4	2.2	18.5	17.8	60.3	69.7	168.5
Halls Run	HR	3.2	17.8	19.5	48.4	64.5	153.4
Elk Creek	Elk1	1.8	23.8	19.9	41.7	70.8	158.0
	Elk2	1.5	20.8	20.5	71.0	69.2	183.0
	Elk 3	2.3	21.8	22.1	62.7	76.0	184.9
	Elk 4	1.5	12.5	17.2	60.6	54.9	146.7
Walnut Creek	WC	1.3	20.0	27.5	69.2	103.7	221.7
McDaniel's Run	MR1	1.6	48.4	74.8	59.0	177.5	361.3
	MR2	2	33.3	75.2	57.4	143.7	311.6
	MR3	1.1	28.0	39.7	68.8	118.7	256.3
4 Mile Creek	4 mile 1	1.3	29.5	30.9	72.2	96.9	230.8
6 Mile Creek	6 mile 1	1.1	27.6	31.2	62.9	109.7	232.5
	6 mile 2	0.3	15.4	45.3	54.4	64.4	179.8
7 Mile Creek	7 mile 1	1.2	15.7	21.8	73.5	83.7	195.9
	7 mile 2	1.1	18.4	25.4	44.1	98.8	187.8
12 Mile Creek	12 mile 1	1.4	20.2	20.0	64.9	78.8	185.3
16 Mile Creek	16 mile 1	0.4	35.7	40.1	93.8	153.3	323.3
	16 mile 2	1.1	26.4	27.9	88.1	110.9	254.4
	16 mile 3	1.5	24.6	32.4	72.4	107.0	237.9

Baker's Creek	BC	2.9	102.2	62.7	77.1	168.6	413.5

Table 9. Heavy metal concentration associated with stream-bed sediments at study sites ranked in descending order according to total metal content.

Stream Name	Site	Cd mg/kg	Cu mg/kg	Pb mg/kg	Ni mg/kg	Zn mg/kg	Total mg/kg
Baker's Creek	BC	2.9	102.2	62.7	77.1	168.6	413.5
Mc Daniel's Run	MR1	1.6	48.4	74.8	59.0	177.5	361.3
16 Mile Creek	16 mile 1	0.4	35.7	40.1	93.8	153.3	323.2
Mc Daniel's Run	MR2	2.0	33.3	75.2	57.4	143.7	311.6
Mc Daniel's Run	MR3	1.1	28.0	39.7	68.8	118.7	256.2
16 Mile Creek	16 mile 2	1.1	26.4	27.9	88.1	110.9	254.3
16 Mile Creek	16 mile 3	1.5	24.6	32.4	72.4	107.0	237.9
6 Mile Creek	6 mile 1	1.1	27.6	31.2	62.9	109.7	232.4
4 Mile Creek	4 mile 1	1.3	29.5	30.9	72.2	96.9	230.7
Walnut Creek	WC	1.3	20.0	27.5	69.2	103.7	221.8
7 Mile Creek	7 mile 1	1.2	15.7	21.8	73.5	83.7	195.9
7 Mile Creek	7 mile 2	1.1	18.4	25.4	44.1	98.8	187.7
12 Mile Creek	12 mile 1	1.4	20.2	20.0	64.9	78.8	185.4
Elk Creek	Elk 3	2.3	21.8	22.1	62.7	76.0	185.0
Elk Creek	Elk2	1.5	20.8	20.5	71.0	69.2	183.0
6 Mile Creek	6 mile 2	0.3	15.4	45.3	54.4	64.4	179.7
Little Elk	LE2	0.8	24.5	27.6	38.1	88.1	179.1
Crooked Creek	CrC4	2.2	18.5	17.8	60.3	69.7	168.5
Little Elk	LE1	0.8	24.3	24.2	38.2	75.1	162.6
Elk Creek	Elk1	1.8	23.8	19.9	41.7	70.8	158.1
Halls Run	HR	3.2	17.8	19.5	48.4	64.5	153.4
Crooked Creek	CrC3	2.3	16.9	13.9	56.4	57.4	146.9
Elk Creek	Elk 4	1.5	12.5	17.2	60.6	54.9	146.6
Crooked Creek	CrC1	2.4	17.8	16.2	45.3	63.6	145.4
Raccoon Creek	RC1	0.4	28.6	11.4	37.2	53.0	130.5
Crooked Creek	CrC2	1.4	19.8	10.6	42.5	53.9	128.2
Raccoon Creek	RC2	0.5	19.5	5.8	17.0	42.6	85.4

When the concentrations of metals at each site were divided by the appropriate LEL value for that metal, we produce toxicity ratios. Table 10 is a presentation of those ratios arranged in descending order. This ranking is slightly different than that in the table above because total metals concentrations tends to mask variation in a highly toxic metal such as cadmium.

Baker Creek was clearly the site most contaminated with heavy metals, with toxicity ratios above 2.0 for all metals but zinc. Hall's Run had very high levels of cadmium and nickel, suggesting contamination from some sort of industrial metal-finishing activity. McDaniel's Run was contaminated with all of the metals measured, averaging toxicity ratios of 2.5 or greater at both sites.

The metal of greatest concern in these watersheds is nickel, which was found at a toxicity ratio of 3.7, followed by cadmium at a mean toxicity ratio of 2.4. Copper was present at a mean ratio of 1.6, while lead and zinc did not appear to be a general problem. It should also be noted that nickel was often found above its SEL, while none of the other metals exceeded their SEL at any site. Interestingly, nickel was also found to be the metal of greatest concern in Presque Isle Bay (Diz, 2005). None of these streams discharge into Presque Isle Bay, but clearly some of the same pollutional factors are at work throughout this general area. Additionally, the bioavailability of these metals has not been addressed, and so it would be imprudent to conclude that heavy metals are having an adverse impact on these stream ecosystems.

Table 10. Toxicity ratios for metals ranked in descending order. Toxicity ratio is the sediment-metal concentration divided by the LEL for that metal.

Site	Cd	Cu	Pb	Ni	Zn	Mean
BC	4.8	6.4	2.0	4.8	1.4	3.9
MR1	2.7	3.0	2.4	3.7	1.5	2.7
MR2	3.3	2.1	2.4	3.6	1.2	2.5
16 mile 1	0.7	2.2	1.3	5.9	1.3	2.3
16 mile 2	1.8	1.7	0.9	5.5	0.9	2.2
HR	5.3	1.1	0.6	3.0	0.5	2.1
16 mile 3	2.5	1.5	1.0	4.5	0.9	2.1
Elk 3	3.8	1.4	0.7	3.9	0.6	2.1
4 mile 1	2.2	1.8	1.0	4.5	0.8	2.1
MR3	1.8	1.8	1.3	4.3	1.0	2.0
CrC4	3.7	1.2	0.6	3.8	0.6	1.9
WC	2.2	1.3	0.9	4.3	0.9	1.9
Elk2	2.5	1.3	0.7	4.4	0.6	1.9
6 mile 1	1.8	1.7	1.0	3.9	0.9	1.9
CrC3	3.8	1.1	0.4	3.5	0.5	1.9
CrC1	4.0	1.1	0.5	2.8	0.5	1.8
7 mile 1	2.0	1.0	0.7	4.6	0.7	1.8
12 mile 1	2.3	1.3	0.6	4.1	0.7	1.8
Elk1	3.0	1.5	0.6	2.6	0.6	1.7
Elk 4	2.5	0.8	0.6	3.8	0.5	1.6
7 mile 2	1.8	1.2	0.8	2.8	0.8	1.5
CrC2	2.3	1.2	0.3	2.7	0.4	1.4
LE2	1.3	1.5	0.9	2.4	0.7	1.4
6 mile 2	0.5	1.0	1.5	3.4	0.5	1.4
LE1	1.3	1.5	0.8	2.4	0.6	1.3
RC1	0.7	1.8	0.4	2.3	0.4	1.1
RC2	0.8	1.2	0.2	1.1	0.4	0.7
mean	2.4	1.6	0.9	3.7	0.8	1.9

6. Summary

For the most part, these streams appear to be of high quality (with notable exceptions) and are worthy of protective efforts. The lesser quality streams are Baker's Creek, McDaniel's Run, and 16 Mile Creek, which ranked poorly for both physical habitat measures and sediment-associated heavy metals concentrations. Isolated other sites also are of concern, such as 6 mile, 7 Mile, and 12 Mile (physical habitat scores) Creeks, and Hall's Run (heavy metals). While bacterial counts were not included in this study, organic pollution in general did not appear to be a problem for any of the sites studied.

7. Literature Cited

APHA, AWWA, WEF. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition . American Public Health Association, Washington, DC.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Diz, H.R.. 2005. An Assessment of Sediment Contamination in Presque Isle Bay, PA, with Historical Comparisons. *Journal of the Aquatic Ecosystem Health & Management Society* 8(1): 21-32.

EPA. 1990. Test methods for evaluating solid waste: physical/chemical methods. 3rd Edition. SW-846.U.S. Environmental Protection Agency, Washington, DC.

Long, E. R. and L. G. Morgan. 1990. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National States and Trends Program. National Oceanic Atmospheric Administration (NOAA) Technical Memorandum No. 5, OMA52, NOAA National Ocean Service, Seattle, Washington.

NYDEC. 1999. Technical Guidelines for Contaminated Sediments. New York State Department of Environmental Conservation.

Persaud, D., R. Jaagumagi, and A. Hayton. 1992. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment, Queen's Printer for Ontario.

USGS. 2001. Selected Findings and Current Perspectives on Urban and Agricultural Water Quality by the National Water-Quality Assessment Program. United States Geological Survey News Release.

8. Appendices