Sediment Remedial Investigation Report for the Buffalo River, New York

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ACRONYMS AND ABBREVIATIONS

%	Percent
ADCP	Acoustic Doppler Current Profiler
AOC	Area of concern
ARCS	Assessment and Remediation of Contaminated Sediment
ASTM	American Society for Testing and Materials
AVS	Acid volatile sulfides
BNR	Buffalo Niagara Riverkeeper
BUI	Beneficial use impairment
CC	Cazenovia Creek
cfs	Cubic feet per second
cm	Centimeters
cm/km	Centimeters per kilometer
cm/sec	Centimeters per second
CPUE	Catch per unit effort
CR	Compression ratio
CRREL	Cold Regions Research and Engineering Laboratory
CY	Cubic yard
DELT	Deformities, eroded fins, lesions, and tumors
DEM	Digital elevation model
dynes/cm^2	Dynes per square centimeter
ECOM	Estuarine, Coastal and Ocean Model
EFDC	Environmental Fluid Dynamics Code
ENVIRON	ENVIRON International Corporation
EPT	Ephemeroptera, Plecoptera, and Trichoptera
EqP	Equilibrium partitioning
EV	Emergent vegetation
f_{oc}	Fraction of organic carbon
FCV	Final chronic value
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
FIS	Flood Insurance Study
fps	Feet per second
FS	Feasibility Study
FSP	Field Sampling Plan

ft	Foot or feet
ft/s	Feet per second
g	Gram
GC/MS	Gas Chromatography/Mass Spectrometry
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
GPS	Global positioning system
GVS	Generalized vertical coordinate
HBI	Hilsenhoff Biotic Index
HEC-RAS	Hydraulic engineering center-river analysis system
Hg	Mercury
Honeywell	Honeywell International Inc.
HSI	Hepatosomatic index
HSP	Heat shock protein
IBI	Index of Biotic Integrity
IGLD	International Great Lakes Datum
IJC	International Joint Commission
in^2/second	Square inches per second
K	Coefficient of condition
K_{oc}	Organic carbon-water partitioning coefficient
K_{pom}	Polyoxymethylene partitioning coefficient
kg	Kilogram
km	Kilometer
LiDAR	Light detection and ranging
MACTEC	MACTEC Engineering and Consulting, Inc.
MDEQ	Michigan Department of Environmental Quality
MeHg	Methylmercury
µm	Micrometer or micron
mg	Milligram
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
µg/L	Microgram per liter
µmol/gOC	Micromol per gram organic compound
m^2	Square meters
mm	Millimeter
n	Sample size

ng/L	Nanogram per liter
N&E	Nature and extent
NCO	Non-Chironomid/Oligochaete
NCSU	North Carolina State University
NOAA	National Oceanic and Atmospheric Administration
NTU	Nephelometric Turbidity Units
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBS	Optical back scatter
OC	Organic compound
PAH	Polycyclic aromatic hydrocarbon
Pb/kg	Lead per kilogram
PCB	Polychlorinated biphenyl
pcf	Pounds per cubic foot
PCOI	Potential constituents of interest
PCT	Project coordination team
POM	Polyoxymethylene
PSD	Particle size distribution
QAPP	Quality Assurance Project Plan
QHEI	Qualitative Habitat Evaluation Index
RAP	Remedial action plan
RBP	Rapid Bioassessment Protocol
RM	River Mile
RSC	Reference Site – Cattaraugus Creek
RST	Reference Site – Tonawanda Creek
SAV	Submerged aquatic vegetation
SEM	Simultaneously extracted metals
SIM	Selected ion monitoring
SOP	Standard operating procedures
SPME	Solid-phase microextraction
SRIR	Sediment Remedial Investigation Report
SWAT	Soil and Water Assessment Tool
TLM	Target-lipid model
TOC	Total organic carbon
TSS	Total suspended solids
TU	Toxicity Units

USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USCS	Unified Soil Classification System
USGS	United States Geological Survey

1 Introduction

This *Sediment Remedial Investigation Report for the Buffalo River, New York* (*SRIR*) has been prepared by ENVIRON International Corporation (ENVIRON), MACTEC Engineering and Consulting, Inc. (MACTEC), and LimnoTech on behalf of Honeywell International Corporation Inc. (Honeywell) pursuant to the Buffalo River Great Lakes Legacy Act (GLLA) Project Agreement. It is being submitted to the Buffalo River GLLA Project Coordination Team (PCT), including the United States Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO), the Buffalo Niagara Riverkeeper (BNR), New York State Department of Environmental Conservation (NYSDEC), United States Army Corps of Engineers (USACE), and Honeywell. This March 6, 2009, report updates the January 30, 2009, draft SRIR, which underwent critical review by the PCT. Comments on the draft SRIR were received from each of the PCT members (USEPA, NYSDEC, USACE, BNR) and their consultants.

The *SRIR* describes the field work activities conducted and data collected as part of the field investigation carried out between August and November 2008, as specified in the Project Agreement, the *Field Sampling Plan for the Buffalo River, New York* (ENVIRON and MACTEC, 2008), and the *Field Sampling Plan Supplement, Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2008a). The purpose of the work presented in this *SRIR* was to further characterize the nature and extent (N&E) of potential constituents of interest (PCOIs), surface water hydrology, and ecological conditions in the geographic area of the Buffalo River Area of Concern (AOC). These results are intended to supplement the existing body of knowledge of the river, and to support the development of multiple lines of evidence to support remedy decision making, as recommended in USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005a). The information collected as part of this effort will be used to support the evaluation of potential remediation measures for the Feasibility Study (FS) being prepared by Buffalo River GLLA PCT for the Buffalo River AOC, targeting certain activities that can improve and assist in the restoration of certain beneficial uses and ecosystem quality.

Specific tasks completed during fall 2008 and summarized in the *SRIR* include:

- Sediment sampling and analysis
- Pore water sampling and analysis
- Bathymetry surveys
- Surface water hydrologic monitoring
- Hydrodynamic modeling
- Aquatic habitat surveys
- Benthic community assessment surveys
- Fish community assessment surveys
- Fish histopathology analysis

As described in the *Field Sampling Plan for the Buffalo River, New York* (ENVIRON and MACTEC 2008a), additional studies, including additional hydrologic monitoring, may be conducted in 2009 to further supplement the work presented in this *SRIR* or to supplement remedy design.

1.1 Objectives of Site Investigation Report

Results from the 2008 site investigation are presented in the *SRIR* and integrated with the existing information and data to better delineate the chemical, hydrological, and ecological conditions of the Buffalo River AOC. The work embodied in the *SRIR* is based on the following objectives:

- Supplement existing information pertaining to sediment, hydrology, chemical fate and transport, chemical bioavailability, and ecological conditions in the Buffalo River AOC.
- Delineate sediment concentrations of PCOIs to identify specific areas that may pose a significant ecological or human health risk, and to use this information to select the most appropriate remedial alternative on an area-specific basis to reduce that risk.
- Develop predictive hydraulic and hydrodynamic models for the Buffalo River to demonstrate potential flooding and hydrodynamic conditions under various flow conditions, and how these conditions may be impacted by various remedial alternatives.
- Provide an understanding of ecological current conditions for the Buffalo River AOC that will be used as part of the process to evaluate alternative remediation measures and establish expected endpoints for improving beneficial uses of the AOC.

1.2 Site Background

The Buffalo River AOC is located in Buffalo, New York (Figure 1-1). The Buffalo River flows from the east and discharges into Lake Erie. There are three major streams in the watershed that feed the Buffalo River: Cayuga Creek, Buffalo Creek and Cazenovia Creek (Figure 1-2). The total drainage area for the Buffalo River Watershed is approximately 1,150 square kilometers (km^2).

The U.S. and Canadian International Joint Commission (IJC) has designated a portion of the Buffalo River as an AOC pursuant to the U.S.-Canada Great Lakes Water Quality Agreement. The Buffalo River AOC (Figure 1-1) includes approximately 10 km (6.2 miles) of the Buffalo River and the entire 2.3 km (1.4 mile) stretch of the City Ship Canal, located adjacent to the river. The IJC identified 14 possible beneficial use impairments (BUIs) that could impact an AOC. The 1989 Remedial Action Plan (RAP) determined that eight BUIs were either “impaired” or “likely impaired”. Table 1-1 identifies the BUI status in 1989, and additional BUI status reviews from 2005 and 2008 (BNR 2008). For the beneficial uses that are considered impaired, draft delisting criteria or targets have been established (J. Jedlicka, personal communication). Table 1-2 describes the draft targets which need to be met in order to “delist” the BUIs of the Buffalo River.

A description of the existing conditions of the Buffalo River AOC and surrounding area is provided in the *Buffalo River Section 312 Environmental Dredging Existing Conditions Report* (*Existing Conditions Report*) (Ecology and Environment 2008). This report describes the historic and current conditions of the Buffalo River AOC, including physical and ecological resources, surface water, and sediment. The

Existing Conditions Report also summarizes many of the relevant technical studies performed to date. The information provided in the *Existing Conditions Report* will be combined with the 2008 data presented in this *SRIR* to develop a comprehensive assessment of current conditions in the river, and to provide the data necessary to complete the FS for the Buffalo River AOC.

1.3 Report Organization

This introduction of the *SRIR* (Section 1) is followed by a description of N&E sampling and analysis results (Section 2). Section 3 presents a discussion of the bathymetry surveys, hydrologic monitoring and hydrodynamic modeling, and Section 4 presents the results of the ecological sampling. A summary of findings is presented in Section 5; this section synthesizes the results presented in Sections 2 through 4, discusses how these findings further our understanding of the physical, chemical, and biological processes in the Buffalo River, and discusses the relevance of this data with respect to the current BUIs for the AOC. References are provided in Section 6.

2 Delineation of Chemicals in Buffalo River Sediments

Sediment sampling was conducted in the Buffalo River to supplement existing geochemical and geotechnical data, and to further characterize the distributions of PCOIs in the river sediments. Sediment sampling locations for the 2008 study were selected based on results from NYSDEC and GLNPO sediment sampling conducted in 2005 and 2007 to provide a more refined delineation of chemical concentrations and distributions in the river sediments, both laterally and vertically. Sampling during 2008 focused on areas where sufficient data did not exist to allow for adequate delineation of PCOIs. Such areas included the center of the river, or between neighboring sample locations with a wide gradient in PCOI concentrations. Sediment chemistry data collected in 2005, 2007, and 2008 will be used to identify specific areas of potentially significant risks, and will inform the selection of the most appropriate remedial alternative on an area-specific basis to reduce that risk.

2.1 Sediment Chemistry

2.1.1 Methods

A complete description of sediment coring and sediment sampling methods employed during 2008 as part of the Buffalo River sediment sampling and processing is included in the *Field Sampling Plan Supplement, Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2008a) and in the *Draft Data Summary Report*, *Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2009). In summary, sediments were collected from 120 locations along the Buffalo River and City Ship Canal as shown on Figure 2-1. Sediment coring was performed using a Vibracore sample collection system mounted on the USEPA's *R/V Mudpuppy*. Coring locations were recorded by differential global positioning system (GPS), using a GPS sensor located on the Vibracore frame. Cores were collected from the top of sediment to refusal. Following extraction of each sample core, the unused portion of the core liner was cut and the core was capped. Capped cores were transferred to a support vessel where sediment cores were logged and sediment samples were collected. Sediment samples were collected at a depth of 0-0.5 feet (ft) and at 0.5-1ft, and at 1-ft intervals thereafter to the bottom depth. Sediment samples collected to assess the potential for chemical bioavailability (acid volatile sulfides [AVS] simultaneously extracted metals [SEM] and alkylated polycyclic aromatic hydrocarbon [PAH] analysis) were collected only to a depth of 3 ft. Table 2-1 indicates the sample intervals analyzed for each core. At locations where Vibracores could not be collected due to impenetrable sediment conditions, surface samples (0-0.5 ft) were collected with a Ponar dredge. Compacted sediments or the presence of gravel prevented the collection of samples from four locations.

Sample handling procedures, analytical methods, and data validation procedures are outlined in the *Quality Assurance Project Plan, Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2008b) and in the *Draft Data Summary Report*, *Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2009). In summary, sediment samples from each core were analyzed for PCOIs, including PAHs (SW846 Method 8270C), polychlorinated biphenyls (PCBs) (SW846 Method 8082), lead (SW846 Method 3050/6010B), and mercury (SW846 Method 7471A), which GLNPO identified as the four primary indicator chemicals in the Buffalo River (GLNPO 2008). Each sediment sample was also analyzed for total organic carbon (TOC) and particle size distribution (PSD). The list of sample analyses for each core is provided in Table 2-1.

A subset of surface samples were also analyzed for alkylated PAHs, AVS, and SEM. Analysis of alkylated PAHs and AVS SEM was conducted to support application of USEPA's equilibrium partitioning (EqP) approach (USEPA 2005b) to assess the potential for chemical bioavailability, of PAHs and metals, respectively. Sediment samples at depths 0-0.5 ft and 0.5-1.0 ft were analyzed for alkylated PAHs and AVS SEM at 25 core locations, as identified in Table 2-1.

2.1.2 Results

A complete set of the analytical results from the 2008 Buffalo River site investigation are available in the data management folder on the GLNPO Sharepoint site (http://akron.glnpo.net/buffalo) and in the *Draft Data Summary Report*, *Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2009). Results from the 2008 sediment sampling were combined with results from NYSDEC and GLNPO sediment sampling conducted in 2005 and 2007 to provide a more refined delineation of chemical concentrations and distributions in the river sediments. Figures 2-2 through 2-5 present analytical results from the 2005/2007 and 2008 sampling events for total PAHs, total PCBs, lead, and mercury detected in surface and subsurface sediment. Surface samples are defined as sample interval with a start depth of 0.0 ft, and subsurface samples are defined as any sample interval with a start depth equal to or greater than 0.5 ft.

For the purposes of this report, USACE river mile (RM) designations are used to facilitate the discussion of sediment chemical concentrations along the Buffalo River. The USACE RM designations are identified on Figures 2-2 through 2-17. RM 0 is located downstream of the river mouth, the downstream boundary of the AOC is located at approximately RM 0.35, and RM 1.0 is located at the Buffalo Skyway bridge. RM 1.0–2.0 is located along the straight section of the river, ending just downstream of the Ohio Street bridge. RM 2.0–3.0 includes the hairpin turn of the river at Hamburg Street and RM 3.0–4.0 encompasses the south and east sides of the Katherine Street Peninsula, ending just downstream of the Lower Conrail Bridge. RM 4.0–5.0 extends from the Lower Conrail Bridge to approximately a quarter-mile downstream of the South Park Avenue bridge, and RM 5.0–6.0 extends from a quarter-mile downstream of the South Park Avenue bridge to just downstream of the confluence with Cazenovia Creek. RM 6.0–7.0 includes the confluence with Cazenovia Creek, the upstream boundary of the AOC (approximately RM 6.2) and extends to just upstream of the Seneca Street bridge. Tables 2-2 through 2-5 provide a summary of the 2005/2007 and 2008 sediment chemical concentrations along the Buffalo River (by RM), in the Buffalo Harbor, in the City Ship Canal, and in the downstream end of Cazenovia Creek. The tables summarize sediment concentrations for total PAHs, total PCBs, lead, and mercury in the surface and subsurface.

In addition to the point maps shown Figures 2-2 through 2-5, the lateral distribution of surface sediment chemical concentrations and the vertical distribution of sediment concentrations throughout the AOC are provided in Figures 2-6 through 2-17. These figures were generated using the sediment chemical concentration data collected during 2005, 2007, and 2008 for total PAHs, total PCBs, lead, and mercury. Thiessen polygon maps are used to show the lateral distribution of surface sediment concentrations for each chemical. Vertical profiles of sediment chemical concentrations are provided for the Buffalo River and the City Ship Canal to demonstrate the distribution of sediment chemical concentrations with depth from the sediment surface. Vertical profiles for the Buffalo River are divided into three longitudinal river segments, the federally-defined navigation channel, the right bank of the navigation channel (looking downstream), and the left bank of the navigation channel. The vertical sediment concentration profiles of the City Ship Canal are provided for the east and west side of the canal. In addition to the vertical profiles provided for the entire length of the river, horizontal cross sections of the river at RMs 3.7 and 4.3 are also provided for total PAHs, total PCBs, lead, and mercury.

2.1.2.1 Total PAHs

As part of the 2005/2007 and 2008 sediment sampling programs, 951 samples were collected from the Buffalo River, the City Ship Canal, and Cazenovia Creek and analyzed for total PAHs; 410 of the samples are characterized as surficial samples (defined as a sample interval with a start depth of 0.0 ft), and 541 of the samples are characterized as subsurface samples (defined as any sample interval with a start depth greater than 0.5 ft). The total PAH concentrations in surface and subsurface sediment samples are shown on Figure 2-2, and a summary of total PAH concentrations along the Buffalo River (per RM), in the City Ship Canal, in the Buffalo Harbor, and in Cazenovia Creek is presented in Table 2-2. Total PAH concentrations were determined by summing the concentrations of the 16 individual Target Compound List PAHs; for non-detect values, one-half the reporting limit was used to estimate PAH concentrations.

The highest average surface total PAH concentration is located in the Buffalo River at RM 4.0-4.5 (27 milligram per kilogram [mg/kg], sample size [n]=30). The geometric mean concentration in RM 4.0– 4.5 is 12 mg/kg. The highest single surface sample total PAH concentration is 300 mg/kg located in the City Ship Canal, and the highest surface sample in the main channel is located at RM 5.0–5.5 (280 mg/kg). The lowest average total PAH surface concentrations are located at Cazenovia Creek (2.8 mg/kg, n=2). The average surface total PAH concentration in the City Ship Canal is 21 mg/kg (n=60) and the geometric mean in the City Ship Canal is 11 mg/kg.

Average total PAH concentrations are typically higher in the subsurface sediments compared to surface sediments across each RM segment. The highest average subsurface total PAH concentration occurs at RM 4.5– 5.0 (120 mg/kg, n=66; geometric mean of 14 mg/kg). The highest single subsurface sample total PAH concentration (1,800 mg/kg) is located at RM 4.5–5.0, and is located at a depth of 5 ft. Figure 2-7 shows the vertical distribution of total PAH concentrations for the Buffalo River. As shown in the figure, sediment samples with the highest concentrations of total PAHs are generally located between RM 3.5 and 5.5 within the federally-defined navigation channel and right bank of the channel, and are typically located in the subsurface. The lowest average subsurface concentration is located at the mouth of the river, downstream of the AOC in (3.8 mg/kg, n=3; geometric mean 3.8 mg/kg). The average subsurface total PAH concentration in the City Ship Canal is 24 mg/kg and the geometric mean is 14 mg/kg (n=54). The vertical distribution of total PAH concentrations in the City Ship Canal is provided in Figure 2-8. Subsurface samples were not collected from the Buffalo River upstream of the AOC or from Cazenovia Creek.

2.1.2.2 Total PCBs

As part of the 2005/2007 and 2008 sediment sampling programs, 951 samples were collected from the Buffalo River, the City Ship Canal, and Cazenovia Creek and analyzed for total PCBs; 410 of the samples are characterized as surficial samples, and 541 of the samples are characterized as subsurface samples. The total PCB concentrations in surface and subsurface sediment samples are shown on Figure 2-3, and a summary of total PCB concentrations along the Buffalo River (per RM), in the City Ship Canal, in the Buffalo Harbor, and in Cazenovia Creek is presented in Table 2-3. Total PCB concentrations were determined by summing the concentrations of all detected individual Aroclors; for non-detect values, one-half of the reporting limit is used to estimate Aroclor concentrations for those Aroclors detected in more than 5 percent (%) of all samples, and a value of zero is assigned to non-detect values for those Aroclors that were detected in less than 5% of the samples.

The highest average surface total PCB concentration is located in the Buffalo River at RM 4.0– 4.5 (0.62 mg/kg, n=30; geometric mean = 0.13 mg/kg). The highest surface sample total PCB concentration is measured at 10 mg/kg and located at RM 4.0–4.5. The elevated surface sediment concentrations of total PCBs at RM 4.0–4.5 is also shown in the Thiessen polygon map provided in Figure 2-9. The lowest average total PCB surface concentration is located in Cazenovia Creek (0.038 mg/kg; n=2). The average surface total PCB concentration in the City Ship Canal is 0.21 mg/kg (n=60) and the geometric mean in the City Ship Canal is 0.14 mg/kg.

Average total PCB concentrations are typically higher in the subsurface sediments compared to surface sediments across each RM segment. The highest average subsurface total PCB concentrations occurred at RM 5.0–5.5 (4. 5 mg/kg, n=55; geometric mean of 0.19 mg/kg) and RM 4.0–4.5 (1.0 mg/kg, n=62; geometric mean of 0.20 mg/kg). The highest single subsurface total PCB concentration of 160 mg/kg is located at RM 5.0–5.5, and is located at a depth interval of 7–8 ft, and a laterally adjacent sample had a total PCB concentration of 38 mg/kg (depth interval of 3–5 ft). Of the 951 samples analyzed for PCBs, these are the only two samples with total PCB concentrations greater than 11 mg/kg. Figure 2-10 shows the vertical distribution of total PAH concentrations for the Buffalo River (up to approximately RM 6.2). As shown in the figure, sediment samples with the highest concentrations of total PCBs are generally located between RM 3.5 and 5.5 within the federally-defined navigation channel and right bank of the channel. The lowest average subsurface concentration is located at RM 5.5– 6.0 (0.10 mg/kg, n=29; geometric mean 0.061 mg/kg). The average subsurface total PCB concentration in the City Ship Canal is 0.54 mg/kg and the geometric mean is 0.19 mg/kg (n=54). The vertical distribution of total PAH concentrations in the City Ship Canal is provided in Figure 2-11.

2.1.2.3 Lead

As part of the 2005/2007 and 2008 sediment sampling programs, 951 samples were collected from the Buffalo River, the City Ship Canal, and Cazenovia Creek and analyzed for lead; 410 of the samples are characterized as surficial samples, and 541 of the samples are characterized as subsurface samples. The lead concentrations in surface and subsurface sediment samples are shown on Figure 2-4, and a summary of lead concentrations along the Buffalo River (per RM), in the City Ship Canal, in the Buffalo Harbor, and in Cazenovia Creek is presented in Table 2-4.

The highest average surface lead concentrations within the Buffalo River are located at RM 4.5 –5.0 (160 mg/kg, n=35; geometric mean, 59 mg/kg), RM 3.5-4.0 (120 mg/kg, n=41; geometric mean, 69 mg/kg), and RM 4.0-5.0 (110 mg/kg, n=30; geometric mean, 73 mg/kg). The highest concentration of lead in a single surface sample from the main channel was located at RM 4.5-5.0 with a concentration of 2600 mg/kg. The elevated lead surface sediment concentrations at RM 3.5–5.0 are also shown in the Thiessen polygon map of surface sediment concentrations provided in Figure 2-12. The lowest average lead surface concentration is located in Cazenovia Creek (15 mg/kg, n=2). The average surface lead concentration in the City Ship Canal is 130 mg/kg and the geometric mean in the City Ship Canal is 70 mg/kg (n=60). The highest concentration of lead in the City Ship Canal surface sediments (2,700 mg/kg) is located approximately 0.2 miles upstream from the confluence with the Buffalo River.

Average lead concentrations are higher in the subsurface sediments compared to surface sediments across each RM segment. The highest average subsurface lead concentrations occurred at RM 4.5–5.0 (390 mg/kg, n=66; geometric mean of 110 mg/kg) and RM 4.0–4.5 (240 mg/kg, n=62; geometric mean of 120 mg/kg). The highest single subsurface lead concentration (8,500 mg/kg) is located at RM 4.5–5.0, and is located at a depth of 2 ft. Figure 2-13 shows the vertical distribution of lead concentrations for the Buffalo River. As shown in the figure, sediment samples with the highest concentrations of lead are generally located between RM 3.5 and 5.0 within the federally-defined navigation channel and right bank of the channel. The lowest average subsurface concentration is located at RM 6.0 and 6.2 (29 mg/kg, n=2; geometric mean 28 mg/kg). The average subsurface lead concentration in the City Ship Canal is 150 mg/kg and the geometric mean 94 mg/kg (n=54). The vertical distribution of total lead concentrations in the City Ship Canal is provided in Figure 2-14.

2.1.2.4 Mercury

As part of the 2005/2007 and 2008 sediment sampling programs, 948 samples were collected from the Buffalo River, the City Ship Canal, and Cazenovia Creek and analyzed for mercury; 408 of the samples are characterized as surficial samples, and 536 of the samples are characterized as subsurface samples. The mercury concentrations in surface and subsurface sediment samples are shown on Figure 2-5, and a summary of mercury concentrations along the Buffalo River (per RM), in the City Ship Canal, in the Buffalo Harbor, and in Cazenovia Creek is presented in Table 2-4.

The highest average surface mercury concentrations within the Buffalo River are located at RM 3.5–4.0 (0.87 mg/kg, n=40; geometric mean, 0.23 mg/kg) and RM 4.0–4.5 (0.81 mg/kg, n=30; geometric mean, 0.21 mg/kg). RM 3.5–4.0 contained the highest surface sample mercury concentration at 9.5 mg/kg. The elevated surface sediment concentrations of mercury at RM 3.5–4.0 and RM 4.0– 4.5 are also shown in the Thiessen polygon map of surface sediment concentrations provided in Figure 2-15. The lowest average mercury surface concentration is located at RM 6.0–6.2 (0.023 mg/kg, n=13), and the single surface sample collected upstream of the AOC at RM 6.5–7.0 had a mercury concentration of 0.019 mg/kg. The average surface mercury concentration in the City Ship Canal is 0.89 mg/kg and the geometric mean in the City Ship Canal is 0.38 mg/kg (n=60).

Average mercury concentrations are higher in the subsurface sediments compared to surface sediments across each RM segment. The highest average subsurface mercury concentrations within the main channel of the AOC occurred at RM 1.5–2.0 (3.0 mg/kg, n=16; geometric mean of 0.92 mg/kg) and RM 4.5–5.0 (3.0 mg/kg, n=64; geometric mean of 0.43 mg/kg. The highest single subsurface mercury concentration (44 mg/kg) is located at RM 5.0–5.5, and is located at a depth interval of 5–6 ft. Figure 2-16 shows the vertical distribution of mercury concentrations for the Buffalo River. Although average mercury concentrations at RM 1.0–1.5 and 1.5–2.0 were higher than most other half-mile river segments, Figure 2-16 shows that the highest concentrations of mercury were typically located at RM 3.5–5.5 at a depth greater than 2 ft below the sediment surface. The lowest average subsurface concentration is located at RM 6.0–6.2 (0.077 mg/kg, n=2; geometric mean 0.043 mg/kg). The average subsurface mercury concentration in the City Ship Canal is 3.2 mg/kg and the geometric mean in the City Ship Canal is 0.77 mg/kg (n=53), which is higher than any average subsurface concentrations from half-mile segments of Buffalo River. The vertical distribution of mercury concentrations in the City Ship Canal is provided in Figure 2-17, and shows samples with elevated mercury concentrations (> 5 mg/kg) are dispersed throughout the length of the channel on both the east and west side of the channel.

2.1.2.5 Total Organic Carbon

As part of the 2005/2007 and 2008 sediment sampling programs, 948 sediment samples were collected and analyzed for TOC. A summary of TOC concentrations along the Buffalo River (by RM), in the City Ship Canal, in the Buffalo Harbor and in Cazenovia Creek is presented in Table 2-6.

Along the Buffalo River, the average sediment concentrations of TOC for each section of the river ranged from 18,521 to 32,869 mg/kg (1.9 to 3.3%), but concentrations within each area occasionally varied over an order of magnitude, including half-mile segments between RM 4.0 and 5.5. The average TOC concentration in the City Ship Canal is similar to that of Buffalo River sediments (27,410 mg/kg; 2.7%), while average TOC concentrations in the Harbor are lower (13,967 mg/kg; 1.4%). The average TOC concentration in Cazenovia Creek sediments is 8,215 mg/kg (0.8%), which is lower than average concentrations along the half-mile segments of the Buffalo River.

2.1.2.6 Chemical Bioavailability Analyses

2.1.2.6.1 AVS SEM

Twenty-five surface samples (0–0.5 ft) and twenty sediment samples with a depth interval of 0.5–1.0 ft were analyzed for AVS SEM. In 2005 USEPA developed recommendations for assessing the risk of sediment toxicity due to mixtures of the divalent metals cadmium, copper, lead, nickel, and zinc based on an understanding of the binding capacity and affinity of these metals for AVS and TOC. While TOC is recognized as the key factor controlling the partitioning (i.e., bioavailability) of hydrophobic organic chemicals in sediment, usually the more important factor controlling the bioavailability of divalent metals is the concentration of AVS (USEPA 2005b). If the concentration of AVS is greater than the concentration of SEM in sediment on a molar basis, metals are not present in freely dissolved form in pore water in sufficient concentrations to cause toxicity (Ankley et al. 1996, USEPA 2005b). This premise has been shown to hold true in toxicity tests of sediments collected from sites contaminated primarily with metals (Hansen et al. 1996). AVS SEM results alone do not definitively determine sediment toxicity, as there may be factors other than metals that contribute to toxicity. AVS SEM is used to determine whether divalent metals are readily bioavailable or are bound primarily as sulfide precipitates. If the molar concentration of AVS in a particular sediment sample exceeds the summed SEM molar concentration, then toxicity related to the presence of divalent metals in pore water is likely to be low, and other factors are more likely to contribute to sediment toxicity[1].

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[1] It is acknowledged that representatives of NYSDEC have stated the agency does not fully accept the USEPA (2005b) method of metals EqP to AVS. NYSDEC representatives also stated that in the presence of toxicity testing results, AVS SEM can be used to show metals are not causing toxicity (i.e., negative toxicity testing results and AVS SEM showing metals are not

A refinement of the SEM – AVS approach, which is used in this evaluation, addresses the role of TOC as an additional factor controlling the bioavailability of metals in sediments where SEM concentrations exceed the concentrations of AVS. As described by USEPA (2005b), one can predict with 90% confidence that sediment toxicity will not occur if the organic-carbon normalized concentration of "excess" metals ([ΣSEM-AVS]/ fraction of organic carbon [f_{oc}]) is less than 130 micromols per gram organic carbon (µmol/gOC). Similarly, sediment toxicity is expected with 90% confidence if (ΣSEM-AVS)/f_{oc} exceeds 3,000 µmol/gOC. The likelihood of toxicity associated with intermediate values is uncertain.

A total of 45 Buffalo River sediment samples were measured for both SEM and AVS, including 25 surface samples (0–0.5 ft) and 20 sediment samples with a depth interval of 0.5–1.0 ft. As shown in Table 2-7a, 89% of sediment samples had AVS concentrations greater than SEM (∑SEM-AVS is $\leq$0.0) indicating that divalent metals are not likely to cause toxicity to benthic invertebrates at the majority of the Buffalo River sampling locations. The sample locations and the results of the AVS SEM analysis are provided on Figure 2-18.

AVS in aquatic sediments has seasonal cycling such that AVS generally increases with a decrease in dissolved oxygen levels in the water column when such conditions affect the sediment-surface water interface (Martello et al. 2007; Howard and Evans 1993). Mean Buffalo River dissolved oxygen levels measured as part of the benthic community assessment were 7.5 mg/L and levels ranged from 8 – 12 mg/L during the hydrodynamic monitoring. Dissolved oxygen levels are expected to decrease in the warmer summer months, which could increase the level of AVS. Therefore, the AVS data collected in the late fall of 2008 likely represents the lower range (i.e., more conservative) AVS concentrations expected throughout the year."

Five of the locations required an additional evaluation of organic-carbon normalized excess metals (USEPA 2005b); the results of this evaluation are presented in Table 2-7b. The organic compound (OC)-normalized excess metal concentrations at four of five locations did not exceed the low-end threshold for effects of 130 µmol/gOC described above. Only one location slightly exceeded the low-end threshold of 130 µmol/gOC (133 µmol/gOC in buried subsurface sediment location 54) and all five values are well below the threshold considered very likely to cause toxicity (3,000 µmol/gOC).

To further evaluate the potential risks from sediments at the one remaining station, two additional steps were employed. First, since it is well known that metals with higher binding affinity for sulfide will displace those with lower binding affinity, a sequential subtraction of SEM from the AVS was conducted. The binding affinity of SEM for AVS follows the order: copper> cadmium> lead> zinc> nickel. When the molar concentrations of these metals were sequentially subtracted from the AVS, the only remaining metals that were not accounted for by AVS and could be bioavailable were zinc and nickel. Secondly, the binding affinity of SEM for TOC follows the order: cadmium> copper> nickel> zinc> lead (Mahony et al. 1996; DiToro et al. 2005). Given that the only bioavailable SEMs in this sample were zinc and nickel,

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bioavailable), but the AVS-SEM approach is not yet considered acceptable by NYSDEC to exclude metals as causing toxicity in the absence of toxicity testing. The approach presented in this SRIR was consistent with NYSDEC and ENVIRON's understanding that NYSDEC may request toxicity testing in the future, but that doing so did not preclude the assessment of the AVS/SEM analysis consistent with USEPA's methodology.

the OC-normalized toxicity threshold for zinc (1,400 µmol/gOC) and nickel (1,100 µmol/gOC) are the appropriate values to determine the risk from this sample. When this comparison is made, the level of OC-normalized zinc and nickel in this sample were far lower than the threshold value for these metals.

2.1.2.6.2 Alkylated PAHs

Sediment samples were analyzed for alkylated PAHs at 25 locations. Analysis of alkylated PAHs is consistent with the EqP approach (USEPA 2005b) to assess the potential for chemical bioavailability and site-specific exposure risks. Surface sediment samples (0-0.5 ft) and buried sediments samples (0.5-1.0 ft) were analyzed for alkylated PAHs. The results of the alkylated PAH analysis are presented in Table 2-8. Further analysis of the alkylated PAH concentrations in the Buffalo River sediments, as they relate to bioavailability and toxicity, are presented in Section 5.3.

2.2 Geotechnical Analysis

2.2.1 Methods

Sediment samples analyzed for chemical constituents were also analyzed for PSD. In addition, sediment cores were collected from 14 locations for additional geotechnical analysis, as shown in Figure 2-1. Cores for geotechnical analysis were collected following the same methods as described for chemical analysis. Sediment samples at depth intervals of 1.0-2.0 ft and 4.0-5.0 ft were submitted for geotechnical analysis. Geotechnical analyses included sediment density (ASTM D 2937), Atterberg limit determination (ASTM D 4318), moisture content determination (ASTM D 2216), gradation (ASTM D 422), and one-dimensional consolidation test (ASTM D 2435), which measures the compressibility of the sediment. A complete description of sample processing, geotechnical analytical methods, and data processing is provided the *Field Sampling Plan Supplement, Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2008a) and *Quality Assurance Project Plan, Buffalo River Area of Concern* (Ecology and Environment and CH2MHill, 2008b).

2.2.2 Results

2.2.2.1 Particle Size Distribution

Sediment samples collected during the 2008 sediment investigation studies were analyzed for PSD. A summary of PSD along the Buffalo River, City Ship Canal and Cazenovia Creek across all sample depths is presented in Table 2-9 and shown on Figure 2-19. Fine sediment grains (particle diameter less than 0.074 millimeter [mm]) dominate the composition of Buffalo River sediments from RM 0.0–6.0. In this six-mile stretch of the river, the average composition of fine-grain sediments across half-mile increments ranged from 72.2 to 94.7%. As shown on Figure 2-19 and Table 2-9, fine-grained sediments generally comprised a smaller fraction of the Buffalo River sediments with increasing distance from the river mouth. Near the river mouth, from the downstream end of the AOC to RM 0.5, fines comprised 94.7% of the sediments, while at RM 2.5–3.0 fines comprised 84.6% of the sediments and further upstream at RM 5.5–6.0, 72.2% of the sediments were fine-grained. Upstream of RM 6.0 gravel sized sediments comprised a larger fraction of the Buffalo River sediments.

Along the downstream portion of Cazenovia Creek, sands (particle diameter of 0.074–4.75 mm) dominated the PSD (69.8%), while fines and gravel comprised 14.9% and 15.6% of the sediments, respectively. Sediments in the City Ship Canal were dominated by fine sediments (87.5%) and samples in Buffalo Harbor, near the downstream end of the AOC were comprised of 55.9% fines, and 26.7% fine sands.

In addition to results from the 2008 field investigation, other studies have also shown the sediments of the Buffalo River AOC are dominated by fine particles. Singer et al. (2008) collected over 600 surface samples throughout the river during 1990 and 2004, and demonstrated an average grain size of 12 µm for both sampling events. Over 90% of the surface samples collected during each event were classified as mud or sandy mud, while coarser sediments including gravel and sandy gravel were typically found upstream of the navigational channel or in the City Ship Canal.

2.2.2.2 Geotechnical Analyses

Based on the results of testing, the samples were classified in accordance with the Unified Soil Classification System (USCS) and American Association of State Highway and Transportation officials. Testing results are provided on Table 2-10. The sediments were characterized as varying gradations of gray and olive-gray silt and clay, with lesser amounts of sand, which was confirmed by gradation testing; USCS classifications consisted of ML (silt), CL (lean clay or lean clay with sand), CH (fat clay or fat clay with sand), and MH (elastic silt, elastic silt with sand, or sandy elastic silt). Atterberg limit determinations resulted in the following range of results:

- Liquid limit: 39 to 71%;
- Plastic limit: 23 to 40%; and
- Plasticity index: 14 to 38%.

Natural moisture contents ranged between 38 and 78%. In general, the natural moisture contents were at, or above, the liquid limit, which indicates that the sediments may be compressible and sensitive to disturbance. It also indicates that the sediments may have low strength. The wet and dry unit weights of the sediment ranged from 77 and 112 pounds per cubic foot (pcf) and 42 and 81 pcf, respectively.

Consolidation testing performed on the sediments indicated that the majority, if not all, samples were under-consolidated to normally consolidated. This is consistent with the formation of fluvial sediment deposits (i.e., river sediments), that likely have not been preconsolidated by past loading. The consolidation testing results indicate that the sediments are compressible (consistent with the results of Atterberg limit testing), and the estimated compression ratio (CR), based on strain versus log of vertical stress, ranged from 0.12 to 0.19 (higher CRs indicating greater compressibility). This indicates the sediments are moderately to very compressible. The coefficient of consolidation, c_v, which is a measure of the time rate in which consolidation might occur, ranged between 10^{-4} and 10^{-6} square inches per second (in^2/second) when vertical stress was below 1 tons per square foot (lower numbers indicating a slower time rate of consolidation might occur).

2.3 Pore Water Chemistry

In addition to the collection of whole-sediment samples, pore water was collected from a subset of surface sediment samples, and analyzed for parent and alkylated PAHs and PCB congeners. Results from pore-water sampling and analyses are used to demonstrate the bioavailability of chemicals in the subsurface and contribute to a more complete understanding of chemical exposure potential for benthic organisms. Pore water results alone do not definitively determine sediment toxicity, as there may be other factors not measured that contribute to toxicity. Therefore, pore-water measurements are combined with the sediment chemistry and biological data collected as part of this study and to contribute to an understanding of mobility and bioavailability of chemicals of interest (in this case, PAHs and PCBs) measured in pore water samples.

2.3.1 Parent and Alkylated PAHs

2.3.1.1 Methods

Surface sediment samples (0–0.5 ft) were collected using a Ponar dredge at 20 locations (Figure 2-1) and analyzed for pore water parent and alkylated PAHs. The preparation of sediment and pore water samples is described in Hawthorne, et al. (2006). In summary, sediment-water slurries were centrifuged in a glass vial, and the separated pore water was removed with a pipette. After the removal of the pore water, the wet sediment was recovered and split for PAH analysis and TOC analysis. Subsamples identified for PAH analysis were dried with sodium sulfate, and extracted for 18 hours in a Soxhlet apparatus. Each extract was spiked with isotopically-labeled internal standards, and the samples were analyzed for PAHs using Gas Chromatography/Mass Spectrometry (GC/MS) with selected ion monitoring (SIM). Sediment extractions were performed in duplicate.

Colloidal material remaining in the pore water was removed by alum flocculation. Pore water samples were measured for parent and alkylated PAHs per ASTM D7363. Through this method PAHs were measured using solid-phase microextraction (SPME) followed by GC/MS analysis in SIM mode. Isotopically-labeled target compounds were introduced prior to the extraction, and are used as quantification references. Pore water samples were analyzed in duplicate.

2.3.1.2 Results

The Buffalo River sediment pore water parent and alkylated PAH concentrations for each sample location are provided in Table 2-11a, and a summary of pore water concentrations across the site is provided in Table 2-11b. Pore water PAH concentrations were generally low. Thirteen of the 34 parent and alkylated PAHs were not detected in any of the 20 surface sediment samples, including acenaphthylene, C3 fluorenes, and the higher-molecular-weight PAHs. The remaining compounds were typically detected in less than half of the pore water samples except for C2 naphthalenes, fluoranthene, and pyrene, which were detected in at least 13 of the 20 pore water samples.

Parent and alkylated PAH concentrations in sediment and pore water and sediment TOC concentrations were used to determine log sediment organic carbon–water partitioning coefficients (K_{OC}) values for each measured parent and alkylated PAH measured in pore water. A summary of the Buffalo River log K_{OC} for each compound is provided in Table 2-11b, the distribution of the log K_{OC} values is presented on

Figure 2-20. As shown on Figure 2-20, the log K_{OC} values for the parent and alkylated PAHs had less than an order of magnitude variation, and fall within the range of experimentally-determined values from other contaminated sediment sites (Hawthorne et al. 2006), and are typically higher than the values derived by USEPA's SPARC Performs Automated Reasoning in Chemistry model (USEPA 2003). The experimentally-derived log K_{OC} values from the Buffalo River indicate a greater partitioning of PAHs to sediments than what would be predicted by the USEPA model. Further analysis of the PAH pore water concentrations and the PAH K_{OC} values, as they relate to bioavailability and toxicity, are presented in Section 5.3.

2.3.2 PCB Congeners

2.3.2.1 Methods

Surface sediment samples (0–0.5 ft) were collected using a Ponar dredge at 20 locations and analyzed for pore water PCB congeners. The pore water PCB congener concentrations were determined through the use of equilibrium passive samplers consisting of polyoxymethylene (POM), as described in Cornelissen et al. (2008). A POM partitioning coefficient (K_{POM}) is first determined for each PCB congener and then used to calculate the concentration of PCB congeners in the pore water. To determine concentrations of PCB congers in the sediment, a subset of each sample was dried and extracted in a Soxhlet apparatus. Each extract was spiked with isotopically-labeled internal standards, and the samples were analyzed for PCB congeners using GC/MS with SIM. Sediment extractions were performed in duplicate.

2.3.2.2 Results

The Buffalo River sediment pore water PCB congener concentrations for each sample location are provided in Table 2-12a. Pore water concentrations determined for 52 individual PCB congeners for each sample. In general, pore water concentrations were higher for the lower molecular weight PCB congeners (di-and trichlorophenyls) and lower for the higher molecular weight compounds (hepta-, hexa- and octachlorophenyls) for each sample. The highest total PCB concentration (sum of all 52 congeners) measured in the pore water was at sample location 54 (RM 3.5–4.0), which had total PCB concentration of 13.5 nanograms per liter (ng/L), while all other samples had total PCB concentrations less that 3.8 ng/L, and 12 of the 20 samples had PCB congener concentrations less than 1.0 ng/L

PCB congener concentrations in sediment and pore water and sediment TOC concentrations were used to determine log K_{OC} values for each PCB congener. A summary of the Buffalo River log K_{OC} values for each congener is provided in Table 2-12b. The log K_{OC} values for PCB congeners were grouped by homolog, as PCB congeners with similar molecular weights tend to have similar log K_{OC} values, and the distribution of these values is presented on Figure 2-21. As shown in Table 2-12b and Figure 2-21, the log K_{OC} values tend to increase with an increase in the molecular weight of the compound, similar to the trend across PAH compounds. The log K_{OC} values calculated for the Buffalo River sediments are typically higher than values determined using spiking studies (Krauss and Wilcke 2001), indicating a greater partitioning of PCBs to Buffalo River sediments, similar to the log K_{OC} values calculated for PAHs in Buffalo River sediments.

3 Hydrodynamic and Physical Sampling

3.1 Hydrodynamic and Physical Sampling Rationale

The primary purposes of the hydrodynamic and physical sampling program was to provide an understanding of Buffalo River hydrodynamic conditions over a range of flows, and to provide data needed to support the development of a hydrodynamic model to evaluate hydrodynamic conditions for various remedial alternatives. Hydrodynamic and physical sampling included velocity and surface water elevation measurements and bathymetric surveys. This information was used in the development and calibration of hydraulic and hydrodynamic models for the Buffalo River, including a three-dimensional Environmental Fluid Dynamics Code (EFDC) model, and a one-dimensional Hydraulic Engineering Center-River Analysis System (HEC-RAS) model. The HEC-RAS model is used to calculate changes in flood elevation and demonstrate potential flooding under various flow conditions and seiche events. The EFDC model was adapted from the existing Estuarine, Coastal, and Ocean Model (ECOM) of the Buffalo River, developed by Atkinson et al. (2006). EFDC model development was performed in collaboration with Dr. Atkinson (University at Buffalo). The calibrated EFDC model provides three-dimensional velocity and shear stress distributions along the river over a range of flow conditions, thus highlighting in-channel areas that may be prone to erosion under high flow conditions. The FS will employ the calibrated EFDC and HEC-RAS models to demonstrate how various remedial alternatives may impact hydrodynamic conditions and flooding potential, or in turn, how hydrodynamic conditions (i.e., flow velocities and hydrodynamic shear forces) influence remedy design. Potential changes in hydrodynamic conditions, including velocity and shear stress distributions, and flooding potential contribute to remedy evaluation, selection, and design.

3.2 Bathymetric Surveys

Bathymetric information is used in the development of the EFDC model for the Buffalo River. Multibeam bathymetric surveys along the Buffalo River were conducted during 2007 and 2008 by the USACE from the mouth of the river to approximately 1800 ft upstream of the confluence with Cazenovia Creek. The multibeam and single point data collected by USACE were used in the development of the HEC-RAS and EFDC model. As part of this study, additional bathymetric data and channel cross section survey data were collected within the Buffalo River upstream of the navigational channel and within Cazenovia Creek to further support model development.

3.2.1 Methods

During May and June 2007, the Buffalo District Army Corps of Engineers Office conducted a project conditions sounding of the Buffalo River between the mouth of the river to the end of the upstream end of the dredged navigational channel, which is approximately 1500 ft downstream of the confluence with Cazenovia Creek. The sounding was conducted in accordance to the USACE technical guidance for performing hydrographic surveys (EM-1110-2-1003) using a multibeam system mounted on a 23-ft SeaArk launch. The multibeam system consists of: (a) a 240 kHz Reson Seabat 8101 multibeam echosounder sonar head with 210 degree array and 1.5 degree beams; (b) an Applanix POS/MV Model 320 position and orientation system and an ASHTECH BR2G system to monitor and measure sonar roll (rotation port and starboard), pitch (rotation fore and aft), and heave (vertical displacement) during data collection; (c) an Innerspace 448 hydrographic echosounder velocity profiler; and (d) the Triton-Elics ISIS computer and data logging software and the HYPACK navigation software. Longitudinal transects were spaced at approximately 35 ft parallel to the river, and cross-channel transects were run from bank-to-bank at approximately 10 ft spacing. In September 2008, the Buffalo District USACE conducted a survey of the Buffalo River from the upstream boundary of the navigational channel to approximately 1800 ft upstream of the confluence with Cazenovia Creek. The sounding was conducted in accordance to the USACE technical guidance for performing hydrographic surveys (EM-1110-2-1003) using a single-beam echo sounder.

During fall 2008, MACTEC conducted single-beam bathymetric surveys along a 2-mile segment of the Buffalo River from the confluence with Cazenovia Creek upstream to approximately 0.2 miles downstream of the Interstate 90 Bridge. Verification survey points were also collected on the Buffalo River near the Park Street Bridge within the 2008 USACE bathymetric coverage area. Along Cazenovia Creek, single-beam bathymetric data were collected along a 1-mile segment from its confluence with the Buffalo River upstream to approximately 0.1 mile downstream of the Cazenovia Street Bridge. Single-beam bathymetric surveys were conducted using an 18-ft jon boat equipped with a Garmin GPSMAP 178/178C bathymetry unit. Prior to collecting bathymetry survey points, a lead line was used to manually check the water depth for comparison to the GPSMAP readings at the same locations. Along the segments of the Buffalo River and Cazenovia Creek previously described, longitudinal transects were run along the left bank, mid-channel, and right bank, followed by cross-channel bank-to-bank transects. Depending on bank width, longitudinal transect spacing ranged from 20-50 ft. Cross-channel bank-to-bank transect spacing ranged at 110-150 ft. Boat speed was approximately 2 to 4 knots, and bathymetry points were recorded approximately every 3 seconds. Relevant site conditions and field observations such as obstructions, interferences, or other conditions that may affect readings were documented by the field crew.

Channel and floodplain cross sections were surveyed at a limited number of selected locations and selected bridges were also surveyed to obtain basic structure and road profile data. This information was used to confirm and extend information available from other sources, including the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS), the hydraulic models (HEC-2 and HEC-RAS), Corps of Engineers hydrographic surveys, and available as-built bridge plans. A survey control network was established using GPS equipment and OPUS. For survey control, four base points over the entire project were established. OPUS is a computer program that enables uploading of data collected from the stationary GPS unit (the base) to the National Geodetic Survey website and receipt of coordinate and elevation values with 1-3 centimeters (cm) accuracy. Accuracy over the three miles was found to be within 2 cms for both horizontal and vertical. Cross section surveys were then conducted at 25 established survey locations on the Buffalo River (upstream of the confluence with Cazenovia Creek) and Cazenovia Creek. Ground surveying was conducted using a survey rod and was supported by the use of metered line from a jon boat in deep water areas. At bridges, top of road profile, bridge abutments, low steel, piers and ice breakers were also surveyed.

3.2.2 Results

The bathymetry of the Buffalo River, lower Cazenovia Creek, and the City Ship Canal are presented on Figure 3-1. The bathymetry data presented in this figure include the data collected during fall 2008 along the Buffalo River and Cazenovia creek upstream of their confluence, and the data collected by USACE during 2007 and 2008. The navigation channel extends from the mouth of the river to approximately 1,500 ft downstream of the confluence with Cazenovia Creek, and is maintained at a depth of 22 ft to 23 ft below the Low Water Datum, which is 569.2 ft above Mean Water Level (International Great Lakes Datum [IGLD] 1985), and approximately two-thirds of the cross-sectional area is the navigable portion. At the upstream end of the navigational channel (approximately RM 5.8), the water depth transitions from a depth to 22 ft to approximately 5 to 10 ft, near the confluence with Cazenovia Creek. Immediately upstream of the confluence (RM 6.1–6.5), Buffalo River water depths are less than 8 ft, and upstream of RM 6.5 water depths typically range from 1 to 12 ft. At the downstream end of Cazenovia Creek, water depths typically range from 2 to 10 ft. The navigation channel in the City Ship Canal is also maintained at a depth of 22 ft to 23 ft below the Low Water Datum (569.2 ft), and extends approximately 1.0 mile from its confluence with the Buffalo River. The results of the bathymetric surveys were used in the development of the EFDC and HEC-RAS models as described in Section 3.4.

3.3 Hydrodynamic and Water Quality Measurements

Both long-term (six weeks) and short-term hydrodynamic and water quality measurements were collected along three transects of the Buffalo River to help establish boundary conditions for the hydrodynamic model, support model calibration, and provide information on flow and suspended solids variability over time and a range of flow conditions. Detailed information regarding methods and instrumentation used for the long-term and short-term hydrodynamic measurements is provided in the *Quality Assurance Project Plan for the Hydrodynamic and Physical Sampling, Buffalo River, New York* (ENVIRON and MACTEC 2008b) and summary of the methodology is provided below.

3.3.1 Methods

Long-term (six-week) stationary measurements and short-term cross-section measurements were collected during the fall of 2008. Long-term stationary measurements were collected through the installation of instruments on stationary structures on the three river transects, and short-term measurements were collected along the three transects using boat-mounted instrumentation.

3.3.1.1 Long-Term (Six-Week) Stationary Measurements

Instrumentation was installed in the river to collect velocity and suspended solids data over a six-week period (October 3, 2008 - November 19, 2008). The instrument installations included a downstream transect near the mouth of the river, a midstream transect, and an upstream transect at the end of the navigational channel (Figure 3-2). The upstream equipment installation was located upstream of South Park Avenue at RM 5.5, on the south side of the river. The midstream transect was located just upstream of the base of Katherine Street at RM 3.2 on the north side of the river, and the downstream transect was located beneath the Buffalo Skyway at RM 1.0 on the southwest side of the river.

The data collected at the long-term monitoring stations included velocity, surface water elevation, and turbidity. The velocity measurements were collected using side looking Acoustic Doppler Current Profilers (ADCP) (SonTek Argonaut-SL500), which provided average channel velocities by measuring a broad spectrum of current velocities across the width of the channel. The ADCPs were mounted on pilings at the downstream and midstream locations and on a concrete wall along the bank at the upstream location. In addition, an up looking ADCP (Teledyne/RDI Workhorse Sentinel) was installed at the mid-stream transect, in approximately the middle of the channel. The Sentinel measured the vertical velocity profile across the water column.

Surface water elevations were monitored from the beginning of October to mid-November 2008 using in-situ pressure transducers (In-Situ LevelTroll 500). The transducers were located with the ADCPs at the upstream and downstream transects, and set to record data every 15 minutes. The surface water elevations were surveyed to vertical reference points located on shore near the equipment installation locations.

Turbidity and temperature were monitored with YSI 6136 turbidity sensors. Turbidity also was measured with optical back scatter (OBS) meters. The YSI turbidity sensors were installed on monitoring buoys which were located in the channel next to each of the ADCP installations. Two sensors were placed on each buoy at approximately 25% and 75% of the river depth to capture the vertical stratification of the river. The OBS meters were installed at the upstream and downstream monitoring buoys at a depth of 75% of the river depth. The instruments were set to record data at 15-minute intervals. The data was either logged internally by the instruments or the instrument was equipped with a data logger. Photographs of the installations are included in Appendix B.

OBS and turbidity sensor readings were correlated to local suspended sediment concentrations by collecting surface water samples during the instrument deployment in October, at the time the instruments were removed in November, and two additional occasions during the monitoring period. Discrete water samples were collected at each of the monitoring buoy installations by lowering tubing from a peristaltic pump to the depth of the OBS and turbidity sensor (25% and 75% of river depth). These samples were analyzed for total suspended solids (TSS) concentrations. The TSS results were coupled with the OBS and turbidity sensor raw output readings to provide a suspended sediment calibration curve specific to the river.

3.3.1.2 Short-Term Transect Measurements

Short-term cross-section measurements were collected at the same three transects as the long-term monitoring transects, including near the mouth of the river, midstream, and upstream near the end of the navigational channel (Figure 3-2). The hydrodynamic and water quality measurements collected as part of the short-term cross-section measurements included surface water elevation, velocity, turbidity, pH, and dissolved oxygen.

The surface water elevation was measured using the pressure transducers installed for the long-term monitoring survey (In-Situ LevelTroll 500). Boat-mounted instrumentation was used to collect real-time hydrodynamic and water quality conditions. Water velocity monitoring was conducted using a Teledyne/RD Instruments 1,200 kHz Rio Grande ADCP. The survey team piloted the survey vessel across the river while at the same time collecting current velocity profiles of the water column. Current velocity data were compiled with a vertical resolution of ½ -meter and a horizontal resolution of five meters. Each transect was traversed four times consecutively to complete an individual cross-section velocity profile. Photographs of the cross-section velocity monitoring are included in Appendix B.

Suspended solids and turbidity was measured using an OBS and a YSI 6920 sonde. Continuous OBS depth profiling was conducted at three locations along each transect. Discrete water samples were collected at each sampling location by attaching tubing from a peristaltic pump to the OBS meter. The continuous OBS profiling was paused at discrete depths to run the pump and collect water samples into separate bottles for each depth. The samples were analyzed for TSS. This data was used to construct a site-specific calibration curve for conversion of OBS turbidity to suspended solids.

Using the YSI 6920 sonde, temperature, dissolved oxygen and pH profiles were also measured at each transect. Continuous profiles of dissolved oxygen, temperature, and pH were measured through the water column at three sampling locations per transect.

3.3.2 Results

3.3.2.1 Long-Term (Six-Week) Stationary Measurements

Surface water elevation data were collected at the upstream and downstream transects on the Buffalo River over the period of October 3, 2008 to November 19, 2008 (Figure 3-3). Changes in surface water level result from upstream riverine flow and Lake Erie seiche conditions. During seiche conditions, wind-driven changes in lake levels induce oscillations in Buffalo River water levels, and waves propagating back and forth in the river. Seiche-induced water-level changes occur over a period of approximately 14 hours; the waves propagate over a period of approximately 1.75 to 2 hours.

Water velocity data was collected from the side-looking ADCPs installed at each of the three transect locations. The results of the ADCP monitoring are presented on Figures 3-4 through 3-6, and a summary of the velocity measurements collected at each transect are presented in Table 3-1. Flow velocities at all three locations typically fluctuated between 1.0 ft/s (downstream direction) and -1.0 ft/s (upstream direction). These oscillations were attributed to the Lake Erie seiche events and the wave effects in the river. The smaller internal wave oscillations were likely induced by the upstream boundary of the navigation channel. As shown on Figures 3-4 through 3-6, the highest velocities were typically observed at the downstream transect, and velocities decreased with increasing distance from Lake Erie.

The uplooker ADCP was installed at the midstream transect location in approximately the middle of the channel, and data collected from the uplooker ADCP include velocity, velocity magnitude, and velocity directions. Results from the uplooker ADCP are provided on Figure 3-7 through 3-9. On Figure 3-7, green areas of the figure indicate velocities between 0.5 and -0.5 ft/s, while blue indicates the occurrence of higher velocities (> 0.5 ft/s) in the downstream direction. Figure 3-8 shows the total velocity magnitude, and the green streaks indicate the occurrence of higher velocity events (typically > 0.5 ft/s). Figure 3-9 shows the oscillation in flow direction of the Buffalo River due to seiche events, with the downstream direction indicated in orange/red, and the upstream direction indicated in blue. Changes in velocity, velocity magnitude, and velocity direction as shown on Figures 3-7 through 3-9 correspond with changes in water elevations generated by seiche events, as previously shown on Figures 3-4 through 3-6.

Turbidity data was collected using YSI turbidity sensors and OBS meters. The YSI sensors were installed at two depths at each of the transect locations (25% and 75% of depth). A summary of the turbidity and temperature data from all three transects is provided in Table 3-2. Turbidity data from the YSI sensors are shown on Figures 3-10 through 3-12. Turbidity values were typically less than 50 Nephelometric

Turbidity Units (NTU) at all three transects, except during increases in water velocity, as presented on Figure 3-4 through 3-6, which resulted in sharp increases in turbidity.

Figure 3-13 shows the turbidity results from the OBS meters, which were installed at 75% depth at the upstream and downstream locations. Peaks in turbidity measured by the OBS meters correspond to the peaks in turbidity measured by the YSI sensors. Prior to October 23, 2008, the peak OBS turbidity measurements were higher than that of the YSI sensor. Biofouling of the OBS meters may have resulted in an increase in turbidity, because after the instruments were cleaned (October 22, 2008) the turbidity returned to the normal range. The YSI turbidity sensors were self-cleaning and therefore did not experience biofouling.

3.3.2.2 Short-Term Transect Measurements

ADCP measurements were collected along the three Buffalo River monitoring transect locations on October 22-23, 2008. A summary of the cross-section velocity data is provided in Table 3-3. Horizontal velocity profiles along the downstream and midstream transect are shown on Figures 3-14 and 3-15. These figures represent ACDP measurements collected during the one cross-sectional pass of the downstream and midstream transect. Figure 3-14 shows a slight stratification in horizontal velocities at the downstream transect; slightly higher velocities occurred at the bottom half of the water column compared to the velocities closer to the water surface. This stratification is likely due to impacts from Lake Erie, as the stratification of velocities dissipates with increasing distance from Lake Erie. As shown on Figure 3-15, the midstream transect the horizontal velocities are more consistent across the depth of the water column.

Turbidity, dissolved oxygen, temperature and pH profiles were collected at three locations along each of the three transects as part of the short term study. The turbidity and water quality results are summarized in Table 3-4 for each transect. Average turbidity measurements for each sampling location ranges from 23.13 to 30.28 NTU, except for the upstream, left descending channel location, where the average turbidity was 16.73 NTU. Turbidity depth profiles are included on Figures 3-16 through 3-18. These profiles show a slight increase in turbidity at a depth of 4 to 6 meters at the midstream and downstream transect.

Water quality depth profiles were also collected at three stations across each of the three transects. Figures 3-19 through 3-21 show depth profiles for the right, center, and left descending stations along the three transects. In general, pH was constant across depth. Temperature typically decreased with depth, with the most dramatic decreases occurring at the downstream transect. Similarly, the most dramatic change in dissolved oxygen concentrations occurred at all three stations of the downstream transect, while dissolved oxygen levels were fairly constant with depth and the upstream and midstream transects, except for a slight increase at the water surface. Dissolved oxygen concentrations were above 10 mg/L at the midstream and upstream transects, and between 7 and 8 mg/L at the downstream transect. In summary, water quality measurements, including turbidity, temperature, and dissolved oxygen, show an increasing, though modest, stratification along the Buffalo River moving from upstream to downstream.

3.4 Buffalo River Hydrodynamic Model

3.4.1 One-Dimensional Model Development

3.4.1.1 Description of Existing HEC-2 / HEC-RAS Models

Existing HEC-2 and HEC-RAS models of the Buffalo River / Cazenovia Creek system were obtained from the NYSDEC. These models were developed as part of the National Flood Insurance Program by the FEMA. The original May 18, 1981 FIS for the City of Buffalo, NY was prepared by Goodkind and O'Dea, Inc., with Parsons, Brinckerhoff, Quade, and Douglas serving as a subcontractor conducting the hydrologic and hydraulic analyses. The initial FIS work was completed in 1979. In the late 1990s a revision of the 1981 FIS was prepared by Leonard Jackson Associates, with work being completed in 1996. The revised FIS was released on August 23, 1999.

Under the 1981 FIS, the Buffalo River, Cazenovia Creek and Scajaquada Creek were studied in detail under an investigation that included collection of bathymetric and topographic survey data. Under the revised FIS conducted in 1999, the Buffalo River model and supporting data were updated to reflect conditions as they existed at the time. The data collection and modeling done as part of the 1999 FIS for the Buffalo River stands as the current model, and a copy of the hydraulic model was obtained from NYSDEC. The FEMA Buffalo River model was developed in the HEC-2 modeling framework, a one-dimensional steady (non-time varying) flow modeling tool developed by the USACE primarily for use in assessing flooding potential in river systems.

In 2007, revised hydrologic and hydraulic analyses were conducted for several streams within Erie County by Medina Consultants P.C. (Hackettstown, New Jersey). These updates included revising the Cazenovia Creek model to include updated bathymetric data, and moving to the now-standard HEC-RAS modeling framework. The HEC-RAS model provides significant improvements over the prior HEC-2 modeling framework, including the ability to represent transient (time-varying) flows and the incorporation of georeferencing (spatial coordinates) into the model. The Buffalo River model was not updated in 2007. The revised models and flood maps, along with the existing 1996 model of the Buffalo River and flood maps were compiled into a county-wide FIS report for Erie County (September 26, 2008). At present, the 2008 FIS stands as the most recent study of flooding potential in the Buffalo River/Cazenovia Creek system.

3.4.1.2 Model Framework and Bathymetric and Topographic Updates

In order to bring the Buffalo River and Cazenovia Creek models into a consistent framework, the Buffalo River model has been updated to the HEC-RAS modeling framework and spatial coordinate data for model transects is being used to create a georeferenced version of the model. As the models now share a common HEC-RAS modeling platform, the Cazenovia Creek and Buffalo River models have been combined into a single branched modeling system.

As part of this investigation, updated bathymetric and topographic data not available at the time of the development of the existing HEC models was incorporated into the models. The bathymetric survey conducted by Buffalo District of the USACE in 2007 and 2008 was incorporated into the updated one-dimensional modeling framework. Also, an updated light detection and ranging (LiDAR) dataset collected by FEMA in July, 2007 was used to update the representation of the floodplain elevations in the models.

3.4.1.3 Boundary Conditions and Model Parameterization

Under the HEC-RAS modeling framework, transient (time-varying) simulations can be conducted to allow investigation of the rise, peak and fall of a river hydrograph, as well as changing downstream conditions that represent the effect of the Lake Erie seiche. The revised model is supported by boundary conditions representing a range of representative upstream flow conditions and downstream lake levels to explore flooding potential under the expected range of future environmental conditions.

A preliminary statistical and modeling investigation of watershed hydrology and lake level variation was conducted by MACTEC (2008). The work conducted by MACTEC provides a description of seiche intensity and flood event recurrence intervals, which will be used to support identification of historic wet weather events and lake seiche timings to be used in further development of boundary conditions, for both the HEC-RAS models and the three-dimensional EFDC model.

In addition to spatial geometry and boundary conditions, key model parameters are the frictional characteristics of the channel and floodplains. HEC-RAS parameterizes friction with Manning's "n" roughness coefficients, which are specified for the channel and floodplain segments of each transect. As reported in the FIS study, the roughness coefficients for the Buffalo River range from 0.035 to 0.045 in the main channels, and from 0.070 to 0.100 in the overbank portions that represent the floodplain.

3.4.1.4 Potential Extent of Flooding

The FEMA FIS existing effective hydraulic models provide water surface elevations used to produce Flood Insurance Rate Maps (FIRMs) and water surface profile drawings. Maps from the effective FIRMs, dated September 26, 2008, covering Buffalo River and Cazenovia Creek areas are provided in Figures 3-22a through 3-22k. The shaded or colored areas of these maps represent the FEMA-estimated 100-year floodplain along the Buffalo River and Cazenovia Creek. These floodplain maps are also viewable on FEMA's web page (http://msc.fema.gov/). It is noted that the Lake Erie 100-year flood elevation (580.2 ft NAVD 1988), controls the flood elevation on the Buffalo River for a distance of approximately 4.0 miles inland from the lake. At approximately RM 4.0, the riverine 100-year flood event water surface profile rises above 581 ft NAVD and controls the 100-year flood elevation, and extent, along the River and along Cazenovia Creek from that point upstream. The FIS 100-year riverine profile is based on a Lake Erie water level of 576.5 ft NAVD occurring coincidentally with the 100-year peak river flow rate. A Lake Erie at Buffalo hourly water level of 576.5 ft NAVD was exceeded on approximately one day out of 200 on the basis of maximum daily water level over the past 38 years and is slightly lower than an annual maximum hourly water level.

FIRM maps for the lower approximately four miles of the Buffalo River available on FEMA's flood map web site continue to be based on older topographic mapping. Preliminary mapping from FEMA with a release date of September 28, 2007, although not the final and effective FIRM map for that area, is based on recent, more detailed, topographic mapping and is provided in Figure 3-23.

The FIS 100-year flood (also known as the 1% chance and base flood) flow rates are 37,290 cubic feet per second (cfs) downstream of the Cazenovia Creek confluence and 21,530 cfs upstream of Cazenovia Creek. The FIS Cazenovia Creek 100-year discharge at the outlet is 16,400 cfs. FEMA's method of establishing flood elevations along a tributary stream discharging into a larger stream or lake is illustrated by the water surface profile on Figure 3-24. The receiving water flood elevation is projected as a flat surface upstream until the tributary flood elevation exceeds the receiving water flood elevation.

The FIS update that became effective on September 26, 2008 resulted in significantly less area near the junction of Cazenovia Creek and the Buffalo River included in the 100-year floodplain. This occurred as a result of new topographic mapping and a re-study and update to the Cazenovia Creek flood assessment model. Figure 3-25 shows the previous (1999) FIRM mapping in that area, where a large portion of the land between Cazenovia Creek and the Buffalo River was inundated. The new FIRM indicates that the Creek and River 100-year flood elevations do not extend far beyond the stream banks, with only Zone X (moderate to low-risk shallow flooding area) land occurring outside the stream in that area. Zone X in this area indicates either 500-year floodplain or 100-year floodplain with flooding depths of less than one foot.

The water surface profiles for Cazenovia Creek were calculated by using the updated HEC-RAS model, separate from the currently effective FIS Buffalo River hydraulic model. The FIS profiles for Cazenovia Creek (Figure 3-26) were calculated based on a starting downstream water elevation determined by a normal depth method with stream slope of 0.0009 ft/ft, which produces a 100-year flood profile with a starting water surface elevation of 580.88 ft NAVD. This approach is consistent with an assumption that the peak discharge in Cazenovia Creek occurs independently of the peak discharge on the Buffalo River, rather than coincidentally. Consequently, similarly to Lake Erie and the Buffalo River, the Buffalo River 100-year flood elevation is projected upstream along Cazenovia Creek until it intersects the Cazenovia Creek 100-year water surface profile.

The other important point to note from the FIS mapping is that the entire AOC segment, as well as the lower portion of Cazenovia Creek, is a FEMA-designated floodway. For communities that participate in the Flood Insurance Program, development may occur in the 100-year floodplain fringe outside the floodway with certain minimum regulatory controls, but development activities within the floodway must result in no increase in 100-year water surface elevations (Code of Federal Regulations, Title 44, Section 60.3 (d)(3)).

3.4.1.5 Extreme Seiche Conditions: January 2008 Event

On January 30, 2008, a large Lake Erie seiche event occurred that raised the water surface elevation of Lake Erie by over 9.6 ft to an elevation of 580.3 ft IGLD85, an elevation that occurs with a return frequency of approximately 100 years. Water surface elevations measured at the mouth of the Buffalo River for the first six weeks of 2008 are shown below in Figure 3-27. Figure 3-28 shows a detailed time-series of the seiche event that occurred on January 30 as measured by the Buffalo gage.

The peak measured Lake Erie WSE during this event was 3.8 ft higher than the Lake Erie water surface elevation of 576.5 ft (NAVD88) used by FEMA as the Buffalo River downstream boundary water surface elevation for the FEMA 100 year flood analysis. This seiche event is likely the event that caused reported flooding in the 1st Ward neighborhood of Buffalo in the winter of 2008. The updated HEC-RAS model of the Buffalo River was used to evaluate the effect that this higher water surface elevation would have on predicted Buffalo River water surface elevations upstream of the harbor.

For the period of the seiche event, no Buffalo River provisional flow data were available from the USGS due to ice effects on the river. Therefore steady state flow runs were performed using the Buffalo River HEC-RAS model and a conservative (high) flow condition. Beginning at the 1.2-year flood recurrence interval, the model predicted water surface elevations in the river adjacent to the 1st Ward that was sufficient to flood portions of the neighborhood. A predicted adjacent in-river water surface elevation of 580.7 ft for the 1.2-year event was predicted by the model. The sections of neighborhood predicted to flood under this event assuming the peak seiche water surface elevation downstream is shown in Figure 3-29. As shown in the figure, elevated flow in combination with the peak seiche water surface elevation measured on January 30 has the potential to cause flooding of a significant portion of the 1st Ward neighborhood. The probability of experiencing an event with a 100-year instantaneous peak lake water level occurring coincidentally with an instantaneous peak river flow of 1.2-year return period is uncertain, because the probability of each of these hydrologic events exhibits both seasonality and some degree of statistical dependence, and determining a quantitative measure of the level of dependence between these two weather-related phenomena is a complex task. Nevertheless, the probability of these events occurring simultaneously is expected to be significantly less than a 1% annual risk (100-year event).

3.4.2 Three-Dimensional Model Development

3.4.2.1 Description of Existing ECOM Model

The existing ECOM model of the Buffalo River was developed to support modeling of sediment transport in the Buffalo River AOC (Atkinson et al. 2006). The model extended from the mouth of the Buffalo River to approximately RM 5.8, which is about a half mile upstream from the point to which the river is currently dredged. The computational grid was based on a curvilinear-orthogonal coordinate system and was boundary-fitted; that is, the orientation of the grid cells followed the bends in the channel. The floodplain was not represented in the model. The width of the river was represented by nine grid cells throughout the length of the model. The width of these cells was approximately uniform at any given row, and ranged from about 8 meters at the narrowest section to about 35 meters near the mouth.

ECOM uses a sigma representation of vertical structure, in which each cell in the horizontal grid has the same number of vertical layers, and the layer thickness depends on the total depth. This representation has certain computational advantages, although it does not perform well in areas where sharp changes in bathymetry are present. The ECOM model of the Buffalo River used 10 vertical layers, and the thicknesses of these layers ranged from around one meter in the deepest, dredged areas to about 0.3 meters in shallow areas, for example upstream of the dredged extent.

3.4.2.2 Adaptation to EFDC Framework

The EFDC framework is similar conceptually to the ECOM framework with the exception of the vertical representation. The current version of EFDC includes the choice of using a “generalized vertical coordinate” (GVC) segmentation scheme, in which the number of layers in each grid cell can vary according to the bathymetry. This scheme permits relatively steep changes in bathymetry to be properly resolved, and eliminates the tendency of sigma grids to introduce spurious vertical transport in these areas. Unlike the standard "z-level" vertical formulation, only the bottom layer elevation is fixed, and the thickness of all active layers varies with water surface elevation instead of only the top layer. In practice, the GVC grid scheme can be thought of as a collection of individual sigma-like stacks of differing numbers of layers that share a common surface elevation.

To implement the GVC scheme, a minimum bed elevation and maximum water surface elevation are specified along with a maximum number of vertical layers. A series of "standard" levels is then computed, based on the difference between the minimum and maximum elevations and the number of layers. The fraction of the total depth given to each layer does not need to be uniform, although it is customary to make them so. For the Buffalo River model, a maximum of 10 layers was selected, and the minimum and maximum elevations were chosen such that the shallowest areas had at least four layers. Of the 1960 horizontal grid cells in the original ECOM model, 996 cells had either 8 or 9 layers after conversion to the EFDC GVC grid. Most of the remaining cells had from five to seven layers; six cells had four layers, and seven cells had ten layers.

Other aspects of the conversion from ECOM to EFDC are discussed in subsequent sections on boundary condition development and model parameterization.

3.4.2.3 Model Grid Development

The existing grid was essentially unchanged when adapted to EFDC, with the exception of the vertical representation. However, the upstream boundary of the ECOM model was relatively close to areas where the effects of concept remedies are to be evaluated, so the grid was extended further upstream to eliminate undesired boundary effects in the areas of interest.

The grid was extended about three miles further upstream, nearly to the confluence with Cayuga Creek. Cazenovia Creek was included to a distance of about 1.2 miles from the confluence, as far as Cazenovia Park. The full grid is shown on Figure 3-30, which also indicates the extent of the original ECOM model. While the extended grid increases confidence in the model predictions throughout the dredged portion of the river, model predictions in the extended reaches may not be useful for high flow events because the floodplain was not included in the grid. Assessment of flood conditions are more appropriately handled by the one-dimensional model as discussed in previous sections of this report.

3.4.2.4 Bathymetric and Topographic Updates

The bathymetry of the lower river grid was based on the May 2008 multibeam sounding data collected by the USACE. Additional USACE singlebeam sounding data were available for a portion of the river in the extended grid, as was a dataset provided by MACTEC that extended further upstream and included Cazenovia Creek as well. Finally, two-foot elevation contours developed from a LiDAR survey were available for the floodplain.

The bathymetric data were used to construct a digital elevation model (DEM) in the form of a triangulated irregular network, which was then overlaid on the model grid. Zonal statistics were calculated within each grid cell to determine an average elevation. The topographic contours were used to define the shoreline, serving as a boundary for fitting the curvilinear grid as well as more fully constraining the DEM.

There remained some areas, particularly in the upstream-most reaches, where gaps in the various data sources led to relatively uncertain bathymetric representation. These areas are far enough upstream, however, to not adversely affect the predictive skill of the model at points of interest.

3.4.2.5 Boundary Condition Development

The model boundary conditions are fully described by water surface elevation at the downstream end, and flow at the two upstream ends. Water surface elevations were obtained from the National Oceanic and Atmospheric Administration (NOAA) Buffalo gage 903260, at six-minute intervals. Upstream flow was derived from three gages operated by the United States Geological Survey (USGS), using drainage area ratios to account for additional flow inputs downstream of the gages. Table 3-5 lists the gages and the drainage area information. Stream discharge at these locations was generally available at either 15-minute or 30-minute resolution.

3.4.2.6 Model Parameterization

Both the ECOM and EFDC model frameworks are largely constrained by the definition of grid geometry, establishment of bathymetry, and the choice of boundary conditions. Further parameterization is generally limited to formulations for bottom friction, and for horizontal and vertical mixing processes.

Bottom friction is described in both models by specification of a roughness height, which is used to relate bottom shear to velocity via a "law of the wall" relationship. In ECOM, however, a single roughness height is applied throughout the grid, whereas in EFDC the roughness is specified individually for each grid cell. A roughness height of 0.0018 meters was used in the original ECOM model, so this value was applied to each cell in the EFDC model as well, subject to adjustment in the calibration process.

For vertical mixing, both model frameworks include a second-order turbulence closure scheme based on the work of Mellor and Yamada (1982). This scheme can be turned off and constant values for mass and momentum diffusivity can be used instead. The original ECOM model used the closure scheme along with a background mixing coefficient of 1.0e-06 square meters per second (m^2/sec); the same approach was used for the EFDC model.

For horizontal mixing, both model frameworks use the parameterization of Smagorinsky (1963) to resolve subgrid processes, and include an option to substitute constant values if desired. The Smagorinsky equation includes a dimensionless parameter that is typically set to 0.1, and this value was used in both the ECOM and EFDC models.

3.4.3 3-D Model Calibration

3.4.3.1 Calibration Dataset

The calibration of the model was checked with the data collected by the three ADCP meters described previously in this report. The three locations were all within the extent of the original ECOM model, although the upstream-most location was close to the original model boundary. The ADCPs provided horizontally-averaged velocity, at a certain water depth, as well as overall water depth. Useful data were obtained from October 1, 2008 through November 19, 2008, with brief interruptions for equipment servicing. Data were recorded at 15-minute intervals through October into early November; for the last two weeks the frequency was increased to five minutes, to better characterize the velocity oscillations that were observed.

Four periods were selected from the calibration dataset that contained interesting variations in upstream flow and seiche-driven downstream water level fluctuations, and are summarized in Table 3-6. The largest wet weather-related flow was observed on October 16, during Period A; total discharge, as determined from the USGS gage information, peaked at about 6500 cfs. The return period of this discharge is estimated to be less than one year. Higher rise rates occurred on October 26-27 (Period B), but these were not sustained and total change in water level was less than 3 ft. One of the sharpest sustained changes in downstream water level occurred on November 8 (Period C), when the level rose 3.0 ft over a period of 2 hours and 30 minutes, with a peak rate of nearly 3.0 ft per hour.

3.4.3.2 Calibration Objectives

The objectives of the calibration are to reproduce the seiche- and flow-driven velocity variations that are observed in the system. Although the model will primarily be used to predict shear stresses and velocities under high flow conditions, the former quantity cannot practically be measured under field conditions; a good calibration for velocity is considered adequate, however, because the theoretical basis for the relationship between velocity and shear is sound.

3.4.3.3 Calibration Results

Figures 3-31 through 3-34 compare the model-predicted velocities and water surface elevations for calibration periods A, B, C, and D. The agreement is generally very good at all locations, and for each of the various flow and seiche conditions present in the selected periods.

Period A (Figure 3-31) illustrates the hydrodynamic behavior of the system under a moderately high flow wet weather event. Throughout the event there is a relatively high-frequency oscillation in the velocity that is believed to represent seiche-like behavior within the dredged portion of the river. The amplitude of this oscillation is progressively attenuated in the upstream direction, and the velocity increase associated with the wet weather flow becomes more visible. Variations in water surface level, interestingly, become progressively greater in the upstream direction, and the model captures this effect as well.

Period B (Figure 3-32) included moderate flows and some rather sharp fluctuations in water level at the downstream end. The resulting velocity fluctuations are quite large in comparison with those in Period A, but the model captures them well. There is perhaps a slight tendency for the model, at the downstream location, to overshoot the highest velocities during times of rapid change. However, the period of the oscillation, which is governed by the geometry of the channel, is captured very well, which suggests that the model grid and bathymetry are appropriately characterized. The attenuation of the velocities and the amplification of the water levels, when proceeding upstream, is captured very well.

Period C (Figure 3-33) included an isolated high seiche event along with consistently lower flows. As seen in the figures, these conditions were also handled well by the model. Notably, lake seiche induces velocities in excess of two feet per second (fps) even when total river flow is relatively low.

Finally, the results for calibration period D are shown on Figure 3-34. This period included the most prolonged steady increase in water level at the downstream end, accompanied by moderate upstream flow. As with the other events, the calibration for both water level and velocity is very good.

3.4.4 Preliminary Assessment of Hydrodynamics

3.4.4.1 Model Applications

The calibrated model was run for several higher-flow conditions, as well as the calibration periods, to explore the potential range of peak velocities and bottom shear stresses in the AOC. Desired high-flow conditions included the 10-year and 100-year events. High-resolution upstream flow data from the USGS gages was available only as far back as 1990, so the greatest historical flows could not be simulated directly. However, several large events were available from this period, and these flows were scaled to reach the peak values of the 10-year and 100-year events. Other applications included a moderate wet weather event (Period A from the calibration data) as well as low-flow conditions.

The following sections discuss model results that are mapped over the model cells in the AOC. The results represent snapshots of the system at a time when the velocities and bottom shear stresses were at or near their peak values from the entire model event, providing a picture of critical conditions. Note that, for ease of comparison, the color scheme in the figures is set to accommodate the full range of velocities and stresses from all events, so as a result there is little spatial variability seen in the figures for the lowest flow.

3.4.4.1.1 Dry Weather Flow Conditions

The data collected for model calibration show a seiche effect within the navigational channel that is distinct (that is, having its own characteristic period) from the seiche of Lake Erie. The channel seiche can produce velocities that are greater than those associated with river discharge under typical dry weather conditions. To illustrate this effect, model results of velocity and shear stress are presented for the entire AOC at two times during Period C, when the river discharge was less than historical median values for those particular days of the year. Figures 3-35 and 3-38 present the velocities and bottom shear stresses, respectively, in the AOC during this low flow period with minimal effect from lake seiche. Figures 3-37 and 3-38 present the same information about a day and a half later, after a sharp change in downstream level induced seiche behavior in the river (see Figure 3-33). During calmer conditions, velocities do not exceed 5 centimeters per second (cm/sec) (0.16 fps), and shear stress does not exceed 0.08 dynes per square centimeter (dynes/cm^2), but the seiche produces velocities greater than 60 cm/sec through much of the AOC; it is notable, however, that these velocities are not sustained for more than five minutes at a time, but instead oscillate as can be seen in the plots of the calibration data.

3.4.4.1.2 Moderate Wet-Weather Event Conditions

The wet weather flow during calibration Period A had an estimated return period of slightly less than a year, and can be considered a moderate event. Peak velocities and shear stresses associated with this event are mapped on Figures 3-39 and 3-40, respectively. Comparison of these results with the peak seiche-induced velocities on Figure 3-27 is of interest. While the general magnitudes are similar, the distributions are different; the wet weather event has more of the higher velocities in the upstream reaches of the AOC (above RM 5.0), whereas the seiche-induced velocities have been attenuated to some extent in the upper reaches. Higher velocities are seen in both cases at the narrowest downstream section, near the Buffalo Skyway bridge and RM 1.0. In this location, the channel is somewhat deeper along the right bank (looking downstream), which is also on the inside of a relatively gradual bend, and the highest velocities and shear stresses are seen here.

3.4.4.1.3 Large Wet-Weather Event Conditions

Two larger wet weather events were also simulated, corresponding to return periods of 10 and 100 years. The peak velocities and shear stresses from these model runs are mapped on Figures 3-41 through 3-44. The distribution of the highest velocities and shears is similar to the moderate wet weather event, although the values are considerably higher. Peak velocities along the narrow reach between RM 1.0 and RM 2.0 exceed 200 cm/sec in both the 10-year and 100-year events, and shear stresses exceed 200 dynes/cm^2 for the 100-year event and reach 150 dynes/cm^2 for the 10-year event. The 100-year event also has velocities and stresses in these ranges at various other narrow points (for example, RM 2.9 and RM 5.2), and while the 10-year event results are also elevated at these locations the values are, expectedly, lower.

3.4.4.2 Summary

The velocities and shear stresses computed by the model for the various events are consistent with the river's function as a dredged navigation channel. Little flooding occurs within the AOC, so high wet weather flows are contained within the river's banks and result in relatively high velocities and bottom shear stresses. During low flows, the ample cross sectional area maintained by periodic dredging results in very low average velocities; superimposed on top of this, however, are the seiche-induced oscillations that likely influence the patterns of sediment deposition. These implications are discussed in more detail in the following section.

3.4.5 Implications for Sediment Transport

3.4.5.1 Review of historical studies of sediment loadings and sedimentation

Several historical studies have been conducted to assess the rate of sediment mass transport (sediment loading) into the lower Buffalo River and Lake Erie, and also to estimate rates of sediment accretion, or shoaling, within the dredged portion of the lower river. Historical USACE dredging records from 1990 to the present show a long-term average rate of dredged solids production in the lower Buffalo River navigational channel of approximately 70,000 cubic yards (CY) per year. To facilitate comparison with this rate of solids removal, the mass loadings estimates provided in other sediment loadings studies were converted to volumes of deposited sediments, assuming an average wet bulk density of sediments of 1,600 kg/m^3.

A 1988 study of shoaling rates in the Buffalo River that predates the available USACE data on dredged solids reported a very similar annual average sediment yield to the river of 94,100 tons, or 70,000 CY per year (USACE 1988). These estimates were based on USACE dredged material production rates not currently available.

In a 1994 study performed by the Assessment and Remediation of Contaminated Sediment (ARCS) Program, the USEPA estimated the annual average suspended sediment load to the Buffalo River at 55,000 metric tons, or 45,000 CY (USEPA 1994). The USEPA's estimate was based on TSS loads calculated from monthly average flows over a 45-yr period and is likely an underestimate of the actual suspended solids load due to the likely disproportionate impact of peak flows on the total solids load.

Inamdar (2004) estimated suspended sediment yield for the Buffalo River watershed using the Soil and Water Assessment Tool (SWAT) model. This study estimated annual suspended sediment load at 64,000 CY (86,719 tons) for the period 1996–2003. Model applications also indicated that the Cazenovia Creek sub-watershed generated the largest portion of the suspended solids (approx. 45% of the total), despite containing a lower percent of cropland when compared to Cayuga and Buffalo Creek sub-watersheds. Steeper slopes and higher water yield contributed to greater sediment loads from the Cazenovia Creek sub-watershed.

3.4.5.2 Conceptual description of sediment transport

The available data provide relatively consistent independent estimates of the total sediment load to the lower Buffalo River, and provide a basis for a preliminary description of sediment transport in the Buffalo.

The ARCS estimate of solids transport was based on measurements of suspended sediments only, and did not include the portion of total sediment load transported via near-bottom saltation, or bedload. The portion of total annual load transported as bedload in midwestern rivers typically varies from as little as 10% to as much as 50%. Under the assumption that the value of 70,000 CY, obtained from dredge records, represents a majority of the total solids load to the lower river, a very coarse estimate of bedload obtained by subtraction of the ARCS report suspended load estimate is 25,000 CY, or approximately 35% of the total load. Comparing the Inamdar (2004) estimate of suspended load to the total dredged materials estimates provided by the Army Corps of Engineers suggests a lower proportion of bedload material, on the order of 10% of the total load.

In either case, it is expected that bed load will make up a significant component of the total solids load transported to the lower river, and consequently that deposition of solids in the navigational channel will occur in two different ways: as suspended solids deposited from the water column, and as bedload transport interrupted by the abrupt change in bathymetry at the upstream end of the navigational channel. In navigationally dredged systems like the Buffalo River, bed load deposition tends to be focused at the upstream limit of navigational dredging, and deposits in a focused "wedge" of relatively coarse materials. If allowed to proceed, this wedge of relatively rapid deposition moves the upper boundary of the navigational channel downstream with successive years of deposition. At the same time, deposition of finer suspended materials occurs at locations downstream, where the greater depths and slower velocities make conditions favorable for solids deposition.

At this point, model development has focused on the prediction of hydrodynamics, allowing for water surface elevations, velocities, and river bottom shear stresses to be predicted. While explicit modeling of sediment transport has not been conducted, the hydrodynamic results provide insight into likely patterns of suspended solids deposition. Deposition will be governed by velocities available to convey sediment and shear stresses that act to scour sediment. Because the channel is regularly dredged, the channel areas are maintained in a state of disequilibrium with respect to erosion and deposition, creating an environment that is generally depositional. Deposition will tend to be greater in areas that have been recently dredged, have lower velocities, and lower stresses available to scour in-place sediments.

3.4.6 Ice Jam Evaluation

An assessment for potential ice jam occurrence along the Buffalo River AOC, the possible locations for these occurrences, and the impacts of potential ice jams on sediment stability is being conducted by Andrew Tuthill from the USACE Cold Regions Research and Engineering Laboratory (CRREL). If not appropriately managed, ice jams have the potential to cause upstream flooding or localized bed scour by decreasing water depth and flow area and increasing under-ice water velocity and turbulence. As a result, the transport of bed sediment can occur under an ice jam where the bed material would be stable under an equivalent (or much higher) open water discharge.

During fall 2008 Andrew Tuthill conducted an ice evaluation of the Buffalo River, which included a review of past ice events and ice processes on the Buffalo River and its tributaries, an assessment of current ice control measures along the Buffalo River AOC and its tributaries, and a review of historical hydro-meterological data associated with historical Buffalo River ice jams. The HEC-RAS numerical model was also used to simulate breakup ice jam profiles and calculate under-ice water velocity within the AOC. The findings from this study are presented in Appendix A, *Buffalo River Area of Concern Ice Investigation*. In summary, the review of historical ice jams along the Buffalo River since 1904 indicate that only two ice jams occurring in 1959 and 1966 have occurred in the AOC and resulted in significant flooding. The lack of observed ice events within the AOC since that time is likely a result of ice management strategies, including ice breaking and the installation of an ice control structure at Cazenovia Creek. HEC-RAS model simulations, using ice jam locations and water velocities similar to the 1966 and 1959 events, showed under ice water velocities ranging from 2-5 ft/s.

In addition to this evaluation, a field observation program led by CRREL is now underway for the 2008-2009 winter season. Field observations will include evidence of past ice jamming such as ice tree scars and ice related damage to bed, banks, structures and vegetation, location and progression of ice cover formation, maximum mid-winter ice cover spatial extent and thickness, and ice cover break up timing and progression. These field observations will complement the historical data and information compiled as part the ice investigation in Appendix A.

4 Ecological Sampling

Ecological sampling was performed in accordance with the Field Sampling Plan (FSP) and the Quality Assurance Project Plan (QAPP*)* (ENVIRON and MACTEC 2008a&c). This section describes the rationale for ecological sampling, and provides a detailed description of the sampling methods and results for aquatic habitat mapping, benthic invertebrate sampling, and fish sampling.

4.1 Ecological Sampling Rationales

A considerable number of ecological data are available for the Buffalo River, as described in the *Existing Conditions Report* (Ecology and Environment, 2008). Ecological sampling data from the 2008 field effort is intended to supplement the existing body of knowledge of the river, and to support the development of multiple lines of evidence to support remedy decision making, as recommended in USEPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005a).

4.1.1 Aquatic Vegetation Mapping Sampling Rationale

A number of studies of shoreline stability and the general presence/absence of plant species in riparian zones along the river have been performed that can be used to support an assessment of existing habitat conditions of the Buffalo River. Although there are anecdotal reports of aquatic macrophyte beds within the AOC, recent data that provide information about the extent of this resource, its characteristics (composition), or its distribution (i.e., main channel border only vs. other habitats) are limited. Functions typically associated with fringing emergent and submergent plant communities include those associated with water quality enhancement, shoreline stabilization, and fish and wildlife habitat. A sufficient understanding of this resource was needed in order to fully evaluate the potential impacts of remedial alternatives on the resource. Therefore, an aquatic vegetation survey was conducted along the length of the Buffalo River to obtain preliminary spatial data regarding the longitudinal distribution of emergent vegetation (EV) and submerged aquatic vegetation (SAV) within the AOC and to obtain qualitative presence/absence information about species composition of EV/SAV beds.

4.1.2 Benthic Invertebrate Sampling Rationale

Benthic invertebrate communities in the Buffalo River AOC have improved from conditions observed in the 1960s; however, reports of continued benthic community impairment have led to a BUI for degradation of benthos (Irvine et al. 2005; BNR 2005). Communities were characterized in 2005 as having low taxonomic richness and diversity and are numerically dominated by pollution-tolerant organisms such as tubificid oligochaetes. An additional indicator of impairment that was reported on the Buffalo River was the incidence of mouthpart deformities found in chironomid midges, a condition that can be associated with pollution (Irvine et al. 2005; Wiederholm 1984; Van Urk et al. 1992).

Benthic invertebrate community surveys were collected in September and October of 2008 in order to provide additional, more current information relevant to the FS process, including assessment of current conditions and projection of restoration timeframes. Samples were collected at locations on the Buffalo River (upstream of and within the AOC), on Cazenovia Creek, and two reference water bodies:

Tonawanda Creek and Cattaraugus Creek. The reference water bodies were identified during a series of stakeholder conference calls held in 2008. It was noted that due to the unique characteristics of the Buffalo River in terms of orientation on Lake Erie and the frequency/magnitude of seiche effects, neither reference watershed is a perfect match. However, after extensive evaluations of proximity and physical similarity in sediment substrates with the Buffalo River, Tonawanda Creek was selected because it is representative of an urban watershed with some seiche effect (indirect from the Niagara River) and Cattaraugus Creek was selected because it best reflects similarity in the seiche effect with limited urban influences[2]. Sediment chemistry samples were collected from Cattaraugus and Tonawanda Creeks and analyzed for the same analytes described in Section 2. This reference site chemistry data was intended to provide a chemical context to facilitate the interpretation of the benthic data collected from the reference sites.

Benthic community samples from the Buffalo River and reference water bodies were collected in 2008 using a well accepted sediment grab sampling technique which allows consideration of benthic community gradients that may exist in the river due to sediment chemical concentrations (USEPA 1999; NYSDEC 2002). This approach allows comparison to previous benthic community studies and consideration of current conditions in relation to the development of remedial targets and remedial alternatives evaluations. In addition, benthic samples were collected using Hester-Dendy artificial substrate samplers placed just above the sediment surface (i.e., elevated enough to avoid getting the sampler filled with mud, but close enough to the sediment surface to attract benthic dwelling organisms). No benthic community studies have been conducted on the Buffalo River using the Hester-Dendy samplers[3]. This approach augments the benthic grab sampling approach because it allows consideration of organisms that exist in the river that have habitat preferences not readily sampled using sediment grab approaches (e.g., those requiring larger grain/cobble substrates or those that inhabit woody debris). As such, this sampling approach can provide insight to potential benthic community gradients in the river (if any) that could be due to sediment characteristic variables because this approach standardizes the habitat structure at each location. Both approaches provide insight into the types of organisms that may recolonize the Buffalo River following remedy implementation.

4.1.3 Fish Sampling

Fish sampling included an evaluation of the fish community using rapid bioassessment protocols (NYSEC 2002; USEPA 1999) and fish histopathology.

4.1.3.1 Fish Population and Community Rationale

Fish population surveys have previously been conducted by Irvine et al. (2005) and researchers from Brockport University and U.S Fish and Wildlife Service (collected in 2007). These historical studies

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[2] Selection of Tonawanda Creek was the result of an evaluation of its characteristics (i.e., sediment substrate characteristics, water depth, dredging frequency, watershed size, urban development, shoreline characteristics, and distance from Lake Erie [seiche effect]), as reviewed in detail by the PCT ecological subgroup during a series of conference calls conducted during the preparation of this SRIR.

[3] Swift et al. (1996) report a benthic community study conducted in 1989 using “artificial substrates” comprised of folded screen placed in a box. This approach, while qualitatively informative, is not quantitatively comparable to the more standardized Hester Dendy approach now recommended by USEPA.

evaluated fish populations throughout the Buffalo River AOC, but did not investigate locations upstream of the AOC. In 2008, upstream locations within Cazenovia Creek and the Buffalo River were sampled to collect data to support a baseline community analysis and selection of remedial goals, and allow determination of the presence of potential recolonizing species. Two sampling locations were established within the AOC in order to compare current conditions with historical data sets. These site-specific data can be useful for the evaluation of long-term and short-term remedy effectiveness.

4.1.3.2 Brown Bullhead Histopathology

Brown bullhead histopathology that was conducted in 2008 significantly enhances existing data for the Buffalo River. This information will be used to inform the remedy alternatives analysis and consideration of remedial targets, to the extent practicable. Surveys of liver cancer in brown bullhead can be an appropriate method of evaluating fish community health, BUI, and beneficial use recovery (MDEQ 2006). In addition, these surveys provide additional data to measure satisfaction of the International Joint Commission (IJC) delisting criterion, which states that the fish tumor BUI may be delisted “when the incidence rates of fish tumors or other deformities do not exceed rates at unimpacted control sites and when survey data confirm the absence of neoplastic or preneoplastic liver tumors in bullheads or suckers” (IJC 2008; United States Policy Committee 2001). Liver cancer in fish has been closely associated with chemicals in sediment from urban and industrial sites; and therefore, liver cancer in brown bullhead can be a line of evidence to evaluate recovery associated with remediation (e.g., Baumann and Harshbarger 1995).

In addition to liver cancer, other forms of lesions were also included in the 2008 sampling, because Irvine et al. (2005) reported that deformities, eroded fins, lesions, and tumors (DELT) anomalies were found in 87% of brown bullhead sampled within the Buffalo River AOC. Brown bullhead are considered to be better sentinel fish species than others for evaluating adverse environmental effects due to contaminated sediments, because they are relatively sensitive fish (Baumann and Harshbarger 1995) and are bottom feeders and so are in close contact with the sediment. They also have a small home range and exhibit good site fidelity (Sakaris et al. 2005). Irvine et al. (2005) reported approximately half of the Buffalo River study sites had higher than average DELTs, while the other study sites had lower than average DELTs. Irvine et al. (2005) did not report the incidence of hepatic lesions separately and some authors have reported that DELTs are not a good measurement of fishery health, because fin erosions and other external lesions are frequently found in association with chlorinated effluents near wastewater treatment plant outfalls (Grizzle et al., 1988) or are due to viral etiology (Baumann et al., 1996). Additionally, DELTs were determined to be an unsuitable endpoint for delisting AOCs (Baumann and Dabrowski, 2006). Therefore, the 2008 histopathology data provide a unique data set for consideration in the Buffalo River FS.

4.2 Aquatic Vegetation Mapping

Aquatic vegetation mapping was completed in August 2008 by MACTEC and ENVIRON along the length of the Buffalo River (mouth to confluence with Cazenovia Creek) (Figures 4-1a and 4-1b).

4.2.1 Methods

Field crews progressed along both shorelines to identify established EV stands/SAV beds and recorded their outside boundary using GPS. Macrophyte species were identified using Hotchkiss 1972, Gleason and Cronquist 1991, and Holmgren 1998. Individual plants or small clusters of plants (i.e., less than 25 square meters [m^2]) were not included in this survey. Presence and composition of individual plants or small clusters were recorded anecdotally. Water depth and approximate widths were also recorded for each stand/bed identified.

For identified stands/beds, species composition was recorded in terms of presence/absence for each identified stand or bed. Field crews used a standard long-handled two-headed rake to obtain samples from observed stands/beds and to obtain representative species for identification. Particular attention was given to the identification of potential invasive species such as purple loosestrife and Eurasian watermilfoil. Representative specimens were retained for most species identified to serve as a voucher collection.

4.2.2 Results

4.2.2.1 Submergent Aquatic Vegetation

The aquatic vegetation survey conducted in August 2008 resulted in the identification 29 SAV beds (23 in shallow water areas outside the navigation channel and 6 within the navigational channel) (Figure 4-1a). The location of SAV beds in relation to shoreline features is presented on Figure 4-1b[4]. All SAV beds were represented by narrow linear fringing beds along shorelines within the AOC. The most upstream SAV bed was located 0.7 miles downstream of the confluence with the Cazenovia Creek. The survey also included the portion of the river approximately 1 mile upstream from the confluence with the Cazenovia Creek (i.e., above the AOC). No SAV beds were located within this reach. Only individual plants or very small clusters were seen within this reach.

Eight species of SAV were identified: coontail (*Ceratophyllum dermersum*), Canadian waterweed (*Elodea canadensis*), American waterwillow (*Justicia americana*), Eurasian watermilfoil (*Myriophyllum spicatum*), curlyleaf pondweed (*Potamogeton crispus*), American pondweed (*Potamogeton nodosus*), sago pondweed (*Potamogeton pectinatus*), and wild celery (*Vallisneria americana*). Sago pondweed, wild celery, and coontail were the most common species found within the SAV beds. Sago pondweed was identified in 26 out of the 29 beds (90%), wild celery was identified in 23 out of the 29 beds (79%), and coontail was identified in 22 out of the 29 beds (76%). American waterwillow and Canadian waterweed were the most uncommon species found in the SAV beds. American waterwillow and Canadian waterweed were identified in only 10% (3 out of 29) and 31% (9 out of 29) of the SAV beds, respectively (Table 4-1). Eurasian watermilfoil is an invasive, exotic species found in the Buffalo River. It was identified in 62% (18 out of 29) of the SAV beds.

Water depth at the 29 SAV beds ranged from 2 to 10 ft (Table 4-1) with an average water depth of 5 ft. SAV bed width for the 29 identified beds ranged from 4 to 25 ft (Table 4-1) with an average of 10 ft.

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[4] Figure notes preliminary information.

Substrate type within the identified beds was typically silt with clay. Silt with gravel was found in SAV locations 8, 9, and 16 (see Figures 4-1a and 4-1b). Silt with rock was found in SAV locations 18 and 20.

4.2.2.2 Emergent Vegetation

The aquatic vegetation survey conducted in August 2008 resulted in the identification of 15 EV stands (10 within the AOC, 4 within the navigational channel, and 1 outside the AOC) (Figures 4-1a and 4-1b). The most upstream EV stand was located 0.8 miles downstream of the confluence with the Cazenovia Creek. Only one EV stand was located within the Buffalo River, upstream of the AOC (location EV-15). This EV stand was located approximately 0.7 miles upstream from the confluence with Cazenovia Creek.

Seven species of EV were identified: purple loosestrife (*Lythrum salicaria*), common reed (*Phragmites australis*), Japanese knotweed (*Polygonum cuspidatum*), broadleaf arrowhead (*Sagittaria latifolia*), softstem bulrush (*Scirpus validus*), broadleaf cattail (*Typha latifolia*), and pickerelweed (*Pontederia cordata*). Purple loosestrife, Japanese knotweed, and common reed were the most common species found in the EV stands, each being identified in 60% (9 out of 15), 60% (9 out of 15), and 53% (8 out of 15) of the EV stands (Table 4-2). Common reed, purple loosestrife and Japanese knotweed are all exotic, invasive species that were commonly found in EV stands. The most uncommon species found within the EV stands were pickerelweed and broadleaf arrowhead which were each only found in 7% (1 out of 15) of the identified EV stands (Table 4-2). Both of these species were identified from the same stand (location EV-13).

4.3 Benthic Invertebrate Community Assessment

The benthic community assessment survey was conducted at eight locations on the Buffalo River (including locations upstream of the AOC), one location on Cazenovia Creek (also upstream of the AOC), three locations on the reference Tonawanda Creek (RST), and three locations on the reference Cattaraugus Creek (RSC) (Figures 4-2a and 4-2b). Benthic community assessment was conducted on Cazenovia Creek to analyze the benthic community that could repopulate the Buffalo River AOC; therefore, it is not used as a reference location. The proximity of reference sites to the Buffalo River is provided on Figure 4-2c.

4.3.1 Methods

4.3.1.1 Sampling Locations

Benthic grab samples (15 stations) and Hester-Dendy artificial substrate samples (14 stations) were collected and evaluated at:

- One location on Cazenovia Creek (CC) upstream of the AOC (CC01).
- Three locations on the Buffalo River upstream of the AOC (BR01 at RM 7.5, BR02 at RM 6.8, and BR03 at RM 6.25)
- Two locations in the upper Buffalo River AOC (BR04 at RM 5.5, BR05 at RM 4.75)

- Three locations in the lower Buffalo River AOC that are subject to seiche effects from Lake Erie (BR06 at RM 2.1, BR07 at RM 1, BR08 at RM 0.3)
- Three locations in the seiche-affected zone of Cattaraugus Creek, a reference stream with limited urban development (RSC01, RSC02, and RSC03)[5].
- Three locations in Tonawanda Creek, as a reference area of similar size and urban use conditions (RST01, RST02, and RST03).

4.3.1.2 Sampling Methods

Benthic macroinvertebrate sampling was conducted using a NYSDEC scientific collection permit (Appendix C) that was approved on September 22, 2008. Surface water quality information, current flow, and GPS coordinates were collected at each location. A Horeba Model U-10 multi-parameter meter was used to measure surface water quality parameters (pH, dissolved oxygen, temperature, conductivity). The meter was calibrated daily before use following manufacturer's instructions. A Secchi disk was used to determine water clarity as a surrogate for turbidity. Current speed was measured with a Marsh-McBirney Flow Mate 2000. The sensor probe was mounted to a top-setting rod and flows taken at 0.6 of total depth if water was less than three feet deep, and at three feet from surface in waters greater than three feet deep. All equipment was calibrated and used according to USEPA specifications (USEPA 2007a, 2007b, 2007c).

The macroinvertebrate sampling followed the USEPA and NYSDEC Rapid Bioassessment Protocols (RBP) III (NYSDEC 2002, USEPA 1989, 1999), modified for nonwadeable streams using the ponar grab sampling and Hester-Dendy techniques. To the extent practical, sampling locations were located in close proximity to concurrent physical sediment sampling locations (e.g., organic carbon content and particle size), as identified in the FSP (ENVIRON and MACTEC 2008a). Prior to sampling, a description of each benthic macroinvertebrate sampling location and a quantitative evaluation of habitat quality were recorded on habitat characterization field data sheets (USEPA 1999).

4.3.1.2.1 Sediment Grab Sampling

The macroinvertebrate sediment grab sampling was conducted using a petite ponar dredge with a surface area of approximately 0.023 m^2. A total of five ponar grab replicates were collected at each station. The petite ponar was equipped with mesh screens and rubber flaps to cover the jaws. This design allows water to pass through the samplers during descent, reducing disturbance from bow waves at the sediment-water interface. The rubber flaps also serve to protect the sample from washout during ascent (USEPA 2007d).

Each sediment sample collected by petite ponar was inspected as soon as it was secured to make sure the sample was appropriately collected (i.e. the sample was undisturbed by the bow waves of the ponar or by washout during sample retrieval) (USEPA 2007d). Multiple casts were required in some locations, particularly RMs 6.25, 6.8, and 7.5, due to the presence of large cobbles that prevented the ponar jaws from closing. In the event that an insufficient sample was collected (e.g., full ponar volume not achieved,

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[5] Note that due to shallow water depth, Hester-Dendy samplers were only placed at two of the three locations (sediment grab samples were collected at all three locations).

rocks and cobbles prevented ponar jaws from closing), the sample was discarded and another sample was collected a few feet away.

The organisms and other material (e.g., sand and organic material) from each ponar grab were individually rinsed in river water through a 500 micrometer (μm) mesh sieve to retain benthic macroinvertebrates greater than 0.5 mm (USEPA 2007e, 1989). The recovered sediment and debris (with macroinvertebrates attached) was packed in zip-lock bags, labeled, and maintained on ice for shipment to the taxonomic laboratory under chain of custody controls (ENVIRON and MACTEC 2008a&b).

4.3.1.2.2 Hester-Dendy Sampling

Hester-Dendy artificial substrate samplers were deployed at each benthic sampling location within the Buffalo River and reference sites with the exception of RST03, at which no Hester-Dendys were deployed due to shallow water depth. Eight Hester-Dendy samplers were placed at each sampling location within the Buffalo River and seven Hester-Dendy samplers were placed at each sampling location within the reference sites. Although seven or eight Hester-Dendy samplers were deployed at each station, anticipated recovery was five samplers. In the event that more than five samplers were recovered at each location, only five samplers (chosen at random) were sent to the laboratory for taxonomic identification.

The artificial substrate samplers consist of a series of 14 round hardboard plates, separated by spacers and fastened together through their centers to a threaded eyebolt. The hardboard sampler is approximately 14 cm long and has a surface area of roughly 0.116 m^2. The Hester-Dendy samplers were attached to a rope which was weighted with a cinderblock anchor and a buoy which kept the Hester-Dendy sampler approximately 12 inches off the river bottom. The Hester-Dendy samplers were in place for 28 days.

During Hester-Dendy sampler recovery, a 500 μm net was held just downstream of the sampler in order to recover dislodged organisms. Once the Hester-Dendy sampler was secured onboard, the sampler and any organisms recovered in the net were immediately placed in a labeled zip-lock bag and placed on ice to be processed once onshore. Once onshore, each Hester-Dendy sampler was dismantled, scraped, and rinsed into a collection tray. All contents collected from the Hester-Dendy samplers were placed into a labeled zip-lock bag and placed on ice for transport to the laboratory under chain of custody controls (ENVIRON and MACTEC 2008a&b).

4.3.1.3 Benthic Macroinvertebrate Laboratory Analysis

Sediment grab samples and Hester-Dendy samples were shipped to Normandeau Associates in Pennsylvania for taxonomic identification. In the laboratory, samples were removed from ice, preserved, and sorted under a 10x magnifying lamp. Since only three ponar grab samples had more than 300 organisms, all of the organisms were sorted, enumerated, and identified. Sorted organisms were preserved and separated into vials for slide-mounted fractions (chironomids and oligochaetes) and nonmountable fractions. Chironomid larvae and oligochaetes were mounted permanently on microscope slides using CMC-10 mounting media.

Invertebrates were identified to the lowest practical taxon, typically genus-level for crustaceans and aquatic insects and family-level for most other taxa (e.g., turbellarians, annelids, and mollusks). Specific details of the invertebrate sorting, enumeration, and identification procedures were presented in the FSP and QAPP (ENVIRON and MACTEC 2008a&b). At least 10% of the chironomid head capsules in each sample were prepared in permanent mounts to inspect the mentum (mouthparts) for deformities.

4.3.1.4 Benthic Community Metric Descriptions

Multiple benthic community metrics were calculated for this assessment as specified in the FSP and QAPP (ENVIRON and MACTEC 2008a&b). Each metric provides a line of evidence about the condition of the benthic community, such as species richness and abundance. In accordance with USEPA (1999) and NYSDEC (2002) approaches, a set combination of metrics and scoring is applied to provide a statement of the benthic community impairment status for the sediment grab samples and Hester-Dendy methods. It is noted that the difference between the USEPA and NYSDEC approaches is that the USEPA approach uses a scoring approach that is directly related to a reference creek/river that is comparable to the waterway of interest. In this case, Buffalo River results were compared to Tonawanda Creek. The NYSDEC approach involves comparison to a contaminant-unimpaired reference with potentially similar sediment substrates, but it is not likely that this reference reflects dense urban development characteristic of the Buffalo River. The metrics included for consideration of the Buffalo River were:

1. **Species Richness**. The total number of species or taxa found in the sample. Higher species richness values are generally associated with higher water quality and habitat conditions (NYSDEC 2002).
2. **Abundance**. Evaluation of organism abundance between stations. Abundance is expressed as the total number of organisms recovered in the sample (USEPA 1999).
3. **Ephemeroptera, Plecoptera, and Trichoptera (EPT) Richness**. EPT denotes the total number of mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) species in the sample. Higher EPT richness values are generally associated with higher water quality and habitat conditions (NYSDEC 2002).
4. **Hilsenhoff Biotic Index (HBI)**. The HBI produces a numerical value to indicate the level of organic pollution (Hilsenhoff 1982). The HBI is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0 to 10 scale, tolerance values range from intolerant (0) to tolerant (10). Tolerance values, listed in the species list (Appendix D1 and D2), are mostly from Hilsenhoff (1977, 1982, 1987, and 1998). High HBI values are indicative of potential organic (sewage) pollution (NYSDEC 2002).
5. **Percent Model Affinity**. A measurement of similarity to a model nonimpacted community based on percent abundance in seven major groups (NYSDEC 2002, Novak and Bode 1992). Percentage similarity, as calculated in Washington (1984), is used to measure similarity to ponar samples. The model is: 20% Oligochaeta, 15% Mollusca, 15% Crustacea, 20% Non-Chironomidae Insecta, and 20% Chironomidae, and 10% Other. Scoring categories for percent model affinity are presented on Figure 4-2d.
6. **Species Diversity**. Species diversity is a value that combines species richness and community balance (evenness). Shannon-Wiener diversity values (base 2) are calculated using a formula in Weber (1973) and presented in Table 4-3. High species diversity values (Figure 4-2d) usually indicate diverse, well-balanced communities, while low values indicate stress or impact (NYSDEC 2002).

7. **Dominance**. Dominance is a simple measure of community balance, or evenness, of the distribution of individuals among the species. Simple dominance is the percent contribution of the most numerous species. Dominance-3 is the combined percent contribution of the three most numerous species. High dominance values indicate unbalanced communities strongly dominated by one or more numerous species (NYSDEC 2002).
8. **Non-Chironomid/Oligochaete (NCO) Richness**. NCO denotes the total number of species other than those in the groups Chironomidae and Oligochaeta. While Chironomidae and Oligochaeta are generally the most abundant groups in impacted communities, NCO taxa are considered to be generally intolerant of degraded physical and chemical conditions. Their presence is generally indicative of good water quality. This measure is the sandy stream counterpart of EPT richness which considers species in the event habitat to support EPT is not present (NYSDEC 2002).
9. **Chironomid Mouthpart Deformities**. Chironomid mouthparts may exhibit deformities in response to various kinds of chemical exposure, particularly in exposure to metals (Jeyasinham and Ling 1997; Bisthoven et al. 2001; MacDonald and Taylor 2006; Martinez et al. 2004, 2006).

4.3.2 Benthic Community Assessment Results

Implementation photo documentation is provided in Appendix B. Reference site sediment chemistry results are presented in Appendix E. Benthic community data are summarized below and presented in Appendix D1 and D2.

4.3.2.1 Water Quality and Habitat Assessment Scoring

Table 4-4 presents water quality measurements taken at each benthic community sampling station. These water quality measurements are typical of many freshwater systems, and show no major differences between the water bodies, with the potential exception of lower specific conductance in Tonawanda Creek (RST01, RST02, and RST03).

Table 4-5 presents the habitat assessment scores as calculated using the USEPA RBP. The habitat scores range from 56 to 134 in the Buffalo River with higher scores upstream of the AOC (i.e., habitat scores of 82 to 134 from RMs 6.25 to 7.5) as compared to locations within the AOC (56 to 85 from RMs 0.3 to 5.5). Cazenovia Creek (105) and Cattaraugus Creek (79 to 114) had similar scores to the upstream Buffalo River sites, while Tonawanda Creek (62 to 81) scored more closely to the downstream Buffalo River. These scores correspond to RBP habitat categories ranging from marginal to suboptimal habitat for benthic macroinvertebrates and demonstrate a range of water quality conditions that could support benthic communities (on a scale that spans poor<marginal<suboptimal<optimal). The comparatively higher epifauna substrate scores at BR02 and BR03 are indicative of a more diverse bottom substrate and presence of cover at these sites, which is consistent with the particle size characterization discussed in Section 2 of this report (Figure 2-15).

4.3.2.2 Benthic Community Metrics

Benthic community metrics were calculated separately for sediment grab and Hester-Dendy samples using the benthic metric procedures defined in Table 4-3 with sediment grab results presented in Tables 4-6a and 4-6b and Hester-Dendy results presented in Table 4-9 and 4-10 for location specific and mean location metric summaries, respectively. The full data set is presented in Appendices D1, D2, and D3 including graphics illustrating a comparison of sediment grab and Hester-Dendy metrics per location. Overall NYSDEC and USEPA impairment status results for sediment grab samples are presented in Tables 4-7a and 4-7c (respectively) and Hester-Dendy samples in Tables 4-11a and 4-11b (respectively). The summary of metric means for the sediment grab samples for the four water bodies is provided on Figures 4-2a and 4-2b, along with the qualitative habitat assessment scoring, and impairment status ratings per USEPA and NYDEC methods.

4.3.2.2.1 Sediment Grab Sample Metrics

The following metric results are briefly described (Figure 4-2a and 4-2b, note that numbers mentioned in the text may be rounded; Appendix D1 has precise measures for each replicate and summary statistics per location). Overall NYSDEC and USEPA impairment status results are provided following the metric descriptions below.

1. **Species Richness** is generally similar among locations upstream and downstream in the Buffalo River (Figure 4-2a), with average metrics from the five replicates ranging from 5.6–14 species per location upstream (BR01, BR02, and BR03) and 5.2-13 species per location downstream (BR04-BR08), Cazenovia Creek (7.2 species), Cattaraugus Creek (3.6-8.8 species per location), and Tonawanda Creek (5.2-6.6 species per location).
2. **Abundance** of organisms is highest in the downstream Buffalo River. Abundance is higher in the Buffalo River than in Tonawanda and Cattaraugus Creeks. The locations in the Buffalo River range from 20 organisms at RM 6.8 to 253 organisms at RM 0.3. Abundance values were higher in the AOC portion of the Buffalo River (120 to 250), than the portion upstream of the AOC (20 to 130).
3. **EPT Richness** is low in the four water bodies. The Buffalo River data (EPT richness = 0.65) are strongly influenced by one ponar grab replicate at RM 5.5 (BR04-PP1 included 12 *Caenis sp.* mayflies). The Buffalo River EPT richness value excluding the replicate BR04-PP1 is 0.3. The AOC portion of the Buffalo River had lower EPT values (0.0-0.2) than the Buffalo River upstream of the AOC (0.4-0.8), when BR04-PP1 is excluded. Tonawanda Creek and Cattaraugus Creeks both had EPT values similar to the AOC portion of the Buffalo River.
4. **Hilsenhoff Biotic Index** values are very close to 10 (the maximum value) in the four water bodies, which indicates communities tolerant of organic pollution. The mean HBI value for Buffalo River upstream locations (9.12) was slightly lower than the downstream location (9.85). These values are comparable to Cazenovia Creek (9.67) and Tonawanda Creek (9.59), but higher than Cattaraugus Creek (8.81).
5. **Percent Model Affinity** is low in the four water bodies, indicating that the samples are only about 16% to 30% similar to the community from an idealized clean-water sample. The AOC portion of the Buffalo River had a similar value (mean 30%) compared to the upstream portion (mean 27%). Values for Tonawanda Creek (mean 16%) and Cattaraugus Creek (mean 23%) were lower than similarity values from the Buffalo River.
6. **Species Diversity** values are uniformly low throughout the sampling areas. The upstream portion of the Buffalo River tended to have higher values (mean 1.78) than the AOC portion of the Buffalo River (mean 1.29). Cazenovia Creek had a lower species diversity index value (mean 1.12) than

Buffalo River. The species diversity values for Tonawanda and Cattaraugus Creeks (means of 1.76 and 1.58, respectively) were slightly higher than the upstream portion of the Buffalo River.

7. **Dominance** values are considered high in the sampling areas, 51% to 79% of the organisms are of one species. In the four water bodies, the most common organism is the tubificid worm, (Oligochaeta) *Limnodrilus sp*. Dominance-3 values were slightly lower in the upstream portion of the Buffalo River (mean of 85%) than the AOC portion (mean of 94%). Cazenovia Creek dominance-3 (mean 94%) was similar to the upstream Buffalo River locations. Dominance-3 values in Tonawanda and Cattaraugus Creeks similar to those of the AOC portion of the Buffalo River.

8. **NCO Richness** is low across the samples. Dominance values in the four water bodies generally show that the samples are strongly dominated by one species of oligochaete. Trends in value between the upstream and AOC portions of the Buffalo River were not discernible (upstream Buffalo River mean of 4.6; Buffalo River AOC mean of 5.24). NCO values for Tonawanda and Cattaraugus Creeks (means of 3.13 and 2.6, respectively) tended to be somewhat lower than those calculated for the Buffalo River. Comparing NCO richness to species richness values for each site indicates generally higher proportions of NCO organisms were present in AOC samples as compared to upstream samples.

9. **Chironomid Mouthpart Deformities** occur at a rate within the AOC consistent with that seen upstream of the AOC (in the Buffalo River and Cattaraugus Creek) and within the Tonawanda reference area with the exception of location BR06 (RM 2.1) where 2 of 6 chironomids had deformities (i.e., 33%). These results are discussed further in a comparison of sediment grab and Hester-Dendy results for this metric.

Overall NYSEC and USEPA Impairment Status Designations

Two additional indices were calculated to compress the data into a single index value. NYSDEC (2002) has published guidance on using a variety of metrics to calculate an index value for sediment grab samples for soft sediments. A graphical scale is used to combine five metrics that are based on water quality (i.e., species richness, species diversity, the HBI, dominance-3, and percent model affinity) into an overall determination of water quality impact. Figure 4-2d presents the NYSDEC scaling system for both sediment grab samples from soft sediments and from multiplate samples from navigable waters. The NYSDEC calculations are presented for the sediment grab samples in Table 4-7a. The USEPA also has a system to combine and scale metrics, but unlike the NYSDEC method, the metrics are scaled against a reference site, as described in Table 4-7b (USEPA 1989). Each result metric (Table 4-7c) is given a score (0-6) based on comparability to a reference station (upper part of Table 4-7b for criteria and Table 4-7c for scores). Scores are totaled and a Biological Condition Category is assigned based on a percent comparability with the reference station score (bottom part of Table 4-7b). For this analysis, the data from Tonawanda Creek were used as the reference location because it most represents an urban river with similar land use and substrates (excluding industrial inputs). The USEPA calculations are presented for the sediment grab samples in Table 4-7c and results are illustrated on Figures 4-2a and 4-2b.

In general, the NYSDEC water quality impact determination for the Buffalo River locations, including those upstream of the AOC, range from moderate (at RM 7.25, RM 5.5) to severe (at the other stations) (Figure 4-2a and 4-2b). The reference areas are severely impacted using the NYSDEC metrics, with the exception of one location at Cattaraugus Creek that was moderately impacted. The USEPA water quality impact determination for the Buffalo River AOC generally shows areas are slightly impacted to moderately impacted compared to the Tonawanda Creek reference for all of the stations (Table 4-7c, Figure 4-2a and 4-2b).

4.3.2.2.2 Hester-Dendy Sample Metrics

Table 4-8 lists the number of samplers deployed and recovered at each station[6]. The calculated metrics for the Hester-Dendy samples are summarized in Table 4-9, with results illustrated on Figures 4-2a and 4-2b. The full data set is presented in Appendix D2. The summary of mean metrics for the Hester-Dendy samples for the four water bodies is provided in Table 4-10.

Overall NYSEC and USEPA Impairment Status Designations

NYSDEC (2002) also has published guidance on using a variety of metrics to calculate an index value for Hester-Dendy (multiple plate) samples from navigable waters (Table 4-11a). Similar to that described for sediment grab samples, a graphical scale is used to combine species richness, species richness, HBI, EPT richness, species diversity into an overall determination of water quality impact (Figure 4-2d). These calculations are presented for the Hester-Dendy samples in Table 4-11a. The USEPA approach for Hester-Dendy samplers is similar to that already described for sediment grab samples. The Hester-Dendy results for the Buffalo River are compared to Tonawanda Creek (Table 4-11b).

The NYSDEC water quality impact determination for the Buffalo River locations, including those upstream of the AOC, range from slight at most locations to moderate at three locations (RM 4.75, RM 6.8, and RM 7.25) (Table 4-11a, Figure 4-2a and 4-2b). Note that two of the three locations identified as moderately impaired are upstream of the AOC. Only one location of all those evaluated was identified as non-impaired using the NYSDEC approach (Cattaraugus Creek). Using the USEPA approach with Tonawanda as a reference location, the majority of the locations are designated as slightly impaired, with the exception of three moderately impaired locations (RM 4.75, RM 5.5, and RM 6.8) and two slight to moderately impaired locations (RM 6.25 and RM 7.25) (Table 4-11b, Figure 4-2a and 4-2b).

4.3.2.2.3 Comparison of Sediment Grab Samples and Hester-Dendy Metrics

Comparisons of sediment grab and Hester-Dendy metric results for species/family richness and percent dominance/chironomid deformities are presented in Figures 4-2e and 4-2f, respectively. The full suite of metrics are graphically illustrated and compared in Appendix D3 (along with full tabular results for each replicate at each location). This comparison is provided for qualitative purposes only because the sampling methods are not directly comparable (the sediment grab samples generally characterize those organisms within or directly on the surface of the sediment and the Hester-Dendy approach characterizes organisms that live just above the sediment column). The differences between these approaches reflect both the potential impacts related to chemicals in sediment and differences in habitat (i.e., the muddy sediment does not provide the same quality as more open surfaces provided by the Hester-Dendy samplers). As indicated in Figure 4-2e, species richness is significantly higher in the Hester-Dendy samplers than those seen in the sediment grab samples. For example, Tables 4-6a and Table 4-9 show that EPT species are found in much higher numbers in the Hester-Dendy samplers in comparison to the sediment grab samples. EPT species preferentially seek stable habitats, such as cobble and woody debris,

[6] At sample locations BR04, RSC01, RSC02, and RST03 only four samplers were recovered.

where optimal species-specific foraging strategies can be implemented (e.g., net spinning, building and securing encasements, and crevices where predation can occur). Similarly, species such as scrapers (i.e., those that scrape algae from cobble surfaces) and shredders (those that consume organics, such as degrading leaves) were present in higher numbers in the Hester-Dendy samplers than those seen in the sediment grab samples. These findings show that organisms lacking habitat in fine grained sediment (organisms that are not typically sampled using the sediment grab approach) are present in the river. Previous studies focused on fine grained sediments have not identified the presence of these species in the river.

Percent dominance is another metric that is important to compare between sediment grab samples and Hester-Dendy because it provides information about diversity of the benthic community. Past studies on sediment grab samples from the Buffalo River have demonstrated the majority of the benthic community is dominated by only a few tolerant species. The 2008 findings in sediment grab samples also show some elevated percent dominance estimates, particularly at RM 4.75 (BR05) where the highest percent dominance was seen from any grab sample. As indicated in Figure 4-2f, and somewhat to be expected based on the species and family richness results described above, the percent dominance is lower in many of the Hester-Dendy samplers in comparison to the sediment grab samples.

Chironomid mouthpart deformities have been identified as a metric of potential relevance to metals toxicity (Irvine et al. 2005). Figure 4-2f presents a comparison of Hester-Dendy and sediment grab results, showing that with the exception of location BR06 (RM 2.25), all of the locations sampled had deformities within the range of deformities seen at reference locations (the maximum number of deformities seen at a reference was approximately 15% seen in Cattaraugus Creek location RSC01). Location BR06 (RM 2.1) showed the highest percent deformities, but this is at least in part due to the low number of chironomids seen, as these findings reflect only 2 organisms with deformities (i.e., 2 of 6 chironomids had deformities; 33%). Hester-Dendy samplers showed lower chironomid deformities than seen in sediment grab samples. There are no apparent trends in deformities within the 2008 data sets, but it is notable that the overall percentages of mouthpart deformities were lower than those reported by Irvine et al. (2005). Specifically, Irvine et al. stated that historic studies have shown 10-46% deformities and the 2003/2004 study showed up to 54% deformities in one location. These 2008 study findings show that reference locations, such as Cattaraugus Creek, can have up to 15% deformities, and the majority of locations fall well below that percentage (0% – 3% deformities were found in Hester Dendy samples, 0 – 33% deformities were found in sediment grab samples, Appendix D3), and well below the 54% seen in 2003/2004.

Sediment grab samples were collected for the Buffalo River and reference locations using identical methods and with identical numbers of replicates per location, unless specifically noted as such in the report (e.g., the occasional missing Hester-Dendy). The fact that some metrics are higher in the Buffalo River compared to the references may be due to issues of natural variability in the biological communities and variability in sediment characteristics (notably, there were no observations of cobble, gravels, or woody debris that explain such differences). These results appear to show that the presence of chemical pressures on the benthic community does not have an equal impact on all of the available metrics. Some metrics may be more susceptible to chemical influences than others (e.g., the metric abundance may look good in a contaminated area but a concurrent metric in the same area, such as diversity, may show impairment).

4.4 Fish Community Assessment

Fish community sampling provides taxonomic information on the population and community structure of Buffalo River and Cazenovia Creek, as well as information on the pre-remediation baseline conditions. Fish communities were evaluated within five locations in Buffalo River and one location in Cazenovia Creek, upstream of the AOC.

4.4.1 Methods

4.4.1.1 Sampling Locations

Fish community sampling reaches were included in this assessment as indicated on Figure 4-3:

- One on Cazenovia Creek upstream of the AOC (CC)
- Three on the Buffalo River upstream of the AOC (BR1 at RM 7.5, BR2 at RM 6.8, and BR3 at RM 6.25)
- Two on the Buffalo River within the AOC (BR4 at RM 5.5 and BR5 at RM 4.5)

Preliminary site reconnaissance determined specific sampling locations, based on the identification of similar habitats among the locations. This ensured representative sampling of the fish community at each site.

4.4.1.2 Habitat Assessment and Water Quality

Because physical habitat characteristics often are linked to fish community richness, a habitat assessment was performed using the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989). The objective was to provide a quantifiable comparison of habitat characteristics at survey stations within and outside of the AOC to provide additional habitat baseline information against which remediation alternatives can be evaluated. The index itself is most frequently used in wadeable streams but can be applied to any system with flowing water. Example metrics used in the method included: types of substrate particles present; estimation of percentage composition of major substrate types; qualitative estimation (heavy, moderate, slight) of siltation; presence and estimated quantities of instream cover elements (e.g., overhanging vegetation, undercut banks, rootwads, macrophytes); width, vegetative cover, and erosion characteristics of the riparian zone; and predominant land use in the floodplain. In addition, water quality parameters, including temperature, dissolved oxygen, conductivity, pH, and Secchi Depth (meters), were recorded at each electroshocking location.

4.4.1.3 Fish Community Sampling

Fish were collected under the scientific collection permit approved by NYSDEC on September 22, 2008 (Appendix C). Field sampling techniques followed those specified in the FSP and standard operating procedures (SOPs) for fish collection methods (ENVIRON and MACTEC 2008a&b) and were applied based on available habitat. A similar level of effort was implemented at each site to ensure data comparability. Sampling relied primarily on electroshocking of near-shore and shallow areas.

Electroshocking was conducted with an 18-foot jon boat equipped with a boat-mounted Smith-Root electrofishing unit. Collection effort for each electroshocking run was approximately 15 minutes. Shocking time for each site was recorded, as well as specific habitat types assessed. For the farthest upstream Buffalo River location, seining was used as a secondary collection technique. This was the only location that was shallow enough to allow for effective seining.

Captured fish from each location were immediately placed into a holding tub filled with site water. Once electroshocking was completed for each location, each individual fish, excluding larvae, was removed from the holding tank and examined by a trained biologist to identify each fish to the species level, using standard taxonomic references, and enumerate any external lesions, anomalies, and parasites. Total length to the nearest 0.5 cm and weight to the nearest gram (g) were recorded for each fish. Three voucher specimens were preserved in 10% formaldehyde and stored in labeled jars for subsequent laboratory species verification. With the exception of a these voucher specimens, all collected fish were returned alive to the site in which they were collected.

4.4.1.4 Fish Community Metric Descriptions

Widely-recognized fish community metrics were utilized that evaluate key community attributes (e.g., species composition, diversity, indicator species, trophic status, abundance) and individual fish health (e.g., condition index), as detailed below, with metric calculation formulae defined in Table 4-12.

1. **Total Taxa**. The total number of species or taxa found within each site. This number decreases with increased degradation; hybrids and introduced species are not included. The number of species is strongly affected by stream size in most small warmwater streams but not at large river sites (USEPA 1999, Ohio EPA 1987).
2. **Percent Centrarchids**. Generally, the sunfish family is moderately tolerant of pollution (USEPA 1999). However, intolerant species are represented by fishes such as the smallmouth bass and flier. Certain taxa within family Centrarchidae are notorious for hybridizing. Most notably, the genus *Lepomis*, which freely hybridizes under a variety of conditions, and hybrids may be more commonplace in degraded streams (USEPA 1999). The number of sunfish species may be dependent on stream size in small streams, but Ohio EPA (1987) found no relationship between stream size and sunfish species in medium to large streams.
3. **Percent Catostomidae**. Suckers are sensitive to physical and chemical habitat degradation and commonly comprise most of the fish biomass in streams. Most species are long-lived and provide a multiyear integration of physicochemical conditions. The richness of these species is a function of stream size in small and medium sized streams, but not in large (e.g., non-wadeable) rivers (USEPA 1999).
4. **Percent Cyprinidae**. Pollution tolerance among the cyprinids (carp and minnows) varies from species to species. Generally, minnows are pool species that decrease in abundance with increased degradation of pools and instream cover (Gammon et al. 1981, Angermeier 1987, Platts et al. 1983). Most of these fishes feed on drifting and surface invertebrates and are active swimmers (USEPA 1999).
5. **Percent Dominant Specie**s. Dominance is a simple measure of community balance or evenness of the distribution of individuals among the species. Simple dominance is the percent contribution of the most numerous species. High dominance values indicate unbalanced communities strongly dominated by one or more very numerous species (USEPA 1999).

6. **Similarity Index**. The Jaccard Similarity Index is a simple statistical measure to determine the similarity of different data sets (e.g., reference data and site data).

7. **Species Diversity**. Species diversity is a value that combines species richness and community balance (evenness). Shannon-Wiener diversity values are calculated using the formula in Weber (1973). High species diversity values usually indicate diverse, well-balanced communities, while low values indicate stress or impact.

8. **Percent Tolerant/Intolerant Species**. This metric distinguishes high and moderate quality sites using species that are intolerant of various chemical and physical perturbations. Intolerant species are typically the first species to disappear following a disturbance. Species classified as intolerant or sensitive should only represent the 5 to 10% most susceptible species. The number of sensitive and intolerant species increases with stream size in small and medium sized streams but is unaffected by size of large (e.g., non-wadeable) rivers. Tolerance values are based on the USEPA (1999) and Halliwell (1999) for the northeastern United States (Appendix F).

9. **Percent Omnivores**. The percent of omnivores in the community increases as the physical and chemical habitat deteriorates (USEPA 1999). Omnivores are defined as species that consistently feed on substantial proportions of plant and animal material (USEPA 1999).

10. **Percent Top Carnivores**. The top carnivore metric discriminates between systems with high and moderate integrity (USEPA 1999). Top carnivores are species that feed, as adults, predominantly on fish, other vertebrates, or crayfish.

11. **Abundance**. This metric evaluates population abundance and varies with region and stream size for small streams. It is expressed as catch per unit effort, either by area, distance, or time sampled. Generally sites with lower integrity support fewer individuals, but in some nutrient poor regions, enrichment increases the number of individuals. In larger streams, where sizes of fish may vary in orders of magnitude, total fish biomass may be an appropriate substitute or additional metric (USEPA 1999).

12. **Condition Factor.**[7] The fish condition factor, or coefficient of condition (K), is generally expressed as the ratio of fish weight to length. Variations in a fish's coefficient of condition primarily reflect state of sexual maturity, degree of nourishment, and age. Generally, larger ratios indicate robust, well-nourished fish.

4.4.2 Fish Community Assessment Results

Fish community data are summarized below and provided in Appendix F. Implementation photo documentation is provided in Appendix B.

4.4.2.1 Habitat Assessment and Water Quality

With respect to water quality values observed at each electrofishing location, conductivity was noticeably higher at the three locations upstream of the Buffalo River AOC and at the Cazenovia Creek location when compared to the two locations within the Buffalo River AOC (Table 4-13a). Temperatures on the other hand, exhibited higher values for the two locations within the AOC and lower values in the

[7] An alternative approach (i.e., length/width) to calculating condition factor for fish is presented in the *FSP* and *QAPP* (ENVIRON and MACTEC 2008a&b). Since fish width was not measured in the field, the condition factor is calculated as the ratio of fish weight to length.

locations upstream of the AOC. These spatial trends observed in conductivity and temperature do not clearly relate to fish abundance. Secchi depths in the Buffalo River ranged from 0.5 to 1.5 and at the Cazenovia Creek location was 1.8 (Table 4-13a). While there can be significant seasonal variations (Irvine et al 2005)[8] dissolved oxygen and pH did not exhibit any apparent spatial patterns in the values observed.

Tables 4-13a and 4-13b present the habitat assessment scores, as calculated using the QHEI (Rankin 1989). QHEI scores ranged from 51 to 59, which correspond to fair habitat quality. The QHEI assessment did not demonstrate any observable differences among the Buffalo River and Cazenovia Creek sample locations.

4.4.2.2 Fish Community Sampling

During the September and October 2008 fish community survey, a total of 23 distinct species were collected by electroshocking. Seining was only conducted at location BR1 and resulted in the collection of six species. The only species unique to seining that was not collected in electroshocking collections was the emerald shiner (*Notropis atherinoides*). Eleven species were collected on the Buffalo River at the three locations upstream of the AOC (RM 6.25 to RM 7.5), while 13 species were collected in the Buffalo River at the two locations within the AOC (RM 4.5 and RM 5.5). The one electroshocking location on Cazenovia Creek (CC) resulted in the collection of 12 species (Appendix F).

Bluegill (*Lepomis macrochirus*), bluntnose minnow (*Pimephales notatus*), common shiner (*Luxilus cornuta*), largemouth bass (*Micropterus salmoides*), and pumpkinseed (*Lepomis gibbosus*) were collected at all six fish community sampling locations. The common carp (*Cyprinus carpio*) was collected at all five of the Buffalo River sampling locations, but not collected within Cazenovia Creek. Species collected at locations upstream, but not within the AOC, included American brook lamprey (*Lampetra appendix*), bigeye chub (*Hybopsis amblops*), brown bullhead (*Ameiurus nebulosus*)[9], rainbow trout (*Oncorhynchus mykiss*), smallmouth bass (*Micropterus dolomieui*), and spottail shiner (*Notropis hudsonius*). Conversely, species collected within, but not upstream of the AOC, included Johnny darter (*Etheostoma nigrum*), smallmouth buffalo (*Ictiobus bubalus*), spotted sucker (*Minytrema melanops*), and yellow bullhead (*Ameiurus natalis*).

Catch per unit effort (CPUE), expressed as number of fish per hour is summarized in Table 4-14a. CPUE ranged from 86 fish/hour (RM 7.25) to 325 fish/hour (RM 4.5). With the exception of the sampling location at RM 4.5, the Cazenovia Creek location (CC) resulted in a higher CPUE (188 fish/hour) than the other Buffalo River locations. However, considering the range and magnitude of CPUE values (86 to 325, with the lowest value at the farthest upstream station), the Cazenovia Creek CPUE (188) is comparable to the average CPUE value (217) for the two most downstream locations (RM 5.5 and RM

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[8] Generally seasonal variations in water quality parameters exist in aquatic environments. For example, the concentration of dissolved oxygen (DO) in solution is inversely proportional to temperature, typically resulting in higher DO concentrations during the cooler months of late fall to early spring compared to warmer summer months. Irvine et al (2005) monitored several water quality parameters within the Buffalo River, including dissolved oxygen (DO) and pH, for approximately 17 weeks in 2003 and 2004 and states that parameters exhibited a level of seasonality.

[9] Brown bullhead were collected within the AOC as part of a separate brown bullhead collection event. However, no brown bullheads were collected within the AOC during the fish community assessment sampling event.

4.5). The Centrarchidae family (sunfishes) and Cyprinidae family (minnows) contributed to the majority of the CPUE totals at every location. These two families represent 70% of the CPUE from RM 7.5, 69% from RM 6.8, 78% from location RM 6.25, 87% from RM 5.5, 82% from RM 4.5, and 90% from location CC. The three locations upstream of the Buffalo River AOC had an average CPUE of 105 fish per hour, while the two locations within the AOC had an average CPUE of 217 fish per hour.

Fish collected during the fish community survey seemed to be in good health. However, a small portion did exhibit some abnormalities. Approximately 2% of the fish collected during the fish community assessment exhibited external evidence of DELTs, as described by Ohio EPA (1987). Other fish anomalies noted during the fish community survey are included in Appendix F. Spatially, the locations within the AOC were observed to have a slightly higher incidence of fish with DELTs (4%) compared to the locations upstream of the AOC (1%). A summary of the DELTs observed in the fish collected during the fish community assessment is presented in Table 4-14b.

4.4.2.3 Fish Community Metric Results

Calculated metrics for the fish community at each sampling location within the Buffalo River and Cazenovia Creek are presented in Table 4-15a and Figures 4-3 and 4-4. The full data are presented in Appendix F. A summary of the metrics for Cazenovia Creek, the Buffalo River AOC, and Buffalo River upstream of the AOC is presented in Table 4-15b and below.

1. **Total taxa**. The highest number of taxa (15) was collected from the farthest upstream and downstream locations in the Buffalo River (i.e., RM 7.5 and RM 4.5). The lowest number of taxa (8) was collected from the Buffalo River upstream of the AOC (i.e., RM 6.8).
2. **Percent Centrarchids**. Centrarchids make up the largest percentage of the fish assemblage in the downstream portions of Buffalo River and the AOC. The percentage of Centrarchids collected in Cazenovia Creek (27%) is similar to the number of Centrarchids collected at the upstream Buffalo River locations (mean of 39%), but is almost half of the Buffalo River AOC (mean of 54%) Centrarchids.
3. **Percent Catostomidae**. The percentage of suckers collected in Buffalo River AOC (mean 4.9%), upstream Buffalo River (mean 4.5%) and Cazenovia Creek (mean 6.3%) are relatively low and vary little among the locations.
4. **Percent Cyprinidae**. Cazenovia Creek (mean 63%) and the upstream Buffalo River locations (mean 41%) had the highest percentage of Cyprinidae collected. In the Buffalo River AOC, the percentage of Cyprinidae collected (mean 31%) was nearly half of the values observed in upstream Buffalo River and Cazenovia Creek.
5. **Percent dominant species**. Cazenovia Creek was strongly dominated by the bluntnose minnow, *Pimephales notatus* (54% dominance). The dominant species in the Buffalo River locations varied but comprised approximately 33% of the Buffalo River AOC and upstream Buffalo River locations.
6. **Similarity Index**. Similarity was compared to Cazenovia Creek. Mean similarity index in Buffalo River AOC locations and upstream Buffalo River locations were 62% and 72%, respectively. Buffalo River sampling locations that were closest to Cazenovia Creek were the most similar to Cazenovia Creek. Similarity decreased with increasing distance from Cazenovia Creek.

7. **Species diversity index**. Fish species diversity was similar among the Buffalo River AOC (2.0), Buffalo River upstream (1.9) and Cazenovia Creek (1.7) locations.
8. **Percent tolerant species**. The highest percentage of tolerant species was calculated for Cazenovia Creek (56%). Percent tolerant species were lower in the Buffalo River AOC and upstream Buffalo River locations (mean of 31%)
9. **Percent intolerant species**. Similar to the percent tolerant species, the highest mean percentages of intolerant species were calculated for Cazenovia Creek (2.1%). The upstream Buffalo River locations mean percent intolerant species was 0.73%. The lowest incidence of intolerant species occurred in the Buffalo River AOC (mean of 0.60%).
10. **Percent omnivores**. The percentage of omnivores within the fish community was similar in Cazenovia Creek (56%) and the upstream Buffalo River locations (mean of 45%). The Buffalo River AOC had a much lower percentage of omnivores (mean of 34%).
11. **Percent top carnivores**. For this evaluation, piscivores were considered the top carnivores of the fish community. Cazenovia Creek and the Buffalo River upstream locations had similar percentages of top carnivores (means of 23% and 17%, respectively). In contrast, top carnivores comprised 32% of the Buffalo River AOC locations.
12. **Abundance**. This metric was calculated using only time spent electroshocking, as this was the one collection technique that was used at all six sites. Both the farthest upstream (RM 7.5) and downstream (RM 4.5) locations in Buffalo River had the highest abundance values.
13. **Condition factor**. Condition factors calculated for the Buffalo River were very similar (1.1 to 1.4). The condition factor for Cazenovia Creek was slightly lower at 0.98.

Overall NYSDEC and USEPA Impairment Status Designations

Two approaches were also considered to merge the metric data into a single index value. NYSDEC (2002) has published guidance on using a variety of metrics to calculate an index profile value for water quality using fish community information. A profile value is calculated using species richness (weighted), percent non-tolerant/intermediate individuals, percent non-tolerant/intermediate species, and percent model affinity (by trophic class). The NYSDEC calculations are presented in Table 4-16a. The NYSDEC approach results in a classification of moderate (RM 4.5 and RM 7.5) to severe impairment (RMs 5.5 to 6.8) for Buffalo River and severe impairment for Cazenovia Creek. Similarly, calculation of the IBI results in a classification of fair (RM 4.5, RM 6.25, and RM 7.5) to poor (RM 5.5 and RM 6.8) for Buffalo River and poor for Cazenovia Creek.

An Index of Biotic Integrity (IBI) is also based on a method to combine multiple metrics into a single, scaled metric. Irvine et al. (2005) calculated an IBI for ten Buffalo River locations based on nine metrics (species richness, total number of insectivore species, total number of sunfish/Cyprinidae species [excluding carp and goldfish], percent tolerant individuals, percent omnivorous individuals, percent insectivorous individuals, percent individuals as top carnivores, total number of individuals caught, percent individuals with DELTS). These nine metrics were modified from the original 12 IBI metrics developed by Karr (1981) to take into account regional conditions. Greer et al. (2002) calculated IBI scores for Cazenovia Creek using nine slightly different metrics than Irvine et al. (2005) (i.e., species richness, number of benthic species, number of intolerant species, % tolerant species, % generalist feeders, % insectivorous species, % top carnivores, individuals per unit area, proportion of individuals with DELTs). The IBI calculations for Buffalo River and Cazenovia Creek are presented in Table 4-16b and are illustrated on Figures 4-3 and 4-4. The fish community in the Buffalo River is identified as fair to poor using the IBI designation. A comparison of the IBI values for each of the 2008 locations is provided in Figure 4-4. As shown, the IBI values and the metrics that comprise these IBIs are similar among locations upstream of the AOC and those upper reaches of the AOC included in the fish community analysis. There are no significant gradients in either the IBI or the individual metrics that comprise the IBI (Figure 4-4). Figure 4-4 also shows locations from the 2003/2004 fish community studies presented in Irvine et al. (2005). Where IBIs overlap (locations BR02, BR04, and BR05), IBIs seen in 2008 exceed those seen in 2003/3004.

4.5 Brown Bullhead Histopathology

4.5.1 Methods

4.5.1.1 Fish Collection, Processing, and Calculation of Somatic Indices

The prevalence of liver tumors and external lesions in brown bullheads was assessed in three zones within the Buffalo River AOC (Figures 4-5a and 4-5b). In general, fish were collected at twilight and night using electroshocking techniques although some fish were collected using gill nets. Fish size was estimated visually and confirmed at the necropsy field area in the Erie Basin Marina parking lot.

As discussed in Section 4.4, specific habitats assessed and general shocking times were recorded for each site. Brown bullheads less than 25 cm (standard length) were tagged with Visual Identification (VI) Alpha tags as described in the *FSP* and *QAPP* (ENVIRON and MACTEC 2008a&b). Brown bullheads of approximately 25 cm length were placed in aerated tubs for live transport to the necropsy area. Thirteen such fish were collected from RM 5.6-6.25, sixteen from RM 3.4-4.6, and eight from RM 1.25-1.9.

Once at the necropsy area, brown bullheads were euthanized using an overdose of tricaine sulfonate (MS222) and weight, length, and gross external lesions were recorded. The abdominal cavity of the fish was then opened and the liver removed and weighed to the nearest 0.1g. The gall bladder was separated from the liver and the contents emptied into a plastic serum vial and frozen on dry ice. The first dorsal spine was excised and treated in the same manner. The remaining carcass was placed in a one-gallon plastic zip-lock bag and frozen on dry ice. The bile, dorsal spine, and carcass were shipped to the NYSDEC Hale Creek Field Station in Gloversville, New York where they were archived for possible further analyses. Fish bile, dorsal spines, and carcasses were assigned individual identification codes by river reach as described in the *FSP* and *QAPP* (ENVIRON and MACTEC 2008a&b).

The liver was examined externally for gross lesions and then sliced into 2 to5 mm thick slices. These were transferred to 10% buffered formalin for 24 to 48 hours. Livers were assigned the same identification codes as described above. After 24 to 48 hours the liver slices were drained and transferred to 10% sucrose solution for shipment, on ice, to the School of Veterinary Medicine at North Carolina State University (NCSU). Here the tissue slices were dehydrated and embedded in paraffin and sections cut for microscopic evaluation by Dr. David Hinton, (Ph.D., Nicolas Professor of Environmental Quality, Duke University) and Dr. Mac Law (DVM, Ph.D., Diplomat of the American College of Veterinary Pathologists, NCSU). At NCSU, new sample identifiers were assigned to each liver so that all histopathic slide reading was conducted blind. Multiple sections were cut and hepatic lesions were evaluated in three to four slices from the three different lobes of the liver. The blind-read analyses of hepatic lesions were provided to ENVIRON for statistical analyses.

Two different general indicators of fish health, condition factor (K) and hepatosomatic index (HSI) were also evaluated. K is a general measure of "fatness" and HSI is a measure of the liver mass relative to the whole body mass. Liver mass usually increases with exposure to chemicals that require metabolism to be eliminated from the body. K and HSI were calculated as:

$$K = \frac{100{,}000\ x\ Body\ Mass\ (g)}{(Body\ Length\ (mm))^3}$$

and

$$HSI = \left(\frac{Liver\ Mass\ (g)}{Whole\ Body\ Mass\ (g)} \right) x\,100.$$

4.5.1.2 Statistical Analyses

Statistical analyses of whole body mass, length, K, HSI and incidence of specific lesions were conducted using standard statistical techniques. The data were analyzed by normality testing followed by one-way ANOVA and pairwise multiple comparison tests using Sigma Stat 3.5 (Systat Software, Pt. Richmond, CA). Statistical significance was assigned at alpha 0.05.

Brown bullhead gross external lesions, internal lesions, and condition indices were calculated based on field-collected data. Brown bullhead liver tumor prevalence was determined by the histopathology laboratory and validated by ENVIRON.

4.5.2 Fish Histopathology Results

Brown bullhead histopathology data are provided in Appendix G. Results of the histopathological evaluation are provided in Table 4-17a. Body length, mass, condition factor, and hepatosomatic index results are presented in Table 4-17b. Both internal and external lesions are described in the following subsections.

4.5.2.1 Microscopic and Gross Internal Lesions

Normal brown bullhead hepatic structure is shown in Figure 4-5c. The hemotoxylin-stained cells (blue) are exocrine pancreas cells surrounding very pale-stained endothelial cells of a blood vessel which contains red blood cells. Other non-stained areas are also blood vessel sinusoids lined by endothelium. The pale eosin-stained cells (pink) are glycogen-rich hepatocytes arranged in tubules. Neoplasms were found in only three of the thirty-seven fish (i.e., 8.1%) collected from the Buffalo River contained hepatic neoplastic lesions (Table 4-17a, Figure 4-5c). One tumor was found in each of the river reaches evaluated. Hepatocellular carcinomas were found in RM 1.25 to 1.9 and 5.6 to 6.25. One hepatocellular adenoma was found in RM 3.4 to 4.6. The carcinoma from RM 1.25 to 1.9 was observed in all three lobes of the liver sectioned and is composed of densely-packed, glycogen-poor hepatocytes without apparent tubular structure (Figure 4-5c). The carcinoma extended into surrounding apparently normal hepatocytes. The hepatocellular carcinoma from RM 5.6 to 6.25 was very similar to an eosinic focus but was larger than usual for an altered focus. It was only observed in one liver lobe. The hepatocellular adenoma from RM 3.4 to 4.6 was small and only observed in one liver lobe. No neoplastic lesions of the biliary system were found. The largest hepatocellular carcinoma was found in the largest of the fish collected and this fish was collected in RM 1.25-1.9 (Figure 4-5a), the reach closest to Lake Erie.

All of the remaining internal lesions were associated with infestations of trematode parasites (Figure 4-5c) or fungal or protozoan infections (Table 4-17a). Externally visible abnormalities of the liver were only observed in RM 3.4-4.6 fish. These abnormalities consisted of: 1) small, raised, white spots of approximately 1 mm diameter, 2) pale liver coloration, 3) apparent bile ducts. However, there was some variability in the condition of the fish. In RM 3.4-4.6, one fish exhibited parasites and clear blebs in the gut cavity, while another fish exhibited a larger than normal quantity of mesenteric fat, indicating a healthy fish.

RM 3.4-4.6 fish also exhibited a greater number of internal non-neoplastic hepatic lesions than fish from either RM 1.25-1.9 or RM 5.6-6.25 (Figure 4-5a). In particular, there was a greater incidence of foci of hepatocellular alterations. These foci included eosinophillic and reactive foci (Figure 4-5c), granulomas and melanomacrophage aggregates associated with encysted trematode worm parasites. The reactive foci were associated with the biliary system and some degree of biliary fibrosis and are also likely associated with parasitic infestations of the liver but the parasite was not always captured in the tissue slices. One RM 3.4-4.6 fish exhibited fungal hyphae in the liver parenchyma and one RM 1.25-1.9 fish exhibited an intralesional protozoan parasite in the liver parenchyma. Parasitic infestations are not uncommon in wild fish. Bile duct proliferation occurs in response to myxozoan parasites and duct ligation leads to hypertrophy and hyperplasia in rainbow trout (Okihiro and Hinton 2000), but it is unknown if bile stasis due to duct blockage contributes to neoplasia in brown bullhead.

4.5.2.2 Somatic Indices and Gross External Lesions

There were no significant differences in either body mass or length between the cohorts collected from the three different sampling locations. There was a significant difference ($p > 0.05$) in K between RM 5.6-6.25 and RM 3.4-4.6 (Table 4-17b). There was no significant difference in K between RM 5.6-6.25 and RM 1.25-1.9 (Figure 4-5b). The largest and presumably oldest fish was collected from RM 1.25-1.9.

Gross external lesion severity was estimated using an arbitrary scale of one to three with three being the most severe (Table 4-17c). No lesions of the barbels were observed in RM 5.6-6.25 fish although apparent oral hyperplasia and melanistic spots were observed in 23% of the RM 5.6-6.25 fish (Table 4-17c; Figure 4-5b). The single incidence of a general skin lesion was a one to two mm raised red spot. Melanistic spots were small, generally less than 0.5 cm diameter. One RM 5.6-6.25 fish exhibited hemorrhagic ulcerations accompanied by fungal growths that extended from the lower external jaw into the oral cavity.

RM 3.4-4.6 fish exhibited general lesions of the skin (6%), barbels (31%), ulcers (19%), oral hyperplasia (19%) and melanistic spots or larger melanistic areas (31%). Only one fish exhibited blebs of the barbel that have been shown in other studies (Blazer et al. 2007) to be due to trematode metacercariae infestations. Two of the fish exhibited large areas of melanism, one covering the entire head, and the other a three cm band between the caudal and dorsal fins. One RM 3.4-4.6 fish exhibited hemorrhagic ulcerations accompanied by fungal growths that extended from the lower external jaw into the oral cavity. The RM 3.4-4.6 fish was the only fish with a severe oral lesion. These ulcerations appear to be associated with fungal infections but it is not known if the fungus causes the ulcerations or if the fungus responds opportunistically to skin abrasions due to another source such as parasites.

RM 1.25-1.9 fish exhibited lesions of the barbels (13%), ulcers (25%), oral papillomas (13%) and melanistic spots (13%). Three fish exhibited reduced or missing barbels but not blebs on the barbels, and another fish had an apparently healthy but bifurcated barbel. One fish had multiple ulcerations while another had severe fin erosion. Because external lesions are not the focus of these studies and were not confirmed histologically, no statistical analyses were conducted.

5 Summary of Findings and Implications for BUIs

This section provides a summary of findings from the 2008 investigation and the implications of these findings relative to earlier sampling activities, as well as related BUIs. This information is relevant to the FS because the FS will focus on remedial action objectives (RAOs) that are intended to contribute to the improvement of some or all of the BUIs for the Buffalo River.

5.1 Nature and Extent

Results of the 2005, 2007, and 2008 sediment sampling and analysis were combined to demonstrate the lateral and vertical distribution of chemical concentrations in the Buffalo River, City Ship Canal, and Cazenovia Creek including total PAHs, total PCBs, mercury, and lead. Results of these studies show that surface sediment concentrations for all four chemicals are typically lower than subsurface concentrations. This trend is clearly demonstrated in the vertical profiles provided for each chemical along the Buffalo River and City Ship Canal. In addition, Tables 2-2 through 2-5 show that the average and geometric mean concentrations for each half-mile segment of the Buffalo River and the City Ship Canal are typically greater for subsurface samples as compared to surface samples for total PAHs, total PCBs, lead, and mercury. The reduced chemical concentration in the surface sediments of the Buffalo River AOC is likely due to the more recent and ongoing deposition of sediments with low chemical concentrations. As discussed in Section 3, the Buffalo River AOC is a depositional environment. Sediments with low chemical concentrations originating from upstream of the AOC have likely been transported and deposited within the AOC, creating a surface layer with lower chemical concentrations as compared to the subsurface sediments.

A review of the sediment chemistry results shows a similar lateral distribution of elevated sediment concentrations for total PAHs, total PCBs, lead, and mercury. In general, the highest sample concentrations for each of these chemicals are located at RM 3.5–5.5. The average total PAH subsurface sediment concentrations across the half-mile segments between RM 4.0–4.5 and 4.5-5.0 are 56 mg/kg and 120 mg/kg, respectively, which are the highest average subsurface total PAH concentrations across all half-mile river segments. In addition, all samples with a total PAH concentration greater than 400 mg/kg occurred in at RM 3.5–5.0. The highest average total PCB subsurface sediment concentrations are located at RM 4.0–4.5 and RM 5.0–5.5, with average concentrations of 1.0 and 4.5 mg/kg, respectively. RM 4.0–4.5 and RM 5.0–5.5 also contained the only samples with total PCB concentrations greater than 10 mg/kg. The highest average lead subsurface concentrations occurred at RM 4.0–4.5 (228 mg/kg) and 4.5–5.0 (390 mg/kg), and all sediments samples exceeding a lead concentration of 800 mg/kg occurred within RM 4.0–5.0 as well. The highest average subsurface sediment mercury concentration is located at RM 1.5–2.0 and RM 4.5-5.0 (3.0 mg/kg). Average subsurface sediment concentrations at RM 1.5–2.0 were also elevated for total PAHs (51.7 mg/kg) and lead (220 mg/kg) compared to other half-mile river segments, but less than the average concentrations at RM 4.0–4.5.

Similar to the lateral distribution of subsurface chemical concentrations, the highest surface sediment concentrations are also typically located at RM 3.5–5.5. The average total PAH surface concentrations at RM 4.0–4.5 is 27 mg/kg, which are the highest average surface total PAH concentrations across all half-mile river segments. The highest average concentrations of lead in surface sediments occurs at RM 3.5–4.0, RM 4.0–4.5, and RM 4.5–5.0, which concentrations of 120 mg/kg, 110 mg/kg, and 160 mg/kg, respectively. Average surface concentrations of mercury at RM 3.5–4.0and 4.0–4.5 are 0.87 mg/kg and 0.80 mg/kg, respectively, which are the highest average mercury concentrations across all half-mile river segments. The highest average total PCB concentrations occurred at RM 3.5–4.0 (0.27 mg/kg), and slightly downstream of the RM 3.5–5.5 reach, at RM 2.5–3.0 (0.32 mg/kg).

Similar to the Buffalo River, the vertical distribution of chemical concentrations in the City Ship Canal shows lower average and geometric mean concentrations of all four chemicals (total PAHs, total PCBs, lead, and mercury) in the surface sediments as compared to the subsurface sediments. A comparison of the average and geometric mean concentrations for the City Ship Canal surface and subsurface sediment are provided in Tables 2-2 through 2-5. In comparison to the Buffalo River, the average surface and subsurface sediment concentrations in the City Ship Canal are greater than most of average concentrations from each half-mile segment of the Buffalo River for all four chemicals. The average subsurface concentrations for the total PAHs, total PCBs, and lead in the City Ship Canal are 24, 0.54, and 150 mg/kg, respectively. Although these average chemical concentrations are less than the maximum average subsurface concentrations measured at half-mile river segments between RM 3.5–5.5, they are greater than most other half-mile increments along the river. The average subsurface sediment mercury concentration in the City Ship Canal is 3.2 mg/kg (geometric mean 0.77 mg/kg), which is greater than all the highest half-mile average subsurface sediment concentrations in the Buffalo River.

Chemical concentrations upstream of the AOC, both in the Buffalo River and Cazenovia Creek, are typically lower than the average concentrations of each half-mile increment in Buffalo River AOC. Subsurface sediment samples were not collected upstream of the AOC, but the four surface samples collected showed average concentrations of 0.051 mg/kg for total PCBs, 18 mg/kg for lead, and 0.04 mg/kg for mercury, which are lower than average surface sediment concentrations within the AOC. The average total PAH surface sediment concentration upstream of the AOC is 6.8 mg/kg. This average surface concentration is greater than many averages from the half-mile Buffalo River segments; however, the elevated average PAH concentration upstream of the AOC is influenced by one sample that had surface concentration of 18 mg/kg, while all other surface samples in this area had a concentration below 3.8 mg/kg.

5.2 Hydrodynamics, Sediment Transport and River Geomorphology

The Buffalo River is typically characterized as a slow-moving river; data collected during the fall of 2008 demonstrated average low flow conditions of approximately 150 cfs and peak high flow conditions of approximately 6,500 cfs. Due to the low river gradient (17 centimeters per kilometer [cm/km]) and the generally low flow conditions, both the direction and magnitude of flow in the lower Buffalo River are frequently affected by seiche-related changes in Lake Erie water levels. Flow velocity data collected during fall 2008 demonstrate oscillations in velocity direction and changes in water levels as a result of Lake Erie seiche events and the wave effects in the river. Seiche-induced water-level changes occur over a period of approximately 14 hours; the waves propagate over a period of approximately 1.75 to 2 hours. Smaller internal wave oscillations were observed as a result of the upstream boundary of the navigation channel.

The hydraulic and hydrodynamic conditions of the Buffalo River were modeled over varying flow conditions to demonstrate the flood elevations and velocity and sheer stress distributions over a range of flow and seiche conditions. The existing three-dimensional ECOM model developed by Joe Atkinson at the University at Buffalo was upgraded to the three-dimensional USEPA EFDC modeling framework, and the original model grid was extended upstream. The upgraded model was calibrated to highly resolved velocity and water level data collected during fall 2008. The velocities and shear stresses computed by the model for the various events are consistent with the river's function as a dredged navigation channel. Results from model simulations demonstrate low velocities and bottom shear stresses throughout the AOC during low flow conditions. An increase in velocity was shown for low flow conditions with a large seiche influence, but these elevated velocities were sustained for less than five minutes. During moderate flow events (1-yr interval) model results demonstrated higher velocities in the upstream areas and attenuation of seiche impacts in upstream reaches. An increase in velocities and shear stress was demonstrated during high flow events (10-yr and 100-yr intervals), but these increases were most notable in narrow sections of the river including RM 1.0–2.0, RM 2.9, and RM 5.2.

In addition to the three-dimensional model, an existing USACE/FEMA model was converted to the HEC-RAS modeling framework and was updated with recently collected bathymetry and topography, to demonstrate the changes in potential flooding within the Buffalo River AOC. Use of the HEC RAS modeling platform to evaluate flood conditions is consistent with FEMA methods to evaluate flood potential. Results demonstrated the river does not flood in the majority of the downstream reaches under the 100-year event. High wet weather flows are contained within the river's banks and result in an increase in velocities and bottom shear stresses, as shown by the EFDC model. Flooding potential is primarily upstream of the confluence with Cazenovia Creek. In general, results from the EFDC and HEC-RAS models provide an understanding the hydrodynamic behavior of the Buffalo River that is consistent with previous studies, and builds on them to provide a greatly improved representation of the river.

The hydrodynamic modeling studies and investigation of sediment bed properties supports an improved understanding of the sediment transport within the Buffalo River AOC, and an understanding of the long-term stability of the system under wet weather and high seiche conditions. In addition, the area has been well-studied under a number of historical studies that focused on characterization of the watershed, measurement of solids loads delivered to the lower river, and sedimentation (shoaling) in the navigational channel (USACE 1988). Because the channel is regularly dredged, the channel areas are maintained in a state of disequilibrium with respect to erosion and deposition, creating an environment that is generally depositional. Sedimentation varies by reach, with bed load deposition predominantly upstream, and deposition of suspended materials decreasing from upstream to downstream. Deposition will tend to be greater in areas that have been recently dredged, have lower velocities, and lower bottom shear stresses. For example, the navigationally dredged sections of the river are generally low energy and depositional under dry weather conditions.

Based on the present knowledge of hydrodynamics and sediment transport, as described above, the river can be subdivided into distinct reaches with unique characteristics. Other factors that support subdivision of the river into distinct reaches include river morphology, cross-sectional and navigational channel configuration, shoreline characteristics, and contaminant levels. Table 5-1 provides a simplified subdivision of the AOC into river reaches with distinct physical characteristics, and corresponding differences in chemical distributions. In summary, an assessment of the relevant physical and chemical characteristics by reach shows the following:

The *mouth reach (RM 0-1)* is shallower and broader than other reaches, with a defined navigational channel and adjacent shoulders. Because of the moderating effect of the lake, this reach is relatively slow moving and sees relatively low stresses on the bottom sediments, event during high flow event conditions. Consequently, the mouth reach sediments contain a high proportion of fines, much of which may be lacustrine in origin. Observed contaminant levels in this reach are generally lower than in other reaches, possibly due to dilution of historically deposited contaminants by lake-derived sediments.

RM 1-2 is a much narrower and generally deeper reach, with steeper side slopes and narrow shoulders. Under high flow conditions, velocities in this reach are elevated relative to other reaches, and stresses exerted on the bottom sediments are also correspondingly high. The effect of these elevated flows and stresses is apparent in the sediment type, which shows a higher proportion of gravel than other reaches, likely due to local armoring of the sediments to the stresses of high flow events. This reach is minimally depositional due to its high energy environment. Contaminant levels in this reach are low to moderate, due to the limited potential for deposition in the reach.

RM 2-3.5 is the lower of two highly sinuous reaches of the AOC. In this reach, water depths vary significantly with location along the major bends of the reach, and also laterally, with indications of point bar formation in lower energy areas and bathymetric depressions in other areas. Flow velocities are moderate in this reach and bottom stresses created by flow events are variable, with some areas of high stress. Consequently, sediment type is also variable, but still shows a high proportion of fines, some sands, and gravels in areas of elevated stress. Some net deposition of sediments occurs in this reach, primarily in the upper half as indicated by historical dredging activities by the Army Corps of Engineers. Moderate levels of contaminants in this reach appear to be associated with historical sediment deposition in the area.

RM 3.5-5 is similarly sinuous to the preceding reach, again with highly variable water depth and bar formation consistent with a highly sinuous morphology. Flow velocities and corresponding levels of bottom shear stress are lower than the neighboring reach, resulting in a more limited occurrence of armored sediments (gravels) and a more generally depositional environment. Due to its closer proximity to the upper river source of sediments, this reach appears to receive a greater proportion of settled sediment and bed load than the downstream reaches, as evidenced by the high fraction of fine sands in the reach and the need for extensive navigational dredging throughout. The higher rates of deposition in this reach correspond with generally elevated contaminant levels.

The *upper reach (RM 5 – upstream terminus of dredging)* is a return to a lower sinuosity, more engineered reach with a defined navigational channel and distinct shoulders. Velocities in this reach are low to moderate through the range of flow events, and bottom shear stresses are low relative to other reaches in the AOC. Consequently, the high proportion of sands found in this reach is not due to armoring of the bed, but rather to deposition of bed load material delivered from the upstream, undredged portions of the river and tributaries. Moderate contaminant levels in this reach may be due to the generally coarser sediments and higher proportion of deposited bed load material.

The distinct characteristics of the reaches described above suggests a need for targeted approaches that recognize the characteristics of each reach and develop sediment management approaches appropriate for each. Future sediment management approaches will need to be based on an understanding of the range of hydrodynamic conditions and sedimentation environments operating in the lower Buffalo River, and their implications for long-term sediment stability and remedy effectiveness.

5.3 Ecology

A wide range of ecological studies have been conducted on the Buffalo River over the last few decades, with several that are particularly relevant to the interpretation of 2008 findings within the context of upcoming FS activities. This section provides a summary of the 2008 ecological studies and compares these findings, as applicable, to existing studies. The existing studies have used a variety of terminology to identify locations (e.g., reaches, zones, and sections), and many have spatial overlaps that are not readily apparent from the designations alone. As such, Figure 5-1 provides an overview of a number of key ecological studies, including sample locations and identification of the types of samples collected (e.g., benthic community, fish community, sediment toxicity, fish tissue residues, etc.). These studies, and others, are referred to throughout this section. Lines of evidence used to evaluate the 2008 ecological studies are presented in Figures 5-2a and 5-2b.

5.3.1 Aquatic Vegetation

The aquatic vegetation survey documented the presence of SAV and EV that should be considered in the FS (Figures 4-1a and 4-1b). Given the ecological benefits typically associated with SAV and EV habitats, their continuing presence may provide opportunities for enhancing habitat-related beneficial uses of the Buffalo River.

5.3.2 Benthic Community Assessment

Benthic invertebrate sampling and analysis supports existing information that can inform the FS and provides baseline conditions of resident assemblages within areas upstream of the AOC and in two reference areas. This effort facilitates the identification of expected and reasonable remediation endpoints and provides information on the presence of taxa that could potentially colonize the Buffalo River AOC.

Habitat scoring on the Buffalo River showed that the habitat ranking using USEPA methods ranged from marginal to suboptimal (on a scale that spans poor<marginal<suboptimal<optimal) (Table 4-5). Given the urban, industrialized, channelized nature of the Buffalo River (and the other water bodies), the high degree of siltation in all water bodies, and the lack of riparian vegetation at many locations, the habitat scores indicate a very altered physical habitat that is favorable to oligochaete worms and chironomid larvae. These physical conditions would likely limit the diversity of benthic macroinvertebrate communities. The consistently high HBI scores, as strictly interpreted using metric definitions provided by NYSDEC (2002) and USEPA (1989), indicates that organic sewage enrichment is prevalent and may be a determinant of benthic macroinvertebrate community quality. The analyses show that benthic habitat is fairly similar between the Buffalo River and the reference sites, which is consistent with the particle size analysis described in Section 2 (Figure 2-15). These results indicate that habitat quality is likely a key factor determining the benthic community structure seen in the sediment grab samples. These results also demonstrate that with limited exceptions, habitat conditions are consistent among sampling locations and there are no particularly optimal habitat locations (based on physical conditions) identified as part of this benthic community assessment.

Benthic community impairment was conducted using NYSDEC and USEPA approaches for sediment grab and Hester-Dendy artificial substrate sampling techniques. The NYSDEC approach for sediment grabs generally showed moderate to severe impairment at most locations, including the upstream locations on the Buffalo River, Cazenovia Creek, and reference locations in Cattaraugus and Tonawanda Creeks. The USEPA approach, which compares Buffalo River conditions to a similar urban reference waterway, showed that sediment grab samples from Buffalo River locations were slightly to moderately impaired compared to Tonawanda Creek, a reference creek identified by the Buffalo River stakeholder group. Hester-Dendy samples showed some slight impairment in the Buffalo River compared to Tonawanda Creek, with the most impaired locations being in the most upstream area within the AOC and upstream of the AOC. These findings, when compared to chemical residue information, do not appear to show a clear and obvious gradient in biological conditions that is tied to chemical conditions; however, this is still being considered by the PCT.

The Hester-Dendy sampling results showed greater species and family diversity than that seen in the sediment grab samples. Other metrics also showed more favorable community structure in the Hester-Dendy samplers than sediments. Differences between sediment grab and Hester-Dendy metric results are at least in part due to the fact that depositional areas included in sediment grab samples, are composed primarily of fine silts and sands mixed with organic matter. This type of substrate offers little diversity in benthic community habitat. Additional differences in the results are also likely in part due to the differences in the sampling approaches which reflect characterization of different organism exposures to chemicals in the environment. As digenesis occurs in soft sediments, organic matter is broken down and ammonia is released. Concurrently, interstitial oxygen is reduced and sulfide is formed. Both ammonia and sulfide are toxic to the larval forms of epibenthic invertebrates but are better tolerated by benthic infaunal species such as oligochaetes and chironomids (Oseid and Smith 1974a, 1974b, 1975). Conversely, Hester-Dendy samplers provide a hard surface for organisms that otherwise preferentially use cobble and woody debris surfaces in the natural environment. As such, sampling with the Hester-Dendy provided insight into the benthic community structure that has not been generally considered in studies of the Buffalo River over time (e.g., Diggins and Snyder 2003; Irvine et al. 2005).

The findings from the benthic community assessment also must be considered within the context of chemical data collected from the 2008 N&E sampling discussed in Section 2, as the habitat differences alone do not necessarily explain the differences observed in the benthic community. The remainder of this section (Section 5.3) discusses the available ecological and chemical data as they relate to each other. Section 5.4 explores the combined ecological and chemical data with regard to trends over time.

5.3.2.1 Evaluation of Benthic Community Metrics Compared to PAH Sediment Delineation

DiToro and McGrath (2000) and USEPA (2003) provide a method for evaluating the potential risk of PAHs to benthic invertebrates by using a toxic units (TU) approach. The likelihood of sediment toxicity due to PAHs was assessed using the USEPA sediment quality guidelines for PAH mixtures (USEPA 2003). These guidelines incorporate final chronic values (FCVs) for individual PAHs, which are used to assess the cumulative toxicity of PAH mixtures. The FCVs are derived using EqP and have been validated using spiked sediment toxicity studies and evaluations of sediment toxicity at sites contaminated with PAHs (USEPA 2003, Di Toro and McGrath 2000). The FCVs are applied to organic carbon normalized PAH mixtures through the calculation of TU values. Toxicity is considered possible if the TU for a PAH mixture exceeds 1. TU values below 1, according to USEPA, are considered to indicate that PAHs are not bioavailable and do not pose an unacceptable risk to benthic organisms (USEPA 2003a). The TU for a PAH mixture is calculated as the sum of each PAH concentration divided by the respective FCV:

$$\sum TU = \frac{[PAH_1]}{FCV_1} + \frac{[PAH_2]}{FCV_2} + \ldots + \frac{[PAH_n]}{FCV_n}.$$

In the present study, the ΣTUs from both surface and subsurface samples ranged from less than 0.1 to a high of 20 and the AOC-wide geometric mean ΣTU was 0.63 (Table 5-2a). Six surface samples and six subsurface samples exhibited ΣTUs greater than or equal to 2. The majority of these samples, as well as the highest ΣTUs (i.e., 20), are found in RM 3.4-4.6, distributed around the Katherine Street peninsula (Figure 5-3a). Much lower ΣTUs were found in the surface sediments (Figure 5-3a). The highest surface ΣTUs (4-5) were found at the same locations that the highest subsurface ΣTUs were also found, although the highest surface location (8; without a subsurface sample) was located in the inner harbor. These results show that if PAHs are impacting the benthic community, this is likely to occur in the area where PAH TUs were the highest (Figure 5-3a). Additionally, ΣTUs were calculated for Cattaraugus Creek and Tonawanda Creek (Table 5-2b and Figure 5-3b). The mean ΣTU for Cattaraugus Creek was 0.6. The mean ΣTU for Tonawanda Creek was 1.4. These results show that considerations of TUs greater than 1, particularly for urban rivers, are relevant for consideration when making remedial decisions.

5.3.2.2 Evaluation of Benthic Community Metrics Compared to Metal Sediment Delineation

DiToro et al. (2005) and USEPA (2003) also provide a method of evaluating the risks of metals to benthic invertebrates by estimating their bioavailability to cause toxicity, as was described in detail in Section 2 of this report where the AVS and SEM data are presented. Approximately 89% of sediment samples had AVS concentrations greater than SEM (Figure 5-3c). The remaining 11% of sediment samples, in which AVS was less than SEM (i.e., five samples) were evaluated for the OC-normalized excess metal concentrations at four of the five locations did not exceed the low-end threshold for effects of 130 µmol/gOC described above. Only one location slightly exceeded the low-end threshold of 130 µmol/gOC (133 µmol/gOC in buried subsurface sediment location 54) and all five values are well below the threshold considered very likely to cause toxicity (3,000 µmol/gOC). The one remaining station sequential was evaluated for AVS SEM based on binding affinity (Section 2). Given that the only bioavailable SEMs in this sample were zinc and nickel, the OC-normalized toxicity threshold for zinc (1,400 µmol/gOC) and nickel (1,100 µmol/gOC) are the appropriate values to determine the risk from this sample. When this comparison is made, the level of OC-normalized zinc and nickel in this sample were far lower than the threshold value for these metals[10].

[10] As stated in Section 2.1.2.6, it is acknowledged that representatives of NYSDEC have stated the agency does not fully accept the USEPA (2005b) method of metals EqP to AVS. NYSDEC representatives also stated that in the presence of toxicity testing results, AVS SEM can be used to show metals are not causing toxicity (i.e., negative toxicity testing results and AVS SEM showing metals are not bioavailable), but the AVS-SEM approach is not yet considered acceptable by NYSDEC to exclude metals as causing toxicity in the absence of toxicity testing. The approach presented in this SRIR was consistent with NYSDEC

5.3.2.3 Potential Benthic Toxicity

The potential toxicity to benthos of sediment-associated contaminants was also evaluated. ENVIRON used the 2005, 2007, and 2008 sediment data to evaluate the potential for toxicity by ΣPAH TU (DiToro and McGrath 2000). A conversion factor was applied to bring the data for 17 PAHs up to the standard of 34 PAHs[11]. The highest surface ΣPAH TUs were found at RM 0 (8), followed by RM 3.8 (5), and RM 4.3 (4) (note that subsurface PAH TUs were also considered and the highest PAH TU of 20 was seen at two subsurface sample locations, RM 3.7 and 4.25). NYSDEC (2006) summarized 10-day toxicity testing with surface sediment that showed 80% or better survival for *Hyalella azteca* or *Chironomus tentans* at 13 different locations in the upstream portion of the Buffalo River AOC (Figure 5-1; RM 2.8, 3.5, 3.7, 4.0, 4.3, 4.5, 4.7, 5.1, 5.2, 5.6, 5.8, 6.0, and 6.2) (it is noted that control samples are considered valid for samples with ≥ 80% survival).

USACE (2003) reported PAHs[12], mercury, and lead in oligochaete worm (i.e., *Lumbriculus variegatus*) tissues from 28-day bioaccumulation tests. ENVIRON used the PAH residue data to evaluate potential toxicity using the target-lipid model (TLM; DiToro et al. 2000) similarly adjusted from 17 to 34 PAHs. It should be noted that both the sediment and worm body residue toxicity benchmarks are based on no effect concentrations and that minor exceedances only indicate the potential for toxicity. The TLM TUs are as follows: lower harbor location at RM 0.7 (2.7), RM 3.8 (3.0), RM 4.6 (1.5), and the southern tip of the Ship Canal (1.1). There was no risk at RM 5.8 (0.5) or at RM 3.3 (0.9). The tissue TLM TU results agree with the sediment ΣPAH TU results in that the highest risk areas are in the harbor mouth, at RM 3.8 and RM 4.3 to 4.6. Furthermore, the only concentrations of PAHs in sediment pore water greater than 1 µg ΣPAH /L (i.e., 17.5 micrograms per liter [µg/L]) were found at RM 3.7 (Table 2-11a).

Potential toxicity to invertebrates due to mercury and lead were also evaluated using the USACE (2003) data. The highest worm mercury residue was 0.227 mg/kg wet weight in the USACE study control group. Residues from the Buffalo River worms were low and relatively constant: 0.014 mg/kg at RM 0.0, 0.022 mg/kg at RM 3.7, 0.027 mg/kg at RM 4.7, 0.022 mg/kg at RM 5.5, and 0.041 mg/kg at the Ship Canal. Borgmann et al. (1993) reported a no effect residue of 56 mg Hg/kg dry weight in *Hyalella azteca* after aqueous exposure for 10-weeks. Assuming these organisms are 80% water, this equates to 11.2 mg Hg/kg wet weight. Therefore, the highest measured worm mercury residue from Buffalo River was two to three orders of magnitude lower than the Borgmann et al. no effect residue. [13]

The sediment mercury concentrations in the Buffalo River are also lower than the lowest no effect concentration published in the literature based on field and laboratory studies of mercury toxicity as illustrated in Table 5-3; Figure 5-4 (Sferra et al. 1999; Winger et al. 1993, Milani et al. 2002; 2007). The lowest available no effect sediment concentration obtained under controlled conditions comes from

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and ENVIRON's understanding that NYSDEC may request toxicity testing in the future, but that doing so did not preclude the assessment of the AVS/SEM analysis consistent with USEPA's methodology.

[11] The conversion factor, 1.68, was calculated based on the site-specific ratio of 34 PAHs to 17 PAHs using the 2008 sediment data.

[12] USACE 2005 also reported whole worm PCB concentrations but these compounds are non-toxic to invertebrates.

[13] Direct comparison of worm mercury residues reported by USACE (2003) and Borgmann et al (1993) can not be certain because the form of mercury (inorganic versus methylmercury) was not reported.

bioassays wherein the amphipod *H. azteca* was exposed to natural sediments containing three different levels of total mercury (Sferra et al. 1999); this no effect sediment concentration is 4.1 mg Hg/kg. Figure 5-4 shows the results of toxicity testing conducted on sediments from mercury contaminated sites (Peninsula Harbour, Lake Superior, and St. Clair River) for worms, amphipods, and mayflies. The vertical lines on Figure 5-4 illustrate that organisms show survival and reproductive ability at concentrations that exceed the Sferra et al. no effect concentration of 4.1 mg/kg. The Sferra et al. no effects concentration is higher than the highest average measured mercury concentration in Buffalo River sediments but lower than three sediments in RM 3.5-4.5 and one sediment in the Ship Canal (Table 2-5a; Figure 2-15). Mortality was the endpoint evaluated in this study but Borgmann et al. (1989) and Milani et al. (2003) have also shown that mortality is as sensitive an endpoint as growth in *H. azteca* exposed to metals. Other no effect concentrations, obtained from bioassays of field samples from predominantly mercury-contaminated sediments at Brunswick, Georgia (Winger et al. 1993) and Peninsula Harbor and the St. Clair River (Milani et al. 2002) are much higher (i.e., 17.8 to 24.7 mg/kg) than any mercury concentrations measured in the Buffalo River surface sediments (Table 2-5a; Figure 2-15). Maximal subsurface mercury concentrations at RM 4.5 to 5.5 (Table 2-5b; Figure 2-5) exceeded these higher no effect concentrations but mean concentrations were lower than the lowest no effect concentration. The lack of toxicity due to mercury in natural sediments has been attributed to the very high affinity of inorganic mercury for sulfide. Mikac et al. (2000) showed that under the acid extraction procedures for measuring AVS SEM, mercury was not released and was, therefore, not bioavailable to cause toxicity (Benoit et al. 1999).

The highest worm lead residue from the USACE (2003) Buffalo River bioaccumulation study was 23.7 mg/kg wet weight but there was high variance between replicates and the geometric mean lead concentration was 8.8 mg Pb/kg at this area (RM 3.3). Controls contained 1.4 mg Pb/kg and worms from other area contained lower mean lead concentrations: 1.8 mg/kg at RM 0, 5.1 mg/kg at RM 3.7, 4.8 mg/kg at RM 4.7, 1.1 mg/kg at RM 5.5, and 5.3 at the Ship Canal. Borgmann and Norwood. (1999) and McLean et al. (1996) reported chronic no effect body residues of 5.2 mg/kg and 7.5 mg/kg wet weight, respectively. Therefore, the highest measured worm lead residue, as well as the average worm residue from RM 3.3 was higher than the no effect residue. With regard to the lead results, Milani et al. (2003) also showed that *H. azteca* is more sensitive than the midge *C. riparius*, the mayfly *Hexagenia spp.* and the oligochaete worm *Tubifex tubifex*.

ASci (2007) reported the results of 10-day toxicity testing with eleven subsurface and two surface sediments from the downstream portion of the Buffalo River AOC, including the Ship Canal (Figure 5-1). Toxicity to one or both species was high in all sediments but the highest survival was found in the two surface sediments (95% *C. tentans* at Buffalo River RM 0.8 and 85% *H. azteca* at Ship Canal RM 0.5). The only other location exhibiting no toxicity was a subsurface sediment location from the Ship Canal. Both metal and organic chemical concentrations are much higher in subsurface sediments than in surface sediments. Given that metal and organic chemical concentrations are generally lower in the downstream portion of the Buffalo River AOC than the upstream portion of the AOC, and that sulfide and ammonia concentrations are expected to be high in subsurface sediments, such non-xenobiotic factors may account for the increased toxicity observed at depth. The potential influences of ammonia and sulfide in the study are under investigation by ASci.

5.3.3 Fish Community Assessment

The fish population and community sampling in the Buffalo River and Cazenovia Creek provides: (1) data concerning the taxonomic composition and abundance of the current fish populations; (2) a general evaluation of community health and condition; (3) preliminary information on the reproductive success of fish populations; (4) additional information about the pre-remediation baseline conditions; and (5) insight into other potential limitations to community success, such as habitat quality. Community information and various metrics based on the 2008 Buffalo River and Cazenovia Creek fish populations are provided in Section 4.4.2.

According to index profile values (NYSDEC 2002) and IBI scores (Irvine et al. 2005), calculated using 2008 data, the quality of the fish community in Buffalo River is slightly decreased at RM 5.5, RM 6.25, and RM 6.8 relative to RM 4.5 and RM 7.5 (Tables 4-16a and 4-16b; Figure 4-4). Irvine et al. (2005) calculated IBI scores, based on 2003/2004 fish community data, for several locations within Buffalo River – three of these locations correspond to 2008 fish community sampling locations at RM 4.5, RM 5.5, and RM 6.25[14]. In 2003/2004, IBI scores indicated that the Buffalo River fish community at locations RM 5.5 and RM 6.25 was very poor. In 2008, IBI scores at these same locations improved to a poor to fair rating. Similarly, in 2003/2004, the IBI score at RM 4.5 indicated that the quality was poor, whereas in 2008, the quality improved to fair at this same location. Greer et al. (2002) calculated IBI scores for several locations within Cazenovia Creek, one of which corresponds to the 2008 fish community sampling location (CC). The IBI scores calculated for Cazenovia Creek indicate that the quality has remained the same (poor rating) from 1999 to 2008.

Although it appears that the fish community in the Buffalo River AOC has improved since 2003/2004, the AOC and Cazenovia Creek fish communities continue to be impacted (i.e., rating of poor to fair). The NYSDEC index value approach focuses on fish community metrics that are indicative of water quality as well as sediment quality. According to this index profile value, the quality in Buffalo River ranges from moderately to severely impacted and severely impacted in Cazenovia Creek. In addition, the QHEI indicates that the habitat associated with the 2008 fish community survey is rated as fair at all locations (Appendix H). Lack of variable habitat contributed significantly to the relatively low habitat scoring (Table 4-13b). However, since low habitat diversity was a constant factor at all of the Buffalo River and Cazenovia Creek locations, it is possible that the Buffalo River and Cazenovia Creek fish communities may also be influenced by other stressors. Therefore, additional consideration is given to these topics in Sections 5.3.4 and 5.3.5, respectively.

5.3.4 Potential Toxicity to the Fish and Wildlife Communities

NYSDEC 2008 fish tissue data collected from four zones within the river (Figure 5-1) were used to evaluate the potential risk to fish populations using whole body fish residue data.[15] Mean total PCB and mercury fish tissue results per zone are presented in wet weight for small fish (<50 g) and large fish (>50

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[14] The fish community assessments were based on two sites in the AOC in 2008 compared to 10 sites sampled twice in two consecutive years (Irvine et al. 2005), so while valid, it is not as robust of a comparison. Additional liver tumor monitoring may be required to corroborate the improvements reflected in the 2008 findings.

[15] The evaluation of the potential risk to fish populations did not include the 2007 carp PCB data due to the fact that the data were in dispute at the time of the SRIR development.

grams) are illustrated in Figures 5-5a and 5-5b. The highest measured total PCB and mercury concentrations were 0.87 mg/kg total PCBs and 0.244 mg/kg mercury (both wet weight), respectively (NYSDEC 2008). The lowest no effect body residues from controlled compound-specific bioassays are 1.6 mg total PCB/kg (Bengtsson 1980) and 0.2 mg MeHg/kg (Matta et al. 2001). The highest measured concentration of total PCBs (0.87 mg/kg wet weight total PCBs) and mean concentrations per zone (Figure 5-5a) are lower than the lowest no effect body residue (Table 5-4a). The highest measured mercury residue (0.244 mg/kg wet weight mg/kg Hg) is only marginally higher than the lowest no effect concentration but mercury[16] increases with age in fish and the highest concentrations of total mercury were found in large, and therefore old, fish while the lowest no effect concentration comes from a small marine fish (*Fundulus heteroclitus*). The mean mercury residues for small fish and large fish collected in 2007 are lower than the lowest no effect mercury residue, lower than the concentrations reported in wild fish from Ontario lakes far removed from human populations and industry (Table 5-4b; Figure 5-5b), and similar to the body residues reported in control fish used in bioassays (Sanderheinrich and Miller 2006, Drevnick and Sanderheinrich 2003). Mercury toxicity also exhibits a high degree of species sensitivity. For instance, and Olson et al. (1975) found no effects on mortality in fathead minnow at up to 12.6 mg MeHg/kg, McKim et al. (1976) found no adverse effects on reproduction in three generations of brook trout at a body residue of 2.7 mg MeHg/kg, and Wobeser (1975) found no effects on mortality in rainbow trout at 30 mg MeHg/kg (Table 5-4b).

The SulTrac ecological risk assessment (2007) considered potential risks to mammal and bird wildlife populations that live and forage in the Buffalo River. The risk assessment was based on many conservative assumptions that have been discussed in detail among reviewers of the risk assessment. While it is possible that wildlife populations are at risk from chemicals in the river, whether such a risk exists, and the scope and magnitude of those potential impacts warrants a transparent evaluation that is beyond the scope of this SRIR. As such, this will be addressed in FS-related efforts to identify appropriate remedial goals for the river, as they may relate to protection of piscivorous wildlife.

5.3.5 Brown Bullhead Histopathology

5.3.5.1 Brown Bullhead Liver Tumors

Liver tumors (hepatic neoplasia) are of primary interest with regard to the data collected because such tumors are related to potential BUI delisting criteria (IJC 2008, United States Policy Committee 2001). The 2008 study of fish histopathology showed only 3of 37 fish had any hepatic neoplasia (i.e., 8.1% total liver tumors), and the largest tumor was found in the largest and potentially oldest fish collected. These findings show that regardless of the etiology of hepatic tumors in the Buffalo River, the incidence has apparently decreased since 1983-1986 when Black and Baumann (1991) reported a 5.5% incidence of hepatocellular neoplasia and an 11.1% incidence of “bileductular” neoplasia (which combined equal 16.6% total liver tumors) and since 1988 when Baumann et al. (1996) reported a 5% incidence of “malignancies” and a 19% incidence of “neoplasms” (which combined is 24% total liver tumors). This shows a progressive recovery in Buffalo River brown bullhead neoplasia (Table 5-5a) that is comparable to the recovery shown by Baumann and Harshbarger (1998) and USEPA (2000) for hepatocellular carcinomas in 3 and 4 year old brown bullhead five years after the closure of a coking plant on the Black

[16] It was assumed that total mercury was 100% methylmercury.

River, Ohio (Table 5-5b). At Black River, the incidence of total liver tumors decreased to 0% in 1994 but then rose to 7% in 1998.

It is noted that understanding trends in the incidence of hepatic neoplasia is hindered by the use of imprecise designators during the past 20 years (McMaster et al. 2008). Early analyses of hepatic lesions in brown bullhead reported only the indiscriminate terms neoplasm, malignancy, cancer, or tumor (Black 1983, Black and Baumann 1991, Baumann et al. 1996). The present study adhered to the definitions proposed by Blazer et al. (2007) to differentiate between hepatocellular and biliary adenomas and carcinomas as well as intermediate and presumably preneoplastic lesions such as foci of cellular alteration (basophilic, eosinophilic, reactive, clear cell) and biliary proliferation and fibrosis. Use of these specific definitions is recommended for any future studies in the Buffalo River so that results can be compared from year to year and among different AOCs. Additional liver tumor monitoring may be required to corroborate the improvements reflected in the 2008 findings; statements of improvement represent preliminary findings being evaluated by the PCT.

The etiology of hepatic lesions is not well understood. Spitsbergen and Wolfe (1995) reported that over 30% of brown bullhead collected from relatively unpolluted water in New York State exhibited either benign or malignant hepatocellular or biliary (cholangiolar) neoplasia. It was subsequently reported that the incidence of these lesions increases with age in brown bullhead (Baumann et al. 1990), suggesting a genetic predisposition to carcinogenesis in this fish species. The incidence of hepatic neoplasia in bullhead has been shown to be reduced by removing coke-contaminated sediments (Baumann and Harshbarger 1995) and reducing effluent chlorine concentration (Grizzle et al. 1981, 1984), but neoplasia probably has a multi-factorial etiology of genetic predisposition, and environmental stressors.

5.3.5.2 Brown Bullhead DELTs

Incidence of DELTs in this and historical studies is presented in Table 5-6. DELTs were included in the 2008 study because Irvine et al. (2005) reported that DELT anomalies were found in 87% of brown bullhead sampled from the Buffalo River in 2003 and 2004. However, Irvine et al. (2005) did not enumerate DELT counts of the individual lesions by type so that it is difficult to determine if recovery is occurring for these external lesions. Nevertheless, their total count is far higher than the incidence reported in the present study (35%) or any other study (Baumann et al. 2000) reported in the Great Lakes (Presque Isle 1994; 56%). In the Buffalo River Baumann et al. (1996) and Yang (2004) only reported external tumors and did not summarize melanistic skin, eroded fins, ulcerations, or vertebral or cranial deformities. The high levels of DELTs reported by Irvine et al. (2005) may be related to fish age since body lengths range from 20 to 56 cm and average greater than 30 cm.

There was an apparent increase in the number and severity of external lesions in RM 3.4-4.6 relative to either upstream or downstream reaches, although one fish from RM 1.25-1.9 exhibited the most severe ulcerations. Baumann et al. (1996) reported a 23% incidence of raised skin lesions[17] in 1988 and Yang (2004) reported a 20.9% incidence of raised lesions in 1998. Only one of the fish in the present study exhibited a raised area that was not melanistic or associated with putative parasite attachment sites. Therefore, the incidence of raised lesions that could possibly be tumors has decreased substantially (i.e., 2.7%) since 1998. The ecological significance of these lesions must also be considered ambiguous since

[17] Raised skin lesions are called external tumors, neoplasms or malignancies in other publications

Baumann and Hurley (2006) reported equivalent incidences of raised lesions in brown bullhead from contaminated and un-contaminated sites and Lesko et al. (1996) reported that although brown bullhead from the Black and Cuyahoga rivers had a higher frequency of external lesions than reference stream, they were larger and more fecund.

Melanistic areas of skin were fairly common in the present study and RM 3.4-4.6 fish had the highest incidence of melanistic pigmentation. The only two fish with large melanistic areas came from RM 3.4-4.6. Okihiro (1988) and Okihiro et al. (1993) summarized the various proposed etiologies of melanistic lesions as: oncogenic viruses, genetic predisposition, normal ageing, UV and ionizing radiation, and exposure to xenobiotic chemicals.

Raised oral lesions were less common than skin lesions in the present study but were more common in RM 3.4-4.6 and RM 1.25-1.9 than in RM 5.6-6.25. Although Black (1983) was able to induce oral papillomas by repeatedly painting extracts of Buffalo River sediment on the lips of brown bullhead, the proximal cause of these lesions is unknown. Possible etiologies for these lesions include: viruses (Bowser 1991), chlorinated wastewaters (Grizzle et al. 1983), as well as xenobiotic chemicals (Baumann et al. 1996). On the basis of heat shock protein (HSP 70) responses, Korkea-aho et al. (2008) also suggested sex-linked factors may also be involved.

RM 3.4-4.6 fish also exhibited significantly lower K and HSI. The lower K indicates that fish of the same age have not gained the weight of fish from upstream and downstream locations. The lower K may indicate the presence of additional physical, chemical, or biological stresses such as an inadequacy of food items or increased competition for food items. The lower HSI found in RM 3.4-4.6 suggests food shortage rather than chemical stress because HSI usually increases in response to chemical exposure. However, another possible explanation is that the lower HSI and K in RM 3.4-4.6 is due to increased exposure to sulfide (Hoque et al. 1998, Larsson et al. 1984). Historically, HSIs were higher in brown bullhead from the Black, Cuyahoga, and Buffalo rivers during the 1980s (mean HSI of 2.83 in 1987) and HSIs decreased subsequent (mean HSI of 1.91) either to clean-up or natural attenuation of chemical stressors during the 1990s (Yang 2004). While all HSIs in fish collected in the present study, conducted in the fall of 2008, (mean HSI of 2.6) were higher than those reported by Yang (2004), fish collected by Yang were collected in the summer of 1998. The variations may be due to seasonal effects on the reproductive cycle but, because Yang (2004) does not provide fish collection locations, could also reflect the sampling of different fish populations.

5.4 Implications for Beneficial Use Impairments

According to BNR, the Buffalo River AOC has seven impaired BUIs (Jill Jedlicka, personal communication): Degradation of Benthos, Fish Tumors and other Deformities, Degradation of Fish and Wildlife Populations, Loss of Fish and Wildlife Habitat, Restrictions on Fish and Wildlife Consumption, Restrictions on Dredging, and Degradation of Aesthetics. The following sections describe the basis for the listings of the BUIs, the present knowledge of chronological trends of improvement and the present degree of impairment.

5.4.1 Degradation of Benthos

This section includes a discussion of the most recent benthic data as they relate to the Degradation of Benthos BUI. The basis for listing is discussed below. Additionally, two different measures of benthic invertebrate community health were evaluated: 1) grab sample macroinvertebrate community structure, and 2) artificial substrate colonizing invertebrate community structure.

5.4.1.1 Basis for Listing

The Degradation of Benthos BUI was listed as impaired based on "macroinvertebrate observations" and acute toxicity of Buffalo River sediment to *Hyalella azteca*, but specific sampling locations were not identified. NYSDEC noted that benthic species observed in samples collected from three different sampling events in 1982 were "typical of those found in organically contaminated sediment" (NYSDEC 1989). The other toxicity tests performed by Ecology and Environment on behalf of NYSDEC indicated that sediment caused no acute effects on *Daphnia magna* and no chronic effects on *Ceriodaphnia dubia* (NYSDEC 1989). In addition, a 28-day bioaccumulation test using *Pimephales promelas* indicated that none of the sediment contaminants were present in the tissues. The 2008 RAP Status update (Buffalo Niagara Riverkeeper, 2008) identifies the likely causes of this BUI as sediments and navigational dredging.

5.4.1.2 Sediment Grab Sample Analyses

The USEPA approach for evaluating sediment community impairment, which compares Buffalo River conditions to a similar urban reference waterway, showed that sediment grab samples from Buffalo River locations were not impaired or were only slightly impaired compared to Tonawanda Creek, a reference creek identified by the Buffalo River stakeholder group.

Researchers of the Buffalo River have reported recovery in the benthic community over the past two decades, in part due to improvements in water quality (e.g., dissolved oxygen, suspended solids, and water temperature) and possibly through navigational dredging, stormwater management, decreased industrialization, and natural attenuation (Irvine et al. 2005). Blum (1964) found no benthic invertebrates in the dredged section of the Buffalo River, but the benthic community demonstrated a notable improvement by the late 1970s to early 1980s (Canfield et al. 1992). This improvement was most significant at the upstream and downstream extents of the AOC, but the benthic community within the middle section was still considered to be degraded. In a review of mostly unpublished historical Buffalo River benthic invertebrate data spanning nearly three decades (1964 to 1993), Diggins and Snyder (2003) documented marked recolonization and expansion of the benthos from the barren conditions reported previously (however it is noted that Diggins and Snyder concluded that the benthic community remained impacted and degraded). According to Diggins and Snyder, many of the early benthic community improvements were likely due to water quality improvements, such as dissolved oxygen, temperature, and suspended solids (Figure 5-6). However, according to Irvine et al. (2005), the benthic community quality declined between 1993 and 2004, based on a comparison of invertebrate family richness. The findings of the 2008 benthic community assessment show the family richness of the sediment grab samples is generally similar to that seen in the 2003/4 study (Figure 5-6). It is unclear whether the current findings reflect degraded benthic community conditions related to chemical contamination or those conditions related to the influences of an urban watershed, particularly given that the USEPA approach shows non-to slight impairment between Buffalo River and Tonawanda Creek (Figure 4-2a). It would be particularly useful to closely evaluate the particular families that were present in the early 1990s to see which families have not recently been seen. This level of detail is not available in the studies where this information was provided (Diggins and Snyder 2003). One could closely evaluate whether species richness (as opposed to family richness) might have accidentally been considered in the cluster of studies in the mid-1990s because as illustrated on Figure 4-2e, the species richness in the sediment grab samples in 2008 is very similar to that seen in the cluster of samples from the mid-1990s. Because the USEPA 1989 RBPs were published just before that time of clustered mid-1990 sampling, and species richness is the metric identified for use (as opposed to family richness), it would be a logical error for such richness to have been accidentally mis-recorded. However, should more detailed evaluation of the historic results confirm that family richness was correctly reported, then the actual families missing in the current studies should be closely evaluated to determine (if possible) whether past dredging or other practices may have changed the available habitat from one that is suitable for such species to one that is not. Finally, the Hester-Dendy family richness metrics from 2008, albeit not directly comparable to the sediment grab metrics over time, do provide insight on family richness within the river that other sampling approaches have not. The Hester-Dendy metrics are discussed further in the next section.

Detailed information from the 2003/4 studies is available in Irvine et al. (2005) for some comparison to the 2008 findings. Irvine et al. reported that the highest number of families (11) occurred between RM 3.5-4 and the lowest number of families at RM 4.5(3) and RM 5.9 (3)[18]. Because the intention of the present study was to fill data gaps in previous studies, no samples were collected between RM 2-4.5 so it is not possible to determine a chronological trend in this area. However, in the present study, the greatest family richness was found at RM 5.5 (with a maximum of 12 families) and the lowest from RM 4.75 (3) and the two reference streams, Cattaraugus and Tonawanda creeks (2 and 3, respectively). The highest mean species richness in the present study of sediment grabs also occurred at RM 7.5 (14.2) and the lowest species richness at the Cattaraugus Creek and Tonawanda Creek reference locations (3.6 and 3.8, respectively). Despite apparently seasonal or annual variability in Buffalo River benthic population dynamics, the Buffalo River populations are equal to or better than those of appropriate regional reference streams (mean and standard deviation results for species and family richness from the 2008 study are provided in Figure 4-2e)

Chironomid mouthpart deformities have been identified as a metric of potential relevance to metals toxicity (Irvine et al. 2005). The results from the 2008 study and the previous studies were compared in great detail in Section 4 of this report. These evaluations (Figure 4-2f) show that chironomids within the sediment do show higher incidence of mouthpart deformities than those outside of the sediment. All of the locations sampled (with the exception of a single location BR06 (RM 2.25)), had deformities within the range of deformities seen at reference locations (up to 15% deformities were seen in Cattaraugus Creek sediment grabs). The 2008 percentages of deformities were well below those reported by Irvine et al. for the 2003/2004 study (54%). Even the most elevated location in the 2008 study was well below this level.

[18] Note that Irvine et al. designation of river miles is slightly different due to the designation of mile 0. The statements herein are based on the river mile designation as identified in this SRIR. Figure 5-1 of this SRIR shows the Irvine et al. (2005) locations in these general areas for reference.

5.4.1.3 Hester Dendy Sample Analyses

Using the USEPA approach for evaluating Hester-Dendy results compared to a reference creek, 2008 Hester-Dendy samples showed some slight impairment in the Buffalo River compared to Tonawanda Creek, with the most impaired location being upstream from the AOC at RM 6.8 (location BR02). Locations in Cazenovia Creek, the upper reaches of the Buffalo River (excluding BR02), and those in Cattaraugus Creek were also listed as slightly impaired, therefore no spatial trends in the Hester-Dendy results were observable.

There is limited information for comparison of Hester-Dendy substrates (or other artificial substrates) over time, which is a data gap in understanding conditions in the river because the 2008 results show favorable conditions in the river that might not be readily apparent using just sediment grab sampling approaches focused on a single habitat type. However, some limited information is available and can be used for qualitative discussion. For example, in 1996, Swift et al. compared macroinvertebrates collected from benthic grab samples to those that settled on artificial substrates (note that the actual samples were collected in 1989). They reported that although the dominant taxa from grab samples were oligochaetes, the artificial substrates (folded screens placed in a box on the sediment surface) contained few oligochaetes and were dominated by amphipods, isopods, and flatworms. The authors ascribed this difference to the physical characteristics of the substrate on which larval forms settle in the natural environment. Larval invertebrates are attracted to certain physical and chemical cues concerning which sediment characteristics are most conducive to successful metamorphosis. High ammonia or sulfide concentrations in sediment could create inhospitable conditions and affect settlement cues for larval forms of benthic invertebrates. Sampling by grab instruments such as petite ponars are also largely restricted to fine depositional substrates and this results in a biased assessment of the benthic community. Swift et al. (1996) concluded that if based entirely on grab samples, most river samples collected from the Great Lakes would be judged to be “highly contaminated because the benthic community consisted almost entirely of the oligochaetes worm, *Limnodrilus hoffmeisteri*”. Hultunen (1969) reported that *L hoffmeisteri* is most common at the mouths of western Lake Erie tributaries and benefits from “enriched river water”. *Limnodrilus* species were certainly the most abundant organisms in the grab samples analyzed in 2008.

Similarly, a NYSDEC 30 Year Trend Report (1972-2002) indicated that water quality has improved dramatically in the Buffalo River since it was first sampled in 1976 (NYSDEC 2004). The river has progressed from severely impacted in 1976 to moderately impacted in 1988 to slightly impacted in 1993 and 2000, based on resident macroinvertebrate communities. This report indicates that caddisflies were first collected in 1988, and more sensitive mayflies were first collected in 2000. In the 2000 multi-plate samples (presumably Hester-Dendy samplers, but if not, something similar), 4 species of clean-water mayflies were found at the Ohio Street bridge site. The 2008 Hester-Dendy sampling showed that the location nearest this bridge (BR06) had the highest caddisfly count of any location (approximately 33 individuals on just one sampler). Mayflies, caddisflies, and stoneflies are the basis of the EPT Index, and the 2008 study showed that EPT were seen at every location sampled in at least one of the replicates (Table 4-9 and Appendix D2).

5.4.1.4 Benthic Community Assessment Conclusions

Benthic communities in the upstream portion of the Buffalo River AOC are recovering, but measures of recovery are highly variable, apparently depending on year and season. Both the lowest and the highest family richness values were found at RM 5.5 in 2003/2004 and again in 2008. The 2005 to 2008 ΣPAH TUs predicted toxicity only at RMs 3.7 to 4.0 and at the river mouth. In 2008, the only areas where SEM was greater than AVS and ΣPAH TUs were greater than 1 were in the same vicinity, at RM 3.8 and 4.2. Further analysis of AVS SEM with respect to organic carbon shows low metal bioavailability. [19] In addition, little or no toxicity was found in surface sediments in this area (ASci 2005). [20]

Results of the artificial substrate analyses revealed a much more diverse fauna than grab samples. Swift et al. (1996) cautioned that sampling using only grab samples cannot differentiate between stations having different types of contamination and that a combination of grab samples and artificial substrates should be recognized as necessary for such differentiation. The present study used both methods and confirmed that the river as a whole shows diversity that is not readily apparent by the evaluation of a single method. This may be at least in part due to habitat differences. A summary of 30 year trends by NYSDEC (2004) showed the first presence of caddisflies in the Buffalo River in 1988 and mayflies in 2000. The 2008 study showed EPT (mayfly, stonefly, and caddisfly taxa) are present at every location sampled. This is also notable given the timeframe of the 2008 Hester-Dendy study because the samplers remained in the river until late October, a timeframe considered late in the season for such sampling (well after the first hard freeze of the winter).

The multiple lines of evidence are presented in Table 5-7.

5.4.2 Fish Tumors and Other Deformities

This section includes a discussion of the most recent fish tumor and deformity data as they relate to the Fish Tumors and Other Deformities BUI. The basis for listing is discussed below. Additionally, the brown bullhead histopathological analysis is evaluated in the context of this BUI.

5.4.2.1 Basis for Listing

The Fish Tumors and Other Deformities BUI was listed as impaired based on the Black et al. (1985) report that Buffalo River sediment extracts induced fish tumors and that Buffalo River brown bullhead had a high prevalence of neoplasms. The 1989 RAP also cites studies by Black et al. in the late 1970s

[19] As stated in Sections 2.1.2.6 and 5.3.2.2, it is acknowledged that representatives of NYSDEC have stated the agency does not fully accept the USEPA (2005b) method of metals EqP to AVS. NYSDEC representatives also stated that in the presence of toxicity testing results, AVS SEM can be used to show metals are not causing toxicity (i.e., negative toxicity testing results and AVS SEM showing metals are not bioavailable), but the AVS-SEM approach is not yet considered acceptable by NYSDEC to exclude metals as causing toxicity in the absence of toxicity testing. The approach presented in this SRIR was consistent with NYSDEC and ENVIRON’s understanding that NYSDEC may request toxicity testing in the future, but that doing so did not preclude the assessment of the AVS/SEM analysis consistent with USEPA’s methodology.

[20] Although toxicity testing and AVS-SEM analysis were not conducted concurrently, it is noted that information on toxicity between RM 3.8 and 4.2 is available and valuable.

and early 1980s. In 2005, NYSDEC (2005) reported the basis for listing this BUI by stating, "Fish tumors and other deformities shall be no greater than expected rates at non-AOC reference communities in species such as brown bullhead and suckerfish". The 2008 RAP Status Update (Buffalo Niagara Riverkeeper 2008) identifies the likely causes of this BUI as sediments and navigational dredging (potentially due to resuspension of contaminated sediments).

The current scientific consensus basis for delisting this BUI is that "Preliminary data from around the Great Lakes…would support a liver tumor prevalence of about 5% in brown bullhead aged three and older as good criterion for an Area of Recovery as opposed to an Area of Concern" (PADEP et al. 2003).

5.4.2.2 Conclusions

The incidence of liver neoplasms in the Buffalo River AOC has decreased since 1998. This improvement has occurred by natural attenuation and is of the scale accomplished on the Black River by dredging.

5.4.3 Degradation of Fish and Wildlife Populations

This section includes a discussion of the most recent fish population assessment in the context of the Degradation of Fish and Wildlife Populations BUI. The basis for listing is discussed below.

5.4.3.1 Basis for Listing

The Degradation of Fish and Wildlife Populations BUI was changed from "likely impaired" to "impaired" based on a 2008 decision by the Remedial Action Committee (Buffalo Niagara Riverkeeper 2008). The 2008 RAP Status Update also differentiated that the fish populations are impaired while wildlife populations are likely impaired. The 2008 RAP Status Update (Buffalo Niagara Riverkeeper 2008) identifies the likely causes of this BUI as low dissolved oxygen, river channelization, and contaminated sediments. Water samples from 1982 to 1986 were compared to New York standards and criteria for fish and fish propagation (Class C stream designation). Less than 10% of the samples exceeded the criteria for zinc, chromium, lead, and pH (NYSDEC 1989). Dissolved oxygen was also determined to be low based on samples collected from the Buffalo River (NYSDEC 1989). Additional fish population limiting factors identified in the 1989 RAP included siltation and habitat degradation (e.g., limited shallow vegetation areas for spawning). Both the 1989 RAP and the 2008 RAP Status Update noted that insufficient evidence was available to conclusively determine whether wildlife populations are impaired. Therefore, according to BNR, the wildlife population portion of this BUI remains a "likely impairment".

5.4.3.2 Analysis

Fish populations have shown a general resurgence since the 1980s. Irvine et al. (2005) summarized unpublished data from 1993 and 2003/2004 and concluded that diversity had not changed since 1993, with the river-wide number of juvenile and adult species caught ranging from 15 to 20. However, location-specific comparisons may be more relevant than river-wide trends, due to the pronounced gradient of habitat conditions from upstream to downstream.

Taxa richness (i.e., total number of species) observed in the 2008 study was similar to that observed in 2003 and higher than that observed in 2004. The highest total number of fish species collected from any one of the ten sites evaluated in 2003 was 14 species in the vicinity of RM 4.8; in 2004 only ten species were collected (Irvine et al. 2005).[21] In the present study, fish populations were evaluated from approximately RM 4.5 to 7.5 (Figure 4-4). Taxa richness was high, with 15 species observed at both RM 4.75 and 7.5. In both 2003 and 2004, the lowest numbers of fish species were collected near RM 6 (eight in 2003 and four in 2004). Similarly, in 2008, eight species were collected from this same area. Note that the seasonal timing of sampling differed between 2008 (October sampling) and the 2003-2004 studies (two sampling events per year in June and August), which could influence sampling results.

Population abundance was evaluated in the 2008 study and presented as CPUE (Table 4-14a). CPUE ranged from 86 to 325 fish/hour (RM 7.25 and RM 4.5, respectively). The three locations upstream of the Buffalo River AOC had an average CPUE of 105 fish per hour, while the two locations within the AOC had an average CPUE of 217 fish per hour. In general, the Cazenovia Creek location resulted in a higher CPUE (188 fish/hour) than the individual Buffalo River locations (with the exception of the sampling location at RM 4.5). The sunfish (Centrarchidae) and minnow (Cyprinidae) families contributed to the majority of the CPUE totals at every location (approximately 77% of the CPUE from the Buffalo River and 90% of the CPUE from location CC).

When evaluated by NYSDEC metrics, all Buffalo River and Cazenovia Creek areas evaluated in 2008 were judged to be either moderately or severely impaired. When the 2008 data were evaluated by IBI metrics, these same areas were judged to be fair to poor, but the conditions in locations upstream of the AOC are similar to those within the AOC. Also, the IBIs seen in 2008 that do overlap with those seen in 2003/4 show some slight increases (Figure 4-4).

An analysis of PCB and mercury chemical residues in fish tissues was also considered as this may related to spatial trends or impairments in the fish community. The results show that body residues are likely to pose adverse impacts, even to the fish with the greatest chemical burdens.

5.4.3.3 Histopathological Analysis

Irvine et al. (2005) summarized the most recent histopathological analyses of Buffalo River fish but only mentioned a high incidence of DELTs (87%) in brown bullhead.[22] As described in Section 5.3.5.2, DELTs have subsequently been shown to be non-discriminatory biomarkers and have been recommended against in establishing BUIs. While DELTs were noted in the 2008 sampling event, they were not histologically verified, and therefore, are not used to evaluate this BUI. However, it should noted that the incidence of raised skin lesions, the only DELTs evaluated by Baumann et al. (1996) and Yang (2004), decreased substantially in the ten years since the previous evaluation.

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[21] Note that Irvine et al. designation of river miles is slightly different due to the designation of mile 0. The statements herein are based on the river mile designation as identified in this SRIR. Figure 5-1 of this SRIR shows the Irvine et al. (2005) locations in these general areas for reference.

[22] Snyder collected a total of 68 brown bullhead in 2003 and 2004. The length of the fish ranged from 20 to 56 cm with a mean greater than 30 cm. Since DELT incidences of 100% were reported in the oldest brown bullhead from the Detroit River, this suggests that DELT incidence, like liver lesion incidence, is also correlated with age.

The incidence of liver neoplasms at greater than 5% has been recently proposed as a scientifically valid basis for listing the BUI. However, the average incidence of liver neoplasms in brown bullhead from two reference areas in the Great Lakes (Baumann et al. 1996) is 5.7% (i.e., 5.9% and 5.6%). Previous studies showed a decrease in total liver tumors in response to natural attenuation and remediation in the Black River (Baumann and Harshbarger 1998, USEPA 2000). Between 1982 and 1987, natural attenuation was associated with a decrease in liver tumors from 60% to 33%. Following dredging, the tumor incidence rose again to a high of 64%, but then decreased to 0% in one year (1994). The tumor incidence rose again in 1998 to 7%, showing variability among years. The incidence at reference areas and the increase from 0 to 7% suggests that 5% should only serve as a rough estimate and that higher incidences occur in clean areas. Based on 1983 and 1986 data, Black and Baumann (1991) reported a liver neoplasm incidence of 16.6% in the Buffalo River. This Buffalo River liver neoplasm incidence subsequently rose to 19% in 1988 (Baumann and Harshbarger 1995). Between 1988 and 2008, the incidence of liver neoplasms decreased to 8.1% (this study), which is similar to the 1998 incidence in the Black River. In comparison, the average incidence of liver neoplasms in brown bullhead from two reference areas in the Great Lakes (Baumann et al. 1996) is 5.7% (i.e., 5.9% and 5.6%). The apparent greater response to natural attenuation in the Buffalo River may be due to the higher initial liver tumor incidence in the Black River (60%) relative to the Buffalo River (19%).

5.4.3.4 Conclusions

The multiple lines of evidence are presented in Table 5-7. The highest concentrations of total PAH, PCB, lead, and mercury occurred between RM 3.5 – 5.5 (as discussed in Sections 2.1.2.1 – 2.1.2.4). When evaluated by NYSDEC metrics, all Buffalo River and Cazenovia Creek areas resulted in either moderately or severely impaired ratings (Table 5-7). When Buffalo River and Cazenovia Creek were evaluated by IBI metrics, all areas were judged to be fair to poor (Table 5-7). The reach between RM 3.5-5.5, specifically, resulted in a moderate to severe rating using NYSDEC metrics and a fair to poor rating using IBI metrics..

5.4.4 Loss of Fish and Wildlife Habitat

5.4.4.1 Basis for Listing

The Loss of Fish and Wildlife Habitat was listed as a BUI based the observation that the downstream portion of the Buffalo River AOC is heavily bulkheaded and that routine navigation dredging occurs in the river (NYSDEC 1989). The 1989 RAP further specifies that the combination of dredging and bulkheading limits spawning and nursery areas in shallow waters and wetlands. The 2008 RAP Status Update (BNR 2008) identifies the likely causes of this BUI as physical disturbances such as bulk heading, dredging and steep slopes and lack of suitable substrate.

5.4.4.2 Analysis

Results from the 2008 field investigation demonstrate that EV and SAV beds are present throughout the Buffalo River AOC. These EV and SAV beds can provide some habitat for ecological communities in the river. However, the available habitat may be limited by the hardened shorelines (Figure 4-2b) and available substrate (Figure 2-15). These limitations are reflected in the habitat assessments completed in

2008. The 2008 RBP habitat scores (from benthic sampling locations) indicated marginal to suboptimal habitat in benthic survey locations (Appendix I). Similarly, the QHEI scores (from fish sampling locations) indicate fair habitat within the AOC (Appendix H). Additional wildlife habitat assessment surveys were not conducted as part of the 2008 field investigation, and therefore, the status of this BUI with respect to the delisting criteria provided in Table 1-2, can not be determined based on the information presented in this *SRIR*.

5.4.5 Restriction on Fish Consumption

This section includes a discussion of the trends in measured concentrations of PCBs in carp from the Buffalo River in the context of the Restriction on Fish Consumption BUI. The basis for listing is discussed below.

5.4.5.1 Basis for Listing

This BUI was identified based on a 1987-1988 New York State Department of Health (NYSDOH) fish and wildlife advisory to eat no carp from the Buffalo River (NYSDEC 1989). This advisory was based on a 1984 composite sample of three fish, which reported a PCB concentration of 6.7 mg/kg, exceeding the Food and Drug Administration (FDA) tolerance level of 2 mg/kg.

5.4.5.2 Analysis

No fish tissues were collected as part of the fall 2008 sampling event to evaluate this BUI. However, PCB concentrations have been measured in carp from the Buffalo River during the period of 1977 through October 2007. These data are summarized in Table 5-8 and indicate that PCB concentrations in carp have been declining over this monitoring period.

Further, data collected in October 2007 by NYSDEC indicate that PCB concentrations in the edible fillet portion of carp sampled from the Buffalo River range from 0.29 to 2.1 mg/kg (NYSDEC 2008). The upper end of the range of detected PCB concentrations in the edible portion of carp exceeds PCB levels currently considered by NYSDOH's for setting fish advisories (1 mg/kg) and slightly exceeds the FDA limit (2 mg/kg).

5.4.5.3 Conclusions

Data collected over the last 20 years indicate that PCB concentrations in carp have been declining, and the most recent data indicate that concentrations in the edible tissue from carp has declined to the point that the low end of the detected concentration range is below the NYSDOH criterion for setting fish consumption advisories. However, the upper end of the range remains above the NYSDOH criterion for setting fish consumption advisories.

5.4.6 Restrictions on Dredging

5.4.6.1 Basis for Listing

The Restrictions on Dredging BUI is based on studies conducted by USEPA, USACE, and Erie County from the 1980s that indicated that contaminant levels in Buffalo River sediments exceeded open lake disposal criteria (NYSDEC 1989). In particular, these contaminants included arsenic, barium, copper, iron, lead, manganese, zinc, and cyanide.

5.4.6.2 Analysis

The distribution of sediment concentrations of total PAHs, total PCBs, lead and mercury in the Buffalo River AOC have been presented in this *SRIR*. Additional historical studies have also shown the distribution of sediment concentrations for other chemicals that may impact the management and disposal of dredge material. However, assessing the current status of Buffalo River sediment contaminant levels with respect to the disposal of dredged sediments without special management measures, as outlined in the delisting criteria for this BUI, are outside of the scope of this *SRIR.*

6 References

Angermeier, P.L. 1987. Spatiotemporal variation in habitat selection by fishes in small Illinois streams. Pages 52-60 in Matthews and Heins (eds.). Community and Evolutionary Ecology of North American Stream Fishes. University of Oklahoma Press, Norman, Oklahoma.

Ankley, G.T., D.M. Di Toro, D.J. Hansen, W.J. Berry. 1996. Technical basis and proposal for deriving sediment criteria for metals. *Environ. Toxicol. Chem.* 15:2056-2066.

ASci Corporation. 2005. *Results of Ten-Day Hyalella azteca and Chironomus tentans Toxicity Tests with Whole Sediments from Buffalo River*. Prepared by ASci Corporation, Duluth, Minnesota, for Engineering & Environment, Inc., Virginia Beach, Virginia.

ASci Corporation. 2007. *Results of Ten-Day Hyalella azteca and Chironomus tentans Toxicity Tests with Whole Sediments from Buffalo River Received June 18, 200.* Prepared by ASci Corporation, Duluth, Minnesota, for Engineering & Environment, Inc., Virginia Beach, Virginia.

Atkinson, J. F. a. F., G.S. 2006. “Sediment Remediation in the Buffalo River.” Final Report, Project GL975074-01-1 (submitted), US EPA Great Lakes National Program Office, Chicago, IL.

Baumann, P., and J. Harshbarger. 1995. Decline in liver neoplasms in wild brown bullhead catfish after coking plant closes and environmental PAHs plummet. Env. Hlth. Perspect. 103: 168-170.

Baumann, P. and J. Harshbarger. 1998. Long term trends in liver neoplasm epizoitics of brown bullhead in Black River, Ohio. Env. Monitor. Assess. 53: 213-223.

Baumann, P. 2005. Fish tumor BUI criteria: Determining numbers for the delisting process. www\glc.org/spacl.

Baumann, P., J. Harshbarger, and K. Hartmann. 1990. Relationship between liver tumors and age in brown bullhead populations from two Lake Erie tributaries. Sci. Tot. Env. 94: 71-87.

Baumann, P., V. Cairns, B. Kurey, L. Lambert, I. Smith and R. Thoma. 2000. Fish Tumors and Other Deformities. Lake Erie LaMP Technical Report No. 6. Lake Erie Lakewide Management Plan (LaMO). pp. 56.

Baumann, P., I. Smith, and C. Metcalf. 1996. Linkages between chemical contaminants and tumors in benthic Great Lakes fish. J. Great Lakes Res. 22: 131-152.

Baumann, P., and S. Hurley. 2006. Tumors in brown bullhead in ponds near the Mass. military reservation. http://www.mmr.org/Community/teams/pct2/20061108%5Cbaumann_bullhead_110806.pdf

Baumann, P. and K. Dabrowski . 2006. Setting Delisting Criteria for Fish Tumor Impairments. United States Environmental Protection Agency Final Report. Grant #GL-96593901.

Bengtsson, B. 1980. Long-term Effects of PCB (Clophen A50) on Growth, Reproduction and Swimming Performance in the Minnow, *Phoxirrus phoxinus.* Water Research, 14: 681-687.

Benoit, J., C. Gilmour, R. Mason, and A. Heyes. 1999. Sulfide controls on mercury speciation and bioavailability to methylating bacteria in sediment pore waters. Env. Sci. Technol. 33: 951-957.

Bisthoven L, Postma J, Vermeulen A, Goemans G, Ollevier F. 2001. Morphological Deformities in Chironomus riparius meigen Larvae After Exposure to Cadmium Over Several Generations. Water, Air and Soil pollution. Vol. 129, no1-4, pp. 167-179.ENVIRON, 2008

Black, J. 1983. Field and laboratory studies on environmental carcinogenesis in Noagara River fish. J. Great Lakes Res. 9: 326-334.

Black, J, and P. Baumann 1991. Carcinogens and cancers in freshwater fishes. Env. Hlth. Persps. 90: 27-33.

Black, J., H. Fox, P. Black, and F. Bock. 1985. Carcinogenic effects of river sediment extracts in fish and mice, pp. 415-427. In: Water Chlorination Chemistry: Environmental Impact and Health Effects, Jollet et al. (eds). Lewis Publishers, MI.

Blazer, V., J. Fournie, J. Wolf, and M. Wolfe. 2007. Manual for the microscopic diagnosis of proliferative liver and skin lesions in the brown bullhead (Ameiurus nebulosus). USGS, NOAA, Penn. Sea Grant. pp. 34.

Blum, J. 1964. Buffalo River studies, 1964. unpublished MS. 45.p. In: Assessment of Potential Aquatic Habitat Restoration Sites in the Buffalo River Area of Concern., Irvine, K., R. Snyder, T. Diggons, B. Sinn, J. Jedlicka, and J. O'Neill (eds.). October 2005.

BNR. 2005. Buffalo River Remedial Action Plan, 2005 Status Report. Buffalo Niagara Riverkeeper.

BNR. 2008. Buffalo River Remedial Action Plan, 2008 Status Report. Draft. Buffalo Niagara Riverkeeper

Borgmann, U., K. Ralph, and W. Norwood. 1989. Toxicity test procedures for *Hyallela azteca*, and toxicity of cadmium and pentachlorophenol to *H. azteca*, *Gammarus fasciatus*, and *Daphnia magna*. Arch. Env. Contam. Toxicol. 18: 756-764.

Borgmann, U., W. Norwood, and C. Clarke. 1993. Accumulation, regulation and toxicity of copper, zinc, lead and mercury in Hyalella azteca. Hydrobiol. 259: 79-89.

Borgmann, U., Norwood, W.P. 1999. Assessing the toxicity of lead in sediments to *Hyalella azteca*: the significance of bioaccumulation and dissolved metal. Can. J. Fish. Aquat. Sci. 56 (8), 1494-1503.

Bowser, P., M. Wolfe, J. Reimer and B. Shane. 1991. Epizootic papillomas in brown bullheads, Ictalurus nebulosus from Silver Stream reservoir, New York. Dis. Aquat. Org. 11:117-127.

Brouwer, H. and T. Murphy. 1995. Volatile sulfides and their toxicity in freshwater sediments. Env. Toxicol. Chem. 14: 203-208.

Canfield, T.J. et al. 1992. Benthic community structure evaluations. In: C.G. Ingersoll, D.R. Buckler, E.A. Crecelius, and T.W. LaPoint, eds. Biological Assessment of Contaminated Great Lakes Sediment. Draft Final Report. Prepared for Great Lakes National Program Office, USEPA. Report 60/***/***, Chicago.

Cornelissen, G., H.P. Arp, A. Pettersen, A. Hauge, G. Breedveld. 2008. Assessing PAH and PCB emissions from the relocation of harbour sediments using equilibrium passive samplers. Chemosphere, 72: 1581-1587.

DeFoe, D.L., G.D. Veith and R.W. Carlson. 1978. Effects of Aroclor® 1248 and 1260 on the fathead minnow (*Pimephales promelas*). J. Fish. Res. Board Canada 35:997-1002.

Diggins, T. P., and R. J. Snyder. 2003. Three decades of change in the macroinvertebrate community and associated water quality parameters of the Buffalo River Area of Concern, 1964 – 1993. Journal of Great Lakes Research 29: 652-663.

DiToro, D., and J. McGrath. 2000. Technical basis for narcotic chemicals and polycyclic aromatic hydrocarbon criteria. II. Mixtures and sediments. Env. Toxicol. Chem. 19: 1971-1982.

DiToro, D., J. McGrath, D. Hansen, W. Berry, P. Paquin, R. Mathew, K. Wu, and R. Santore. 2005. Predicting metal toxicity using a sediment biotic ligand model: Methodology and initial application. Env. Toxicol. Chem. 24: 2410-2427.

Drevnick, P. and M. Sanderheinrich. 2003. Effects of dietary methylmercury on reproductive endocrinology of fathead minnows. Env. Sci. Technol. 37: 4390-4396.

Ecology and Environment. 2008. Buffalo River Section 312 Environmental Dredging Existing Conditions. Prepared for the Buffalo District Army Corps of Engineers. November.

Ecology and Environment and CH2MHill. 2008a. Field Sampling Plan Supplement, Buffalo River Area of Concern. September.

Ecology and Environment and CH2MHill. 2008b. Quality Assurance Project Plan, Buffalo River Area of Concern. September.

Ecology and Environment and CH2MHill. 2009. Draft Data Summary Report, Buffalo River Area of Concern. February.

ENVIRON and MACTEC 2008a. Field Sampling Plan for the Buffalo River, NY. August.

ENVIRON and MACTEC 2008b. Quality Assurance Project Plan for Hydrodynamic and Physical Sampling, Buffalo River, NY. August.

ENVIRON and MACTEC 2008c. Quality Assurance Project Plan for Ecological Sampling, Buffalo River, NY. August.

Gammon, J.R., A. Spacie, J.L. Hamelink, and R.L. Kaesler. 1981. Role of electrofishing in assessing environmental quality of the Wabash River. Pages 307-324 STP 730 in J.M. Bates and C.I. Weber (editors). Ecological Assessments of Effluent Impacts on Communities of Indigenous Aquatic Organisms. American Society for Testing and Materials, Philadelphia, Pennsylvania.

Gleason, H.A. and Cronquist, A. 1991. Manual of Vascular Plants of the Northeastern United States and Adjacent Canada, Second Edition. The New York Botanical Garden. Bronx, New York.

Great Lakes National Program Office, GLNPO. 2008. Memo: Various Criteria for Buffalo River. February.

Greer, M., K. Irvine, and T. Tang. 2002. Evaluating ecosystem integrity in Great Lakes tributaries. Clearwat. 32: 16-19.

Grizzle, J., T. Schwedler, and A. Scott. 1981. Papillomas of black bullheads, Ictalurus melas (Rafinesque), living in a chlorinated sewage pond. J. Fish Dis. 4: 354-351.

Grizzle, J.M., P. Melius and D.R. Strength. 1984. Papillomas on fish exposed to chlorinated wastewater effluent. J. Natl. Cancer Inst. 73:1133-1142.

Grizzle, J.M.., S.A. Horowitz, and D.R. Strength. 1988. Caged fish as monitors of pollution: effects of chlorinated effluent from a wastewater treatment plant. Water Resources Bulletin 24(5): 951-959.

Halliwell, D.B., R.W. Langdon, R.A. Daniels, J.P. Kurtenbach, and R.A. Jacobson. 1999. Classification of freshwater fish species of the northeastern United States for use in the development of IBIs.

Pages 301-337 in T.P. Simon (editor). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Florida.

Hansen, D.J., W.J. Berry, J.D. Mohoney, W.S. Boothman, D.L. Robson, G.T. Ankely, D. Ma, Q. Yan, and C.E. Pasch. 1996. Predicting the toxicity of metals contaminated field sediments using interstitial water and acid volatile sulfide normalizations. *Environ. Toxicol. Chem.* 15:2080-2094.

Hawthorne, S.B., C.B. Grabanski, D.J. Miller. 2006. Measured partitioning coefficients for parent and alkyl polycyclic aromatic hydrocarbons in 114 historically contaminated sediments. Environmental Toxicology and Chemistry, 25 (11):2901-2911.

Hilsenhoff, W.L. 1977. Use of arthropods to evaluate water quality of streams. Technical Bulletin. Wisconsin Department of Natural Resources. Number 100. 15pp.

Hilsenhoff, W.L. 1982. Using a biotic index of to evaluate water quality in streams. Technical Bulletin. Wisconsin Department of Natural Resources. Number 132. 22pp.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. Great Lakes Entomology 20: 31-39.

Hilsenhoff, W.L. 1998. A modification of the biotic index of organic stream pollution to remedy problems and to permit its use throughout the year. Great Lakes Entomology 31: 12pp.

Holmgren, N.H. 1998. Illustrated Companion to Gleason and Cronquist's Manual: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada. The New York Botanical Garden. Bronx, New York.

Holm, G., L. Norrgren, T. Andersson, and A. Thuren. 1993. Effects of exposure to food contaminated with PBDE, PCN or PCB on reproduction, liver morphology and cytochrome P450 activity in the three-spined stickleback, Gasterosteus aculeatus. Aquat. Toxicol. 27:33-50.

Hoque, M., F. Yusoff, and M. Syed. 1998. Effect of hydrogen sulfide on liver somatic index and Fulton's condition factor. J. Fish Biol. 52: 23-30.

Hotchkiss, Neil. 1972. Common Marsh, Underwater, and Floating-leaved Plants of the United States. Dover Publications, Inc., New York, New York.

Hultunen, J. 1969. Distribution of oligochaetes in western Lake Erie, 1961. Limnol. Oceanogr. 14: 260-264.

Inamdar, 2004. Sediment Modeling for the Buffalo River Watershed. Great Lakes Center.Buffalo State College. Buffalo. NY.

IJC. 2008. Restoring beneficial uses in Areas of Concern. Website. http://www.ijc.org/rel/boards/annex2/buis.htm. Last accessed 7/31/2008.

Irvine, K., R. Synder, T. Diggins, C. Chuey, J. Jedlicka, and J. O'Neill. 2005. Assessment of Potential Aquatic Habitat Restoration Sites in the Buffalo River Area of Concern. Prepared for NYSDEC, Region 9.

Jarvinen, A.W. and G.T. Ankley. 1999. Linkage of effects to tissue residues: development of a comprehensive database for aquatic organisms exposed to inorganic and organic chemicals. SETAC Technical Publication Series. SETAC Press. Society of Environmental Toxicology and Chemistry, Pensacola, FL.

Jeyasingham K, Ling N. 1997. Head capsule deformities in Chironomus zealandicus (Diptera: Chironomidae): influence of site and substrate. New Zealand Journal of Marine and Freshwater Research, 1997, Vol.31: 175—184

Karr, J.R. 1981. Assessment of Biotic Integrity Using Fish Communities. Fisheries 6(6):21-27.

Korkea-aho, T., E. Vehnianen, J. Kukkonen, and J. Taskinen. 2008. The effects of treated effluents on the intensity of papillomatosis and HSP 70 expression in roach. Ecotoxicol. Env. Saf. 70: 462-468.

Krauss, M. and W. Wilcke. 2001. Predicting soil–water partitioning of polycyclic aromatic hydrocarbons and polychlorinated biphenyls by desorption with methanol–water mixtures at different temperatures. Environmental Science and Technology, 35: 2319-2325.

Larsson, A., C. Haux, M. Sjobeck, and G. Lithner. 1984. Physiological effects of an additional stressor on fish exposed to a simulated heavy-metal-containing effluent from a sulfide ore smeltery. Ecotoxicol. Env. Safety 8: 118-128.

Lesko, L., S. Smith, and . Blouin.. 1996. The effect of contaminated sediments on fecundity of the brown bullhead in three Lake Erie tributaries J. Great Lakes Res. 22: 830-837

Loganathan, B.G., K. Kannan, I. Watanabe, M. Kawano, K. Irvine, S. Kumar, and H.C. Sikka. 1995. Isomer-specific determination and toxic evaluation of polychlorinated biphenyls, polychlorinated/brominated dibenzo-p-dioxins and dibenzofurans, polybrominated biphenyl ethers, and extractable organic halogen in carp from the Buffalo River, New York. Environmental Science and Technology. 29: 1832-1838.

MacDonald E, Taylor B. 2006. Incidence of mentum deformities in midge larvae (Diptera:Chironomidae) from Northern Nova Scotia, Canada. Hydrobiologia, 563:277–287.Martinez et al 2004

MacLean, R.S., Borgmann, U., Dixon, D.G. 1996. Bioaccumulation kinetics and toxicity of lead in *Hyalella azteca* (Crustacea, Amphipoda). Can. J. Fish. Aquat. Sci. 53, 2212-2220.

MACTEC Engineering and Consulting, Inc. 2008. Preliminary Evaluation of Conceptual Remedies on Flood Elevations within the Buffalo River Area of Concern. Prepared for Honeywell Corporation. August 15.

Mahony, J., D. DiToro, A. Gonzalez, M. Curto, M. Dilg, L. de Rosa, and L. sparrow. 1996. Partitioning of metals to sediment organic carbon. Env. Toxicol. Chem. 15: 2187-2197.

Martello, L.B., Sorensen, M.T., P.C. Fuchsman, and R.J. Wenning, 2007. Chromium geochemistry and bioaccumulation in sediments from the lower Hackensack River, New Jersey. Archives of Environmental Contamination and Toxicology, 53:337-350.

Martinez E, Moore B, Schaumloffel J, Dasgupta N. 2004. Effects of Exposure to a Combination of Zinc- and Lead-Spiked Sediments On Mouthpart Development and Growth In Chironomus tentans. Environmental Toxicology and Chemistry, Vol. 23, No. 3, pp. 662–667.

Martinez E, Wold L, Moore B, Schaumloffel J, Dasgupta N. 2006. Morphologic and Growth Responses in Chironomus tentans to Arsenic Exposure. Arch. Environ. Contam. Toxicol. 51, 529–536.

Matta, M. J. Linse, C. Cairncross, L. Francendese, and R. Kocan. 2001. Reproductive and transgenerational effects of methylmercury or Aroclor 1268 on *Fundulus heteroclitus*. Env. Toxicol. Chem. 20: 327-335.

McKim, J., G. Olson, G. Holcombe, and E. Hunt. 1976. Long-term effects of metylmercury chloride on three generations of brook trout (*Salvelinus fontinalis*): Toxicity, accumulation, and elimination. J. Fish. Res. Bd. Can. 33: 2726-2739.

McMaster, M., J. Sherry, S. Brown, B. Evans, B. Park and C. Portt. 2008. Re-assessment of liver tumor incidence in wild fish from Canadian areas of concern. Proc. 29th

MDEQ 2006. Guidance for delisting Michigan's Great Lakes Areas of Concern. MI/DEQ/WB-06/001.

Mellor, G.L. and T. Yamada. 1982. "Development of a Turbulence Closure Model for Geophysical Fluid Problems", Rev. Geophys. Space Phys. 20, pp. 851-875.

Milani, D., L.C. Grapentine, T.B. Reynoldson. 2002. BEAST Assessment of Sediment Quality in Peninsula Harbour, Lake Superior. Environment Canada, Burlington, ON.

Milani, D., T. Reynoldson, U. Borgmann, and J. Kolasa. 2003. The relative sensitivity of four benthic invertebrates to metals in spiked-sediment exposures and application to contaminated field sediment. Env. Toxicol. Chem. 22: 845-854.

Milani, D., L.C. Grapentine, T.B. Reynoldson. 2007. Assessment of mercury contamination and biological impacts in the St. Clair River. WSTD Contribution No. 07-527. Environment Canada, Burlington, ON.

Mikac, N., S. Niessen, B. Ouddane, and J-C. Fischer. 2000. Effects of acid volatile sulfide on the use of hydrochloric acid for determining solid-phase association of mercury in sediments. Env. Sci. Technol. 34: 1871-1876.

Nebeker, A.V., F.A. Puglisi, and D.L. DeFoe. 1974. Effect of polychlorinated biphenyl compounds on survival and reproduction of the fathead minnow and flagfish. Trans. Amer. Fish. Soc. 103:562-568.

NYSDEC. 1987. Toxic Substances in Fish and Wildlife Analyses since May 1, 1982 Volume 6. Division of Fish and Wildlife. Albany, NY.

NYSDEC. 1989. Buffalo River Remedial Action Plan - Final and Draft.

NYSDEC. 1991. Quality Assurance Work Plan for Biological Stream Monitoring In New York State. Bode RW, Novak MA, Abele LA. Stream Biomonitoring Unit, Bureau of Water Assessment and Management Division of Water.

NYSDEC. 2002. Quality Assurance Work Plan for Biological Stream Monitoring In New York State. Bode RW, Novak MA, Abele LA, Heitzman DL, Smith AJ. Stream Biomonitoring Unit, Bureau of Water Assessment and Management Division of Water.

NYSDEC 2004. 30 Year Trends in Water Quality and Rivers and Streams in NY. Division of Water. http://www.epa.gov/bioindicators/pdf/NYSDEC30yrTrendsReport.pdf

NYSDEC. 2005. The Niagara River-Lake Erie Drainage Basin. Sampling Years 2000-2001. Report prepared by the Statewide Waters Monitoring Section. New York State Department of Environmental Conservation. February 2005.

NYSDEC. 2006. Chemical residues in carp from Buffalo River and upper Niagra River, 2004 data (memo). Division of Fish, Wildlife and Marine Resources. Albany, NY.

NYSDEC. 2008. Data Report for Residues of Organic Chemicals and Four Metals in Edible Tissues and Whole Fish for Fish Taken from the Buffalo River, NY. Draft. Albany, NY.

Novak, M.A. and R.W. Bode. 1992. Percent model affinity, a new measure of macroinvertebrate community composition. Journal of the North American Benthological Society 11(1): 80-85.

Ohio EPA. 1987. Biological criteria for the protection of aquatic life: volumes I-III. Ohio Environmental Protection Agency, Columbus, Ohio.

Okihiro, M. 1988. Chromatophoromas in two species of Hawaiian butterflyfish (Chaetodon multicintus and C. miliaris). Vet. Pathol. 25: 422-431.

Okihiro, M., J. Whipple, J. Groff, and D. Hinton. 1993. Chromatophoromas and chromatophore hyperplasia in Pacific rockfish (Sebastes spp.). Cancer Res. 53: 1761-1769.

Okihiro, M. and D. Hinton. 2000. Partial hepatectomy and bile duct ligation in rainbow trout (Oncorhynchys mykiss): Histologic, immunohistochemical and enzyme histochemical characterization of hepatic regeneration and biliary hyperplasia. Toxicol. Pathol. 28: 342-356.

Olson, G., D. Mount, V. Snarski, and Y. Thorslund. 1975. Mercury resides in fathead minnows, Pimephales promelas Rafinesque, chronically exposed to methylmercury in water. Bull. Env. Contam. Toxicol. 14: 129-134.

Oseid, D. and L. Smith. 1974a. Chronic toxicity of hydrogen sulfide to Gammarus pseudolimnaeus. Trans. Am. Fish. Soc. 103: 819-822.

Oseid, D. and L. Smith. 1974b. Factors influencing acute toxicity estimates of hydrogen sulfide to freshwater invertebrates. Wat. Res. 8: 739-746.

Oseid, D. and L. Smith. 1975. Long-term effects of hydrogen sulfide on Hexagenia limbata (Ephemeroptera. Env. Entomol. 4: 15-18.

PADEP, USEPA, and Pennsylvania Sea Grant. 2003. Second Fish Tumors Related to Great Lakes Areas of Concern Conference Proceedings. August.

Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for Evaluating Stream, Riparian, and Biotic Conditions. U.S. Department of Agriculture, U.S. Forest Service, Ogden, Utah. General Technical Report INT-138.

Rankin, E. 1989. The qualitative habitat evaluation index (QHEI): Rationale, methods and application. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Columbus, OH.

Sakaris, P., R. Jesien, A. Pinkney. 2005. The brown bullhead as indicator species: Seasonal movement patterns and home ranges within the Anacostia River. Trans. Am. Fish. Soc. 134: 1262-1270

Sanderheinrich, M. and K. Miller. 2006. Effects of dietary methylmercury on reproductive behavior of fathead minnows (*Pimephales promelas*). Env. Toxicol. Chem. 25: 3053-3057.

Sferra, J., P. Fuchsman, R. Wenning and T. Barber. 1999. A site-specific evaluation of mercury toxicity in sediment. Arch. Env. Toxicol. Chem. 37: 488-495.

Singer, J., J. Atkinson, P. Manley and P. McLaren. 2008. Understanding sediment dynamics using geological and engineering approaches: a case study of the Buffalo River area of concern, Buffalo, New York. Intl. J. River Basin Management. 6: 1-10.

Smagorinsky, J. 1963. “General Circulation Experiments with the Primitive Equations, I: The Basic Experiment”, Monthly Weather Review, vol 91, pp. 99-164.

Spitzbergen, J. and M. Wolfe. 1995. The riddle of hepatic neoplasia in brown bullhead fro relatively unpolluted waters in New York state. Toxicol. Pahtol. 23: 716-725.

SulTrac. 2007. Final Screening-Level Ecological Risk Assessment and Food-Chain Model Assessment of Potential Risks to Site Receptors: Upper Buffalo River Area of Concern, Buffalo, New York. Prepared by SulTRAC for U.S. Environmental Protection Agency Region 5, Chicago, Illinois.

Swift, M., T. Canfield, and T. LaPoint. 1996. Sampling benthic communities for sediment toxicity assessments using grab samplers and artificial substrates. J. Great Lakes Res. 22: 557-564..

Thoma, R.R. 1998, Biological monitoring and an index of biotic integrity for Lake Erie's nearshore waters. IN: T.P. Bimon (ed). Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Boca Raton, Fl. Pp 417-461.

United States Army Corps of Engineers (USACE), 1988. Buffalo River Sedimentation Study. Buffalo and West Seneca, NY.

USACE. 2003. Sediment Sampling, Biological Analyses, and Chemical Analyses for Buffalo River Area of Concern, Buffalo New York. Engineer Research and Development Center. December.

USACE. 2008. Buffalo River Section 312 Environmental Dredging Existing Conditions report. Prepared for the Buffalo District, USACE by ecology and environment, inc., Lancaster, NY

United States Environmental Protection Agency (USEPA). 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish. Office of Water. EPA/440/4-89/001 (also known as Plafkin et al., 1989).

USEPA. 1993. Baseline Human Health Risk Assessment: Buffalo River, New York, Area of Concern. Assessment and Remediation Of Contaminated Sediments (ARCS) Program. EPA 905-R93-008.

USEPA. 1994. Assessment and Remediation of Contaminated Sediments Program. Model data requirements and mass loading estimates for the Buffalo River mass balance study. USEPA, Chicago, Illinois. Document number: EPA 905-R94-005.

USEPA 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers- Periphyton, Benthic Macroinvertebrates, and Fish. EPA 841-B-99-002. USEPA Office of Water. Washington, DC.

USEPA. 2000. Health of bullhead in an urban fishery after remedial dredging. Final Report- January 31, 2000. USEPA Great Lakes Monitoring. http://www.epa.gov/greatlakes/sediment/Bullhead/report.html

USEPA. 2003. Procedures for the derivation of equilibrium partitioning sediment benchmarks (ESBs) for the protection of benthic organism: PAH mixtures. EPA-600-R-02-013. Office of Research and Development. Washington, DC 20460.

USEPA. 2005a. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites*. Available at: http://www.epa.gov/superfund/programs/clp/guidance.htm. EPA-540-R-05-012. December.

USEPA. 2005b. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metals Mixtures. EPA-600-R-02-001. Office of Research and Development.

USEPA. 2007a. In Situ Water Quality Monitoring, SESDPROC-111. Field Branches Quality System and Technical Procedures. USEPA, Region 4, Science and Ecosystem Support Division, Athens, Georgia. http://www.epa.gov/region4/sesd/fbqstp/Insitu-Water-Quality-Mon.pdf

USEPA. 2007b. Global Positioning System, SESDPROC-110. Field Branches Quality System and Technical Procedures. USEPA, Region 4, Science and Ecosystem Support Division, Athens, Georgia. http://www.epa.gov/region4/sesd/fbqstp/Global-Positioning-System.pdf

USEPA. 2007c. Wastewater Flow Measurement, SESDPROC-109. Field Branches Quality System and Technical Procedures. USEPA, Region 4, Science and Ecosystem Support Division, Athens, Georgia. http://www.epa.gov/region4/sesd/fbqstp/Global-Positioning-System.pdf.

USEPA. 2007d. Sediment Sampling, SESDPROC-200. Field Branches Quality System and Technical Procedures. USEPA, Region 4, Science and Ecosystem Support Division, Athens, Georgia. http://www.epa.gov/region4/sesd/fbqstp/Sediment-Sampling.pdf

USEPA. 2007e. Benthic Macroinvertebrate Sorting and Taxonomic Identification, SESDPROC- 509. Field Branches Quality System and Technical Procedures. USEPA, Region 4, Science and Ecosystem Support Division, Athens, Georgia. http://www.epa.gov/region4/sesd/fbqstp/Benthic-Macroinvert-Sorting-and-Tax-Id.pdf

U.S. Policy Committee. 2001. Restoring United States Areas of Concern: Delisting Principles and Guidelines. Adopted by the United States Policy Committee. December 6, 2001.

Van Urk, G., F.C.M. Kerkum, and H. Smit. 1992. Life cycle patterns, density, and frequency of deformities in Chironomus larvae over a contaminated sediment gradient. Canadian Journal of Fisheries and Aquatic Sciences 49:2291-2299.

Washington, H.G. 1984. Diversity, biotic, and similarity indices. Water Research 18(6): 653-694.

Weber, C. I. (ed.) 1973. Biological field and laboratory methods for measuring the quality of surface water and effluents. National Environmental Research Center, USEPA, Cincinnati, OH.

Weiner, and D. Spry. 1996. Toxicological significance of mercury in freshwater fish, pp. 297-339. In: Environmental Contaminants in Wildlife. Interpreting tissue concentrations, Beyer et al. (eds.). SETAC Press, FL.

Wiederholm, T. 1984. Incidence of deformed chironomid larvae (Diptera:Chironomidae) in Swedish lakes. Hydrobiologia 109:243-249.

Winger P.V., P.J. Lasier, and H. Geitner. 1993. Toxicity of sediments and pore water from Brunswick Estuary, Georgia. Arch. Environ. Contam. Toxicol. 25:371-376.

Wobeser, G. 1975. Prolonged oral administration of methyl mercury chloride to rainbow trout (*Salmo gairdneri*) fingerlings. J. Fish. Res. Bd. Can. 32: 2015-2023.

Wobeser, G., N.O. Nielsen, B. Schiefer. 1976. Mercury and mink II. Experimental methyl mercury intoxication. Can. J. Comp. Med. 40:34-45.

Yang, X. 2004. Use of fish biomarkers to assess the contaminant exposure and effects in Lake Erie tributaries. Ph.D thesis, Ohio State University, pp. 150.

Tables

Table 1-1
Buffalo River AOC Beneficial Use Impairment Indicators
Buffalo River, NY

Impairment Indicator	1989 Status	2005 Status	2008 Status	Known or Likely Cause
1. Restrictions on Fish & Wildlife Consumption	Impaired	Impaired	Impaired	PCB's and Chlordane in sediments.
2. Tainting of Fish & Wildlife Flavor	Likely Impaired	Likely Impaired	Likely Impaired	PAHs in sediments.
3. Degradation of Fish & Wildlife Populations	Likely Impaired	Likely Impaired	Impaired/Likely Impaired*	Low dissolved oxygen, river channelization, and contaminated sediments. *Fish Populations are Impaired while Wildlife Populations are Likely Impaired.
4. Fish Tumors and Other Deformities	Impaired	Impaired	Impaired	Sediments, navigational dredging.
5. Bird or Animal Deformities or Reproductive Problems	Likely Impaired	Likely Impaired	Likely Impaired	PCBs, DDT, and metabolites in sediments.
6. Degradation of Benthos	Impaired	Impaired	Impaired	Sediments, navigational dredging.
7. Restrictions on Dredging	Impaired	Impaired	Impaired	Various contaminants in sediments.
8. Eutrophication or Undesirable Algae	Not Impaired	Unknown	Not Impaired	Not Applicable.
9. Restrictions on Drinking Water Consumption or Taste and Odor Problems	Not Impaired	Not Applicable	Not Applicable	Not Applicable.
10. Beach Closings	Not Impaired	Not Applicable	Not Applicable	Sediments, CSOs, and bacterial loading from upper watershed.
11. Degradation of Aesthetics	Not Impaired	Impaired	Impaired	Floatables, debris and foul odor from CSOs and upper watershed.
12. Added Costs to Agriculture and Industry	Not Impaired	Not Impaired	Not Impaired	Not Applicable.
13. Degradation of Phytoplankton and Zooplankton Populations	Not Impaired	Not Impaired for Zooplankton; Unknown for Phytoplankton	Not Impaired	Not Applicable.
14. Loss of Fish & Wildlife Habitat	Impaired	Impaired	Impaired	Physical disturbance such as bulk heading, dredging and steep slopes, and lack of suitable substrate.

Source: BNR 2008

Table 1-2
Summary of Buffalo River Draft BUI Delisting Criteria/Restoration Targets
Buffalo River, NY

BUI No.	Beneficial Use	Status	Delisting Criteria/Restoration Target(s)
1	Restriction on Fish & Wildlife Consumption	Impaired	1) There are no AOC-specific fish and wildlife consumption advisories by New York State (e.g. carp for PCBs); AND 2) When contaminant levels due to watershed or in-place contaminants in resident native and exotic fish and wildlife populations that could be consumed do not exceed current NYS standards.
2	Tainting of Fish and Wildlife Flavor	Likely Impaired	1) No exceedances of water quality standards or criteria for compounds (specifically phenols) associated with tainting within the AOC; AND 2) No reports of tainting from fish and wildlife officials or informed public observers
3	Degradation of Fish and Wildlife Populations	Impaired	**Fish Populations** 1) Fish surveys find that the resident fish community is fair to good based on applicable fish community biolgical indices (IBI) for two consecutive surveys; AND 2) The frequency of occurrence of DELT anomalies in bottom-dwelling fish does not exceed recommended levels; AND 3) Whole-body concentrations of Endocrine Disruptors (including but not limited to: PCBs, dioxins, and pesticides) in bottom dwelling fish do not exceed critical tissue concentrations for adverse effects on fish; AND 4) Water quality measures (based on NYS RIBS or other monitoring) meet state standards for at least a Class C river. **Wildlife Populations** 1) Wildlife surveys find that diversity and abundance of birds, mammals, reptiles, and amphibians in the AOC is comparable to a suitable reference site; AND 2) Wildlife assessments confirm no significant toxicity from water column or sediment contaminants; AND 3) Diversity of amphibian populations in AOC pocket wetlands is similar to upstream and/or Tifft marsh levels; AND 4) Diversity of benthic populations in the AOC is comparable to upstream levels.
4	Fish Tumors and Other Deformities	Impaired	1) Survey data confirm the absence of neoplastic liver tumors in bullheads (as compared to control site) for two consecutive sampling events; AND 2) Contaminants in water and sediments in the AOC do not exceed NYS standards
5	Bird or Animal Deformities or Reproductive Problems	Likely Impaired	1) No reports of deformities or reproductive problems in sentinel wildlife species from wildlife officials or trained observers; AND 2) Concentrations of bioaccumulative chemicals in fish do not exceed levels associated with reproductive problems in piscivorus wildlife; AND/OR 3) Concentrations in sediment do not exceed levels associated with benthic impairment that could result in reproductive problems in omnivorous and benthivorous birds and wildlife.
6	Degradation of Benthos	Impaired	1) Benthic macroinvertebrate communities are "non-impacted" or "slightly impacted" according to NYSDEC indices; OR 2) In the absence of conclusive community structure data, the toxicity of sediment-associated contaminants is not statically higher than controls.
7	Restrictions on Dredging	Impaired	1) There are no restrictions on routine commercial or recreational navigation dredging by the USACE or another entity across any part of the AOC, such that no special management measure or use of a confined disposal facility are required from the dredged material due to chemical contamination.
8	Eutrophication or Undesirable Algae	Not Impaired	Not applicable
9	Restrictions on Drinking Water	Not Impaired	Not applicable
10	Beach Closings	Not Impaired	TBD
11	Degradation of Aesthetics	Impaired	1) Minimize debris, general litter, floatables, or contaminants in the river or shoreline via point source or non-point sources through the implementation of Best Management Practices; AND 2) Organic, chemical, and biological contaminants should not persist in concentrations that can be detected as visible film, sheen, or discoloration on the surface, detected by odor, or form deposits on shorelines and bottom sediments.
12	Added Costs to Agriculture or Industries	Not Impaired	Not applicable
13	Degradation of Phytoplankton Zooplankton Populations	Not Impaired	Not applicable
14	Loss of Fish and Wildlife Habitat	Impaired	**Restore Habitat Connectivity** 1) A minimum 100-foot buffer of native vegetation on new development on each riverbank is maintained and enforced upstream from the Ohio Street Bridge. 2) Significant floodplain, wetland, or riparian habitat areas in the AOC are protected and/or restored, (see list). 3) A minimum 25% of the AOC shoreline is restored to natural slope, shallows, and aquatic (emergent and submerged) native vegetation, including naturalizing areas of the City Ship Canal shoreline. **Improve Stream Quality Index scores from "poor" to at least "good"** 1) Basic water quality measures (based on NYS RIBS) consistently meet state standards for a Class C or higher river. 2) Aquatic habitat scores are fair to good AND/OR the lower Buffalo River is no longer listed as "stressed" for aquatic life on the NYS Priority Waterbodies List. **Restore hydrologic function to support habitat and species goals** 1) Reduce navigational dredging in the AOC to support aquatic habitat and species goals (BUI #3) AND/OR 2) Restore and protect natural flows, meanders, and stream habitat in River Corrido opportunity areas upstream of the AOC.

Source: Jill Jedlicka, personal communication. Draft BUI Delisting Criteria, October 15, 2008

Table 2-1
Sediment Core Depths, Sample Depths, and Sample Analysis
Buffalo, NY

Core Number	Collection Date	Depth of core, ft	Sample Intervals[a]	Analyses[b]
001	9/15/2008	3.2	A	Standard Chemicals, GSD
002	9/16/2008	4.0	A	Standard Chemicals, GSD
003	9/15/2008	1.3	A	Standard Chemicals, GSD
004	9/16/2008	3.5	A	Standard Chemicals, GSD
005	9/15/2008	2.7	A	Standard Chemicals, GSD
006	9/16/2008	4.4	A	Standard Chemicals, GSD
007	9/16/2008	2.5	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
008	9/15/2008	2.0	A	Standard Chemicals, GSD
009	9/15/2008	1.8	A	Standard Chemicals, GSD
010	9/15/2008	0.5	D	Standard Chemicals, GSD
011	9/16/2008	3.3	C	Standard Chemicals, GSD
012	9/16/2008	4.6	A	Standard Chemicals, GSD
013	9/16/2008	5.1	C	Standard Chemicals, GSD
014	9/16/2008	3.4	A	Standard Chemicals, GSD
015	10/6/2008	0.5	D	Standard Chemicals, GSD
016	9/16/2008	7.8	A	Standard Chemicals, GSD
017	9/16/2008	2.1	A	Standard Chemicals, GSD
018	9/16/2008	1.4	A	Standard Chemicals, GSD
019	9/17/2008	4.3	A	Standard Chemicals, GSD
020	9/17/2008	6.3	A	Standard Chemicals, GSD
021	9/17/2008	7.5	A	Standard Chemicals, GSD
022	9/17/2008	1.9	A	Standard Chemicals, GSD
023	10/16/2008	0.5	D	Standard Chemicals, GSD
024	9/17/2008	3.3	A	Standard Chemicals, GSD
025	9/17/2008	8.9	C	Standard Chemicals, GSD
026	9/17/2008	2.1	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
027	9/17/2008	4.9	A	Standard Chemicals, GSD
028	9/19/2008	8.7	A	Standard Chemicals, GSD
029	10/6/2008	0.5	D	Standard Chemicals, GSD
030	9/19/2008	3.2	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
031	10/6/2008	0.5	D	Standard Chemicals, GSD
032	10/6/2008	0.5	D	Standard Chemicals, GSD
033	9/19/2008	4.8	C	Standard Chemicals, GSD
034	9/19/2008	9.5	A	Standard Chemicals, GSD
035	10/6/2008	0.5	D	Standard Chemicals, GSD
036	9/20/2008	1.7	A	Standard Chemicals, GSD
037	9/20/2008	0.9	A	Standard Chemicals, GSD
038	9/20/2008	4.0	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM

Table 2-1
Sediment Core Depths, Sample Depths, and Sample Analysis
Buffalo, NY

Core Number	Collection Date	Depth of core, ft	Sample Intervals[a]	Analyses[b]
039	9/20/2008	3.7	B	Standard Chemicals, GSD
040	9/20/2008	8.9	A	Standard Chemicals, GSD
041	9/20/2008	5.3	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
042	9/20/2008	2.5	C	Standard Chemicals, GSD
043	9/20/2008	2.8	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
045	10/15/2008	0.5	D	Standard Chemicals, GSD
046	9/20/2008	9.0	C	Standard Chemicals, GSD
047	9/20/2008	4.9	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
048	10/18/2008	11.7	A	Standard Chemicals, GSD
048	9/22/2008	11.7	A	Standard Chemicals, GSD
049	9/22/2008	6.1	A	Standard Chemicals, GSD
050	9/22/2008	9.1	A	Standard Chemicals, GSD
051	9/22/2008	9.1	A	Standard Chemicals, GSD
052	10/18/2008	12.8	A	Standard Chemicals, GSD
052	9/22/2008	12.8	A	Standard Chemicals, GSD
053	9/22/2008	9.9	A	Standard Chemicals, GSD
054	9/22/2008	9.8	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
055	9/22/2008	2.8	A	Standard Chemicals, GSD
056	9/22/2008	2.8	A	Standard Chemicals, GSD
057	9/22/2008	2.9	A	Standard Chemicals, GSD
058	9/22/2008	5.0	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
059	9/22/2008	2.4	B	Standard Chemicals, GSD
060	9/24/2008	6.2	C	Standard Chemicals, GSD
061	9/24/2008	8.6	A	Standard Chemicals, GSD
062	9/23/2008	7.1	A	Standard Chemicals, GSD
063	9/23/2008	2.4	A	Standard Chemicals, GSD
064	9/23/2008	4.8	A	Standard Chemicals, GSD
065	9/23/2008	6.0	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
066	9/23/2008	2.4	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
067	9/23/2008	2.6	A	Standard Chemicals, GSD
068	9/23/2008	5.0	A	Standard Chemicals, GSD
069	9/23/2008	8.4	A	Standard Chemicals, GSD
070	9/23/2008	2.1	A	Standard Chemicals, GSD
071	10/18/2008	13.7	A	Standard Chemicals, GSD
071	9/23/2008	13.7	C	Standard Chemicals, GSD
072	9/23/2008	7.3	A	Standard Chemicals, GSD
073	9/24/2008	4.7	A	Standard Chemicals, GSD
074	9/24/2008	5.0	B	Standard Chemicals, GSD

Table 2-1
Sediment Core Depths, Sample Depths, and Sample Analysis
Buffalo, NY

Core Number	Collection Date	Depth of core, ft	Sample Intervals[a]	Analyses[b]
075	9/24/2008	8.8	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
076	9/24/2008	7.0	A	Standard Chemicals, GSD
077	9/24/2008	6.5	A	Standard Chemicals, GSD
078	9/24/2008	8.4	A	Standard Chemicals, GSD
079	9/24/2008	1.4	A	Standard Chemicals, GSD
080	9/25/2008	9.6	C	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
081	10/8/2008	0.5	D	Standard Chemicals, GSD
082	10/17/2008	0.5	D	Standard Chemicals, GSD
083	9/25/2008	8.1	A	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
085	9/25/2008	3.9	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
087	9/25/2008	4.5	A	Standard Chemicals, GSD
088	9/25/2008	5.8	A	Standard Chemicals, GSD
089	9/25/2008	2.6	A	Standard Chemicals, GSD
090	9/25/2008	2.2	A	Standard Chemicals, GSD
091	10/8/2008	0.5	D	Standard Chemicals, GSD
092	9/26/2008	6.1	A	Standard Chemicals, GSD
093	9/26/2008	4.7	C	Standard Chemicals, GSD
094	9/27/2008	4.6	A	Standard Chemicals, GSD
095	9/27/2008	4.4	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
096	10/8/2008	0.5	D	Standard Chemicals, GSD
097	10/18/2008	9.3	A	Standard Chemicals, GSD
098	9/27/2008	4.6	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
099	9/26/2008	3.3	B	Standard Chemicals, GSD
100	9/27/2008	3.2	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
101	9/27/2008	8.8	A	Standard Chemicals, GSD
102	9/26/2008	4.9	B	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
103	9/26/2008	4.0	A	Standard Chemicals, GSD
104	9/26/2008	4.6	A	Standard Chemicals, GSD
105	9/27/2008	7.3	A	Standard Chemicals, GSD
106	9/26/2008	13.3	A	Standard Chemicals, GSD
106	10/18/2008	13.3	A	Standard Chemicals, GSD
107	9/26/2008	3.2	A	Standard Chemicals, GSD
108	10/8/2008	0.5	D	Standard Chemicals, GSD
109	10/8/2008	0.5	D	Standard Chemicals, GSD
110	10/8/2008	0.5	D	Standard Chemicals, GSD
111	10/8/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
113	9/16/2008	7.0	A	Standard Chemicals, GSD
114	10/21/2008	0.5	D	Standard Chemicals, GSD

Table 2-1
Sediment Core Depths, Sample Depths, and Sample Analysis
Buffalo, NY

Core Number	Collection Date	Depth of core, ft	Sample Intervals[a]	Analyses[b]
115	10/21/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
116	10/8/2008	0.5	D	Standard Chemicals, GSD
117	10/16/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
118	10/16/2008	0.5	D	Standard Chemicals, GSD
119	10/16/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
120	10/16/2008	0.5	D	Standard Chemicals, GSD
121	10/16/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
122	10/16/2008	5.9	B	Standard Chemicals, GSD
123	10/16/2008	0.5	D	Standard Chemicals, GSD, alkylated PAHs, AVS SEM
124	10/16/2008	0.5	D	Standard Chemicals, GSD

(a) Sample Intervals

A Sampled and analyzed at 0-0.5 ft, 0.5-1.0ft; after top foot alternated analyzing and archiving each 1-ft interval (i.e. Analyze, 1-2 ft, archive 2-3 ft, analyze 3-4 ft), including botton 1-ft interval.

B Sampled and analyzed at 0-0.5 ft, 0.5-1.0ft, and 2-3 ft. Archive 1-2 ft.

C Sampled and analyzed at 0-0.5 ft, 0.5-1.0 ft and each 1-ft interval thereafter for the entire length of the core.

D Ponar dredge sample, sampled and analyzed 0-0.5 ft.

(b) Standard chemical analyses include TOC, PCBs, PAHs, Lead, and Mercury

PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
TOC	Total Organic Carbon
AVS	Acid Volatile Sulfide
SEM	Simultaneously Extracted Metals
GSD	Grain Size Distribution

Table 2-2a
Total PAH Surface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	6	6	3.9	5.9	4.6	0.75	4.6
River Mile 0.5 - 1.0	33	33	2.0	48	8.4	10	6.1
River Mile 1.0 - 1.5	24	20	0.66	23	6.5	4.3	5.4
River Mile 1.5 - 2.0	24	23	0.66	15	5.7	3.0	5.0
River Mile 2.0 - 2.5	22	22	3.3	18	5.3	3.1	4.8
River Mile 2.5 - 3.0	26	26	3.2	39	6.9	7.1	5.6
River Mile 3.0 - 3.5	26	26	2.5	47	9.9	9.6	7.5
River Mile 3.5 - 4.0	41	41	3.5	91	16	22	8.7
River Mile 4.0 - 4.5	30	29	2.5	150	27	40	12
River Mile 4.5 - 5.0	35	35	2.5	85	13	21	6.9
River Mile 5.0 - 5.5	34	34	1.1	280	13	48	5.0
River Mile 5.5 - 6.0	23	23	1.2	10	5.5	2.3	5.0
River Mile 6.0 - 6.2	13	13	1.5	16	4.0	4.0	3.1
River Mile 6.2- 6.5, Upstream of the AOC	1	1	18	18	18	-	18
River Mile 6.5 - 7.0, Upstream of the AOC	1	1	3.8	3.8	3.8	-	3.8
Buffalo Harbor, Downstream of the AOC	9	9	1.8	42	7.1	13	3.6
City Ship Canal	60	57	1.7	300	21	41	11
Cazenovia Creek	2	2	2.1	3.4	2.8	0.94	2.7

mg/kg - milligrams per kilogram

Table 2-2b
Total PAH Subsurface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	12	12	3.1	41	15	16	9.3
River Mile 0.5 - 1.0	32	32	3.8	82	15	18	9.8
River Mile 1.0 - 1.5	38	36	0.62	110	23	27	12
River Mile 1.5 - 2.0	16	16	0.64	160	51	49	24
River Mile 2.0 - 2.5	21	21	3.1	58	12	16	7.0
River Mile 2.5 - 3.0	36	36	3.5	330	26	57	11
River Mile 3.0 - 3.5	25	25	2.2	42	11	9.9	8.0
River Mile 3.5 - 4.0	90	89	2.1	450	47	80	14
River Mile 4.0 - 4.5	62	60	2.4	410	56	90	18
River Mile 4.5 - 5.0	66	66	2.0	1800	120	330	14
River Mile 5.0 - 5.5	55	55	2.1	160	16	29	7.2
River Mile 5.5 - 6.0	29	29	2.1	13	5.5	2.8	5.0
River Mile 6.0 - 6.2	2	1	5.0	5.4	5.2	0.34	5.2
River Mile 6.2- 6.5, Upstream of the AOC	0	-	-	-	-	-	-
River Mile 6.5- 7.0, Upstream of the AOC	0	-	-	-	-	-	-
Buffalo Harbor, Downstream of the AOC	3	3	3.5	4.3	3.8	0.41	3.8
City Ship Canal	54	50	2.1	250	24	37	14
Cazenovia Creek	0	-	-	-	-	-	-

mg/kg - milligrams per kilogram

Table 2-3a
Total PCB Surface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	6	2	0.048	0.067	0.052	0.0074	0.052
River Mile 0.5 - 1.0	33	20	0.035	1.3	0.16	0.28	0.086
River Mile 1.0 - 1.5	24	9	0.030	0.70	0.10	0.14	0.065
River Mile 1.5 - 2.0	24	15	0.027	0.55	0.11	0.12	0.076
River Mile 2.0 - 2.5	22	10	0.044	0.54	0.094	0.11	0.071
River Mile 2.5 - 3.0	26	25	0.044	1.5	0.32	0.37	0.20
River Mile 3.0 - 3.5	26	15	0.038	0.60	0.16	0.16	0.10
River Mile 3.5 - 4.0	41	23	0.032	4.7	0.27	0.73	0.11
River Mile 4.0 - 4.5	30	18	0.012	10	0.62	1.9	0.13
River Mile 4.5 - 5.0	35	12	0.033	2.3	0.16	0.41	0.067
River Mile 5.0 - 5.5	34	12	0.032	1.1	0.12	0.20	0.075
River Mile 5.5 - 6.0	23	4	0.029	0.18	0.058	0.033	0.053
River Mile 6.0 - 6.2	13	2	0.027	0.36	0.063	0.090	0.042
River Mile 6.2- 6.5, Upstream of the AOC	1	0	0.069	0.069	0.069	0.00	0.069
River Mile 6.5 - 7.0, Upstream of the AOC	1	0	0.045	0.045	0.045	0.00	0.045
Buffalo Harbor, Downstream of the AOC	9	3	0.032	0.13	0.055	0.029	0.050
City Ship Canal	60	47	0.030	1.4	0.21	0.23	0.14
Cazenovia Creek	2	0	0.036	0.039	0.038	0.0021	0.037

mg/kg - milligrams per kilogram

Table 2-3b
Total PCB Subsurface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	12	11	0.038	1.0	0.33	0.36	0.18
River Mile 0.5 - 1.0	32	32	0.046	4.1	0.60	0.95	0.29
River Mile 1.0 - 1.5	38	32	0.029	3.1	0.47	0.82	0.17
River Mile 1.5 - 2.0	16	13	0.029	2.6	0.55	0.63	0.28
River Mile 2.0 - 2.5	21	16	0.039	1.4	0.22	0.32	0.12
River Mile 2.5 - 3.0	36	35	0.0033	2.9	0.41	0.56	0.22
River Mile 3.0 - 3.5	25	16	0.00087	1.6	0.22	0.35	0.080
River Mile 3.5 - 4.0	90	54	0.010	5.1	0.42	0.90	0.12
River Mile 4.0 - 4.5	62	40	0.032	10	1.0	2.1	0.20
River Mile 4.5 - 5.0	66	38	0.030	7.4	0.39	1.2	0.10
River Mile 5.0 - 5.5	55	33	0.035	160	4.5	22	0.19
River Mile 5.5 - 6.0	29	9	0.030	0.74	0.10	0.15	0.061
River Mile 6.0 - 6.2	2	1	0.047	0.86	0.45	0.58	0.20
River Mile 6.2- 6.5, Upstream of the AOC	0	-	-	-	-	-	-
River Mile 6.5- 7.0, Upstream of the AOC	0	-	-	-	-	-	-
Buffalo Harbor, Downstream of the AOC	3	3	0.083	0.22	0.13	0.073	0.12
City Ship Canal	54	39	0.029	4.9	0.54	0.97	0.19
Cazenovia Creek	0	-	-	-	-	-	-

mg/kg - milligrams per kilogram

Table 2-4a
Lead Surface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	6	6	26	38	33	5.0	33
River Mile 0.5 - 1.0	33	33	27	320	65	69	49
River Mile 1.0 - 1.5	24	24	10	490	69	99	43
River Mile 1.5 - 2.0	24	24	3.1	74	41	18	35
River Mile 2.0 - 2.5	22	22	26	250	45	47	38
River Mile 2.5 - 3.0	26	26	32	200	62	36	56
River Mile 3.0 - 3.5	26	26	25	250	70	57	56
River Mile 3.5 - 4.0	41	41	27	1100	120	180	69
River Mile 4.0 - 4.5	30	30	8.1	690	110	140	73
River Mile 4.5 - 5.0	35	35	19	2600	160	440	59
River Mile 5.0 - 5.5	34	34	14	430	51	71	38
River Mile 5.5 - 6.0	23	23	12	120	32	20	29
River Mile 6.0 - 6.2	13	13	6.2	98	26	26	19
River Mile 6.2- 6.5, Upstream of the AOC	1	1	24	24	24	0.00	24
River Mile 6.5 - 7.0, Upstream of the AOC	1	1	19	19	19	0.00	19
Buffalo Harbor, Downstream of the AOC	9	9	9.2	66	31	22	25
City Ship Canal	60	60	1.9	2700	130	340	70
Cazenovia Creek	2	2	12	18	15	4.2	15

mg/kg - milligrams per kilogram

Table 2-4b
Lead Subsurface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Location	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	12	12	34	260	85	71	65
River Mile 0.5 - 1.0	32	32	34	600	130	150	88
River Mile 1.0 - 1.5	38	38	9.1	730	160	170	94
River Mile 1.5 - 2.0	16	16	12	640	220	200	140
River Mile 2.0 - 2.5	21	21	31	530	110	130	71
River Mile 2.5 - 3.0	36	36	31	450	110	95	87
River Mile 3.0 - 3.5	25	25	11	230	76	51	61
River Mile 3.5 - 4.0	90	90	14	740	140	150	88
River Mile 4.0 - 4.5	62	62	14	1300	240	310	120
River Mile 4.5 - 5.0	66	66	24	8500	390	1100	110
River Mile 5.0 - 5.5	55	55	22	740	100	130	62
River Mile 5.5 - 6.0	29	29	14	120	39	22	35
River Mile 6.0 - 6.2	2	2	20	39	29	14	28
River Mile 6.2- 6.5, Upstream of the AOC	0	-	-	-	-	-	-
River Mile 6.5- 7.0, Upstream of the AOC	0	-	-	-	-	-	-
Buffalo Harbor, Downstream of the AOC	3	3	45	74	58	15	56
City Ship Canal	54	54	7.5	580	150	140	94
Cazenovia Creek	0	-	-	-	-	-	-

mg/kg - milligrams per kilogram

Table 2-5a
Mercury Surface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Mile Marker	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	6	6	0.053	0.17	0.11	0.047	0.10
River Mile 0.5 - 1.0	33	33	0.047	6.1	0.53	1.20	0.18
River Mile 1.0 - 1.5	24	20	0.0055	0.80	0.14	0.17	0.074
River Mile 1.5 - 2.0	24	22	0.0047	0.58	0.15	0.14	0.10
River Mile 2.0 - 2.5	22	22	0.031	0.37	0.10	0.075	0.087
River Mile 2.5 - 3.0	26	25	0.014	2.1	0.25	0.42	0.15
River Mile 3.0 - 3.5	26	24	0.013	1.8	0.25	0.36	0.14
River Mile 3.5 - 4.0	40	37	0.0085	9.5	0.87	1.70	0.23
River Mile 4.0 - 4.5	30	28	0.0090	7.1	0.81	1.60	0.21
River Mile 4.5 - 5.0	34	33	0.011	3.5	0.38	0.70	0.13
River Mile 5.0 - 5.5	34	33	0.0060	4.8	0.27	0.81	0.10
River Mile 5.5 - 6.0	23	18	0.0090	0.36	0.066	0.071	0.045
River Mile 6.0 - 6.2	13	4	0.0049	0.14	0.023	0.038	0.012
River Mile 6.2- 6.5, Upstream of the AOC	1	1	0.10	0.10	0.10	0.00	0.10
River Mile 6.5 - 7.0, Upstream of the AOC	1	1	0.019	0.019	0.019	0.00	0.019
Buffalo Harbor, Downstream of the AOC	9	9	0.026	0.44	0.11	0.13	0.078
City Ship Canal	60	56	0.0050	8.5	0.89	1.50	0.38
Cazenovia Creek	2	2	0.012	0.041	0.027	0.021	0.022

mg/kg - milligrams per kilogram

Table 2-5b
Mercury Subsurface Sediment Concentrations, Summary Statistics
Buffalo River, NY

Mile Marker	Number of Samples	Number of Detects	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation	Geometric Mean Result (mg/kg)
Buffalo River							
Downstream AOC Boundary - River Mile 0.5	12	12	0.066	4.0	1.1	1.4	0.41
River Mile 0.5 - 1.0	32	32	0.097	9.7	1.4	2.2	0.49
River Mile 1.0 - 1.5	38	37	0.0040	14	2.3	3.5	0.42
River Mile 1.5 - 2.0	16	15	0.0038	9.0	3.0	3.3	0.92
River Mile 2.0 - 2.5	21	21	0.066	5.8	0.89	1.7	0.27
River Mile 2.5 - 3.0	36	36	0.061	6.3	0.75	1.3	0.29
River Mile 3.0 - 3.5	25	25	0.036	2.7	0.53	0.77	0.23
River Mile 3.5 - 4.0	87	84	0.0043	15	2.0	3.2	0.46
River Mile 4.0 - 4.5	62	58	0.0081	9.2	1.8	2.6	0.43
River Mile 4.5 - 5.0	64	64	0.031	32	3.0	6.2	0.43
River Mile 5.0 - 5.5	55	55	0.044	44	1.9	6.4	0.25
River Mile 5.5 - 6.0	29	29	0.021	0.34	0.094	0.070	0.077
River Mile 6.0 - 6.2	2	1	0.014	0.14	0.077	0.089	0.043
River Mile 6.2- 6.5, Upstream of the AOC	0	-	-	-	-	-	-
River Mile 6.5- 7.0, Upstream of the AOC	0	-	-	-	-	-	-
Buffalo Harbor, Downstream of the AOC	3	3	0.10	0.37	0.21	0.14	0.18
City Ship Canal	54	49	0.0033	21	3.2	4.5	0.77
Cazenovia Creek	0	-	-	-	-	-	-

mg/kg - milligrams per kilogram

Table 2-6
Summary of Total Organic Carbon Concentrations
Buffalo, NY

Location	Number of Samples	Minimum Result (mg/kg)	Maximum Result (mg/kg)	Average Result (mg/kg)	Standard Deviation (mg/kg)
Buffalo River					
Downstream AOC Boundary - River Mile 0.5	18	19,000	37,400	25,517	4,796
River Mile 0.5 - 1.0	64	11,000	54,800	25,488	7,159
River Mile 1.0 - 1.5	62	4,050	46,400	23,640	8,128
River Mile 1.5 - 2.0	39	16,400	38,300	23,146	6,065
River Mile 2.0 - 2.5	43	16,300	49,600	22,621	5,220
River Mile 2.5 - 3.0	62	15,200	56,100	24,235	7,736
River Mile 3.0 - 3.5	51	10,100	27,100	19,296	4,003
River Mile 3.5 - 4.0	131	8,990	59,100	25,021	7,050
River Mile 4.0 - 4.5	92	3,230	64,800	25,922	11,345
River Mile 4.5 - 5.0	101	3,500	271,000	32,869	32,935
River Mile 5.0 - 5.5	89	5,160	68,400	25,740	9,045
River Mile 5.5 - 6.0	52	4,060	38,600	24,021	6,361
River Mile 6.0 - 6.2	14	1,720	46,000	18,521	11,895
River Mile 6.2- 6.5, Upstream of the AOC	1	31,000	31,000	31,000	-
River Mile 6.5 - 7.0, Upstream of the AOC	1	18,900	18,900	18,900	-
Buffalo Harbor, Downstream of the AOC	12	3,670	26,200	13,967	7,700
City Ship Canal	114	1,670	118,000	27,410	17,008
Cazenovia Creek	2	6,900	9,530	8,215	1,860

mg/kg - milligrams per kilogram

Table 2-7a

Evaluation of Acid Volatile Sulfides and Simultaneously Extracted Metals in Buffalo River Sediments

Buffalo River, NY

Location	Sample ID	AVS (umol/g)	Cadmium (umol/g)	Copper (umol/g)	Lead (umol/g)	Mercury (umol/g)	Nickel (umol/g)	Zinc (umol/g)	Total Organic Carbon[a] (mg/kg)	∑SEM[b] (sum of metals) (umol/g)	SEM-AVS[c] (μmol/g)
Surface Sediments (0 - 6")											
066	066-MA2-R-C-Z1a	29.1	0.028	1.1	1.8	0.00013	0.25	6.4	35,800	9.58	-19.52
007	007-MA1-C-C-Z1a	21.4	0.015	0.55	0.4	0.00013	0.24	3.5	23,600	4.71	-16.69
085	085-HB1-L-C-Z1a	16.1	0.0044	0.33	0.14	0.00013	0.18	1.2	25,900	1.85	-14.25
083	083-EA1-R-C-Z1a	13.3	0.0067	0.36	0.45	0.00013	0.18	1.3	20,300	2.30	-11.00
080	080-MC1-C-C-Z1a	12.5	0.0064	0.3	0.12	0.00013	0.16	1	25,000	1.59	-10.91
102	102-HB1-R-C-Z1a	11	0.0031	0.24	0.097	0.00013	0.13	0.79	19,400	1.26	-9.74
075	075-MA1-C-C-Z1a	11.4	0.0041	0.32	0.13	0.00013	0.16	1.1	21,800	1.71	-9.69
054	054-MA1-R-C-Z1a	31.2	0.038	2	1.3	0.00013	0.25	19.7	31,600	23.29	-7.91
065	065-MA1-C-C-Z1a	9.6	0.0044	0.37	0.24	0.00013	0.18	1.6	20,000	2.39	-7.21
038	038-HB1-L-C-Z1a	8.1	0.0044	0.24	0.15	0.00013	0.11	1.4	18,200	1.90	-6.20
043	043-HB1-L-C-Z1a	15.8	0.02	0.21	0.57	0.00013	0.18	8.9	18,600	9.88	-5.92
098	098-HB2-R-C-Z1a	7.1	0.0024	0.29	0.1	0.00013	0.11	0.83	28,100	1.33	-5.77
095	095-HB1-R-C-Z1a	7.2	0.0098	0.38	0.21	0.00013	0.1	1.1	22,300	1.80	-5.40
100	100-HB1-L-C-Z1a	5.2	0.0026	0.21	0.1	0.00013	0.075	0.63	15,100	1.02	-4.18
115	115-HBO-U-CP	4.9	0.0028	0.096	0.039	0.00013	0.31	0.49	6,900	0.94	-3.96
047	047-HB1-C-C-Z1a	5.5	0.0084	0.34	0.27	0.00013	0.11	1.5	24,500	2.23	-3.27
041	041-HB1-L-C-Z1a	4.3	0.0036	0.22	0.11	0.00013	0.12	0.94	20,700	1.39	-2.91
121	121-EA-CP	5	0.0047	0.31	0.11	0.00013	0.73	1.2	17,600	2.35	-2.65
111	111-HBO-L-CP	3.1	0.0023	0.1	0.076	0.00013	0.095	0.49	9,530	0.76	-2.34
123	123-EA-CP	4.9	0.0045	0.17	0.21	0.00013	0.099	2.1	9,700	2.58	-2.32
058	058-HB1-R-C-Z1a	8.3	0.018	0.63	0.69	0.00013	0.19	4.7	26,500	6.23	-2.07
119	119-EA-CP	1.4	0.0065	0.055	0.032	0.00013	0.046	0.23	3,670	0.37	-1.03
117	117-EA-CP	1.1	0.0022	0.1	0.056	0.00013	0.065	0.42	10,400	0.64	-0.46
026	026-HB1-C-C-Z1a	0.28	0.0022	0.11	0.046	0.00013	0.061	0.29	16,900	0.51	0.23
030	030-HB1-R-C-Z1a	0.305	0.0056	0.11	0.057	0.00013	0.087	0.42	31,100	0.68	0.37

Table 2-7a

Evaluation of Acid Volatile Sulfides and Simultaneously Extracted Metals in Buffalo River Sediments

Buffalo River, NY

Location	Sample ID	AVS (umol/g)	Cadmium (umol/g)	Copper (umol/g)	Lead (umol/g)	Mercury (umol/g)	Nickel (umol/g)	Zinc (umol/g)	Total Organic Carbon[a] (mg/kg)	∑SEM[b] (sum of metals) (umol/g)	SEM-AVS[c] (µmol/g)
Buried Sediments (6 - 12")											
007	007-MA1-C-C-Z1b/D	27.1	0.018	0.4	0.51	0.00013	0.24	4.1	28,300	5.27	-21.83
007	007-MA1-C-C-Z1b	22.4	0.017	0.13	0.48	0.00013	0.24	5	26,600	5.87	-16.53
038	038-HB1-L-C-Z1b	20.4	0.0069	0.39	0.33	0.00013	0.13	4.6	22,000	5.46	-14.94
083	083-EA1-R-C-Z1b	16.5	0.0042	0.28	0.25	0.00013	0.13	0.99	20,600	1.65	-14.85
085	085-HB1-L-C-Z1b	13.5	0.0046	0.29	0.11	0.00013	0.15	0.95	30,800	1.50	-12.00
075	075-MA1-C-C-Z1b	12.8	0.0048	0.31	0.12	0.00013	0.18	1.1	22,500	1.71	-11.09
102	102-HB1-R-C-Z1b	11.9	0.0035	0.18	0.064	0.00013	0.1	0.61	20,800	0.96	-10.94
080	080-MC1-C-C-Z1b	9.1	0.003	0.28	0.11	0.00013	0.18	1	27,100	1.57	-7.53
043	043-HB1-L-C-Z1b	13	0.011	0.17	0.39	0.00013	0.11	5.8	16,400	6.48	-6.52
065	065-MA1-C-C-Z1b	8.6	0.0055	0.38	0.28	0.00013	0.14	1.5	21,700	2.31	-6.29
100	100-HB1-L-C-Z1b	6.6	0.0095	0.16	0.059	0.00013	0.055	0.45	24,500	0.73	-5.87
095	095-HB1-R-C-Z1b	6.8	0.0036	0.26	0.15	0.00013	0.089	0.83	22,100	1.33	-5.47
098	098-HB2-R-C-Z1b	6.4	0.0031	0.34	0.13	0.00013	0.12	1	29,000	1.59	-4.81
047	047-HB1-C-C-Z1b	8.5	0.024	0.69	0.55	0.00013	0.23	2.9	32,400	4.39	-4.11
041	041-HB1-L-C-Z1b	4.2	0.0031	0.25	0.12	0.00013	0.17	1	20,200	1.54	-2.66
058	058-HB1-R-C-Z1b	20.1	0.025	1.7	1.2	0.00013	0.29	14.6	28,700	17.82	-2.28
026	026-HB1-C-C-Z1b	1.0	0.001	0.07	0.024	0.00013	0.048	0.23	14,500	0.37	-0.63
030	030-HB1-R-C-Z1b	0.3	0.004	0.09	0.028	0.00013	0.077	0.28	22,600	0.48	0.19
066	066-MA2-R-C-Z1b	15.6	0.046	2.5	2.5	0.00013	0.33	13.5	49,200	18.88	3.28
054	054-MA1-R-C-Z1b	3.6	0.004	0.88	0.5	0.00013	0.11	5.8	27,600	7.29	3.69

(a) Location-specific TOC is used for each sample

(b) Sum of Metals = Divalent metals cadmium, copper, lead, mercury, nickel, and zinc.
Analytes that were not detected are presented here as 1/2 of the detection limit.
Mercury SEM results were rejected based on no matrix spike recovery from project samples
Because mercury was not detected at any of the sample locations. One-half of the maximum detection limit reported was used.

(c) In 89% of sediment samples (40 of 45 samples) AVS exceeds SEM indicating that toxicity due to divalent metals is very unlikely.
In two surface and three buried sediment samples, SEM minus AVS is positive indicating that SEM > AVS at those locations.
Additional evaluation of these samples are prestented in Table 2-7b.

AVS	Acid Volatile Sulfide
SEM	Simultaneously Extracted Metals
µmol/g	micromoles per gram dry sediment
mg/kg	milligram per kilogram dry weight

Table 2-7b
Evaluation of Divalent Metals where Total SEM Exceeds AVS
Buffalo River, New York

Sample ID	Sample Date	∑SEM[a] (sum of metals) (umol/g)	AVS (umol/g)	∑SEM-AVS[b] (µmol/g)	Total Organic Carbon[c] (mg/kg)	Fraction Organic Carbon (foc)	(SEM-AVS)/foc[d] (µmol/goc)	Exceeds USEPA 2005 lower effects threshold[d]?
Surficial Sediments (0 - 6")								
026-HB1-C-C-Z1a	09/17/08 13:57	0.51	0.28	0.23	16,900	0.017	13.57	No
030-HB1-R-C-Z1a	09/19/08 16:05	0.68	0.31	0.37	31,100	0.031	12.05	No
Buried Sediments (6 - 12")								
030-HB1-R-C-Z1b	09/19/08 16:05	0.48	0.30	0.19	22,600	0.023	8.26	No
066-MA2-R-C-Z1b	09/23/08 14:10	18.9	15.6	3.28	49,200	0.049	66.6	No
054-MA1-R-C-Z1b	09/22/08 14:47	7.29	3.60	3.69	27,600	0.028	134	Yes

(a) Sum of Metals = Divalent metals cadmium, copper, lead, mercury, nickel, and zinc.
Analytes that were not detected are presented as 1/2 of the detection limit.
Mercury SEM results were rejected based on no matrix spike recovery from project samples
Because mercury was not detected at any of the sample locations. One-half of the maximum detection limit reported was used.
(b) Data are shown only for sediment samples in which SEM exceeds AVS. In 89% of sediment samples,
SEM was less than AVS, indicating that toxicity due to divalent metals is very unlikely.
At the locations shown above, SEM minus AVS is positive (SEM > AVS) and samples were further analyzed through the
evaluation of OC-normalized excess metals (USEPA 2005b; See note (d))
(c) Location-specific TOC is used for each sample
(d) Toxicity to benthic invertebrates is very unlikely at concentrations below 130 µmol/goc and very likely at
concentrations above 3,000 µmol/goc. Toxicity at intermediate concentrations in possible but uncertain (USEPA 2005b)

AVS	Acid Volatile Sulfide
SEM	Simultaneously Extracted Metals
µmol/g	micromoles per gram dry sediment
mg/kg	milligram per kilogram dry weight
µmol/goc	micromoles per gram organic carbon

Table 2-8
PAHs in Sediment
Buffalo River, NY

Core Location	**007**			**026**		**030**		**038**		**041**		**043**		**047**		**054**		**058**		**065**		**066**		**075**	
Sample Depth (ft)	0.0-0.5	0.5 -1.0	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0
Reporting Limit (ug/kg)	140	130	140	82	78	84	87	110	88	120	120	100	92	110	110	1,200	5,400	580	1,100	120	110	770	4,300	120	120
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
PAH																									
Acenaphthene	160	120	77	ND	ND	ND	ND	250	1,000	ND	ND	330	310	260	200	4,400	16,000	2,000	4,100	ND	49	1,200	23,000	ND	ND
Acenaphthylene	96	110	89	ND	ND	ND	ND	99	210	ND	ND	ND	ND	98	99	ND	ND	270	320	ND	ND	250	ND	ND	ND
Anthracene	440	450	240	ND	ND	ND	ND	900	2,000	39	32	370	330	770	570	5,600	21,000	3,100	7,100	57	99	2,800	19,000	32	ND
PHNAN-AN-C1	470	660	360	ND	ND	23	31	900	2,700	100	96	1,600	1,300	1,700	1,300	5,900	22,000	4,900	12,000	140	260	5,800	31,000	ND	ND
PHNAN-AN-C2	470	670	450	ND	ND	29	46	1,100	2,800	130	130	3,000	2,300	2,400	1,900	4,900	16,000	4,200	9,700	ND	190	6,600	27,000	ND	ND
PHNAN-AN-C3	390	570	430	ND	ND	ND	41	870	2,400	120	120	3,300	2,700	2,200	1,700	3,800	9,400	3,500	6,100	ND	140	4,800	18,000	ND	ND
PHNAN-AN-C4	200	300	230	ND	ND	ND	ND	300	830	ND	ND	2,400	2,000	1,100	860	1,300	ND	1,100	2,300	ND	ND	2,200	7,100	ND	ND
Benzo (a) anthracene	990	1,200	650	ND	ND	ND	ND	560	1,400	160	140	710	610	870	750	2,600	6,600	1,800	3,500	240	410	3,500	11,000	160	130
Benzo (a) pyrene	930	1,100	620	ND	ND	ND	ND	490	1,000	180	160	250	240	770	740	1,500	3,500	1,100	1,800	250	390	2,800	6,600	170	130
Benzo (b) fluoranthene	1,200	1,600	940	ND	ND	ND	ND	560	1,800	230	230	490	490	1,600	1,200	1,600	5,400	1,300	1,600	340	930	2,300	10,000	410	160
Benzo (e) pyrene	740	900	520	ND	ND	ND	ND	370	730	160	150	330	280	580	570	920	2,000	760	1,200	230	320	1,600	4,000	170	120
Benzo (g,h,i) perylene	170	140	100	ND	ND	ND	ND	62	77	49	45	30	ND	97	80	950	ND	290	420	70	74	480	3,900	67	55
Benzo (k) fluoranthene	1,200	1,700	810	ND	ND	ND	ND	600	1,200	260	200	320	220	940	1,100	1,200	ND	960	1,900	380	ND	2,200	ND	ND	190
Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	78	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	1,200	1,500	920	ND	ND	ND	27	640	1,300	240	220	730	670	890	820	2,500	6,200	1,800	3,300	370	560	3,100	11,000	250	180
CHRYS-C1	990	1,200	750	ND	ND	ND	ND	810	1,800	170	150	1,900	1,600	820	720	1,400	ND	1,400	2,500	240	230	2,200	7,700	150	ND
CHRYS-C2	830	730	590	ND	ND	ND	ND	530	1,100	83	55	1,500	1,200	590	470	860	ND	840	1,300	82	100	1,700	3,800	ND	ND
CHRYS-C3	410	540	390	ND	ND	ND	ND	340	310	ND	ND	550	500	150	130	ND	ND	530	870	76	190	1,300	ND	ND	ND
CHRYS-C4	190	230	170	ND	ND	ND	ND	210	200	ND	ND	270	240	ND	ND	ND	ND	240	850	ND	73	1,000	ND	ND	ND
Dibenz (a,h) anthracene	73	53	37	ND	ND	ND	ND	ND	31	ND	ND	ND	ND	ND	ND	330	ND	ND	ND	ND	38	ND	ND	ND	ND
Fluoranthene	2,400	2,900	1,500	ND	ND	ND	ND	1,600	ND	460	400	1,200	970	2,600	2,200	9,900	33,000	7,100	16,000	700	1,300	8,000	36,000	430	340
FLRAN-PYREN	990	1,300	850	ND	ND	ND	ND	920	2,800	180	170	1,900	1,600	1,800	1,500	4,000	11,000	4,000	7,300	290	490	4,700	17,000	150	ND
Fluorene	210	220	110	ND	ND	ND	ND	640	2,100	ND	ND	400	340	300	250	3,700	14,000	1,900	4,100	36	61	1,200	17,000	ND	ND
FLUOR-C1	91	110	76	ND	ND	ND	ND	230	730	ND	ND	350	290	570	390	1,300	5,000	1,400	2,900	ND	ND	1,100	10,000	ND	ND
FLUOR-C2	55	69	49	ND	ND	ND	ND	250	960	ND	ND	720	590	920	710	1,700	ND	1,300	3,300	ND	ND	2,000	6,600	ND	ND
FLUOR-C3	ND	ND	ND	ND	ND	ND	ND	420	1,100	ND	ND	1,200	880	1,200	970	1,700	ND	1,700	3,500	ND	ND	2,200	12,000	ND	ND
Indeno (1,2,3-cd) pyrene	210	160	120	ND	ND	ND	ND	77	84	57	51	26	ND	96	73	790	1,400	340	460	82	88	570	3,700	86	66
1-Methylnaphthalene	ND	54	36	ND	ND	ND	ND	240	1,000	ND	ND	300	180	150	120	2,100	7,300	1,100	2,600	ND	ND	1,100	9,800	ND	ND
2-Methylnaphthalene	71	96	86	ND	ND	ND	ND	220	1,400	ND	ND	150	240	170	120	1,500	14,000	160	350	ND	ND	1,200	20,000	ND	ND
Naphthalene	43	56	47	ND	ND	ND	28	140	410	ND	ND	87	68	120	86	730	1,700	360	760	ND	ND	790	4,600	ND	ND
NAPHT-C1	42	71	51	ND	ND	ND	ND	260	1,200	ND	ND	240	150	130	120	2,200	13,000	800	1,800	ND	ND	1,400	19,000	ND	ND
NAPHT-C2	89	150	98	ND	ND	ND	ND	550	2,000	ND	ND	990	780	750	600	5,000	19,000	3,800	9,200	ND	ND	4,400	36,000	ND	ND
NAPHT-C3	130	220	140	ND	ND	ND	ND	640	1,900	ND	ND	1,400	1,100	1,500	1,200	5,900	20,000	5,000	12,000	ND	ND	6,700	43,000	ND	ND
NAPHT-C4	100	200	110	ND	ND	ND	ND	450	1,400	ND	ND	1,200	890	1,500	1,200	4,000	13,000	3,700	8,800	ND	ND	3,900	26,000	ND	ND
Phenanthrene	1,300	1,400	610	ND	ND	26	36	1,600	ND	200	170	1,400	1,200	1,500	1,100	16,000	63,000	8,200	21,000	300	560	6,500	59,000	180	160
Pyrene	2,000	2,100	1,200	ND	ND	ND	27	1,000	1,900	350	300	820	670	1,300	1,100	7,400	23,000	4,400	9,600	440	670	4,300	25,000	310	250
Total PAHs[a], (16 PAHs, USEPA TCL)	12,622	14,809	8,070	656	624	656	640	9,273	14,600	2,525	2,248	7,263	6,302	12,266	10,423	59,800	205,600	35,210	76,510	3,505	5,394	40,375	236,250	2,455	2,021
Total PAHs, (All 36 PAHs)	19,090	23,009	13,596	1,476	1,404	1,464	1,498	18,938	42,038	4,248	3,899	30,613	25,168	30,606	25,113	110,080	378,900	75,930	165,630	5,403	7,992	96,660	540,700	3,945	3,281

(a) In the summation of Total PAHs, non-detect results were assigned a value of one-half the reporting limit
(b) Values in the table that are less than the reporting limit, were qualified as estimated by the laboratory

ft	foot
ug/kg	microgram per kilogram
ND	Non detect
TCL	Target Compound List

Table 2-8
PAHs in Sediment
Buffalo, NY

Core Location	**080**		**083**		**085**		**095**			**098**		**100**		**102**		**111**	**115**	**117**	**119**	**121**	**123**
Sample Depth (ft)	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.5 -1.0	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5	0.0-0.5
Reporting Limit (ug/kg)	120	120	110	110	140	130	0.12	0.11	0.44	0.12	0.13	0.11	0.11	0.12	0.12	0.11	0.099	0.11	0.086	0.12	0.61
	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
PAH																					
Acenaphthene	ND	ND	34	ND	ND	ND	47	57	830	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2500
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	27	ND	590
Anthracene	36	ND	68	40	40	47	120	100	5200	ND	39	ND	ND	ND	ND	67	ND	31	140	32	2500
PHNAN-AN-C1	ND	ND	150	110	ND	ND	190	190	9900	66	97	ND	ND	ND	ND	120	ND	ND	140	ND	2600
PHNAN-AN-C2	ND	ND	160	130	ND	ND	230	210	14000	79	96	ND	ND	ND	ND	140	ND	ND	ND	ND	1300
PHNAN-AN-C3	ND	ND	160	ND	ND	ND	210	180	5400	ND	ND	ND	ND	ND	ND	92	ND	ND	ND	ND	830
PHNAN-AN-C4	ND	ND	ND	ND	ND	ND	ND	ND	2000	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzo (a) anthracene	190	150	260	180	220	200	370	310	550	140	170	61	130	140	130	240	130	110	210	150	3600
Benzo (a) pyrene	200	150	260	180	290	200	340	300	430	140	200	59	140	150	150	230	130	110	150	150	2400
Benzo (b) fluoranthene	220	230	320	250	380	220	380	330	550	160	240	75	310	240	190	300	180	120	220	200	1600
Benzo (e) pyrene	170	140	220	160	280	170	290	230	380	130	180	62	140	150	130	190	100	98	84	140	1200
Benzo (g,h,i) perylene	97	72	95	72	120	72	91	78	ND	52	62	37	37	76	60	95	58	100	75	87	740
Benzo (k) fluoranthene	250	150	310	200	360	270	500	400	410	200	290	83	ND	170	190	200	120	120	ND	160	2500
Biphenyl	ND	ND	ND	ND	ND	ND	ND	ND	1400	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chrysene	300	220	380	270	400	280	500	430	750	210	280	90	230	240	210	350	200	160	260	200	3100
CHRYS-C1	130	ND	250	140	210	160	370	310	1500	100	150	ND	ND	ND	ND	180	ND	ND	ND	ND	1900
CHRYS-C2	ND	ND	110	ND	ND	140	140	94	1200	ND	ND	ND	ND	ND	ND	120	ND	ND	ND	ND	ND
CHRYS-C3	ND	ND	ND	ND	ND	ND	ND	ND	940	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CHRYS-C4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenz (a,h) anthracene	ND	31	40	30	ND	ND	33	34	ND	ND	ND	ND	ND	ND	ND	39	ND	ND	35	37	430
Fluoranthene	490	390	700	480	680	560	1000	990	1200	380	530	160	360	390	360	700	410	280	370	370	7600
FLRAN-PYREN	150	130	260	180	42	180	400	310	2200	110	160	ND	110	38	ND	160	ND	ND	230	ND	4200
Fluorene	ND	ND	42	30	ND	42	57	59	910	ND	ND	ND	ND	ND	ND	53	ND	ND	ND	ND	2900
FLUOR-C1	ND	ND	ND	ND	ND	ND	ND	ND	2500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	700
FLUOR-C2	ND	ND	ND	ND	ND	ND	ND	ND	4300	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
FLUOR-C3	ND	ND	ND	ND	ND	ND	ND	ND	4600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Indeno (1,2,3-cd) pyrene	110	80	93	85	130	89	94	82	ND	70	79	31	48	84	72	98	66	100	81	100	880
1-Methylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	2100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND	34	ND	ND	ND	ND	2900	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	ND	ND	41	ND	ND	ND	ND	ND	2500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	220
NAPHT-C1	ND	ND	ND	30	ND	ND	ND	ND	3200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
NAPHT-C2	ND	ND	ND	ND	ND	ND	44	70	10000	ND	ND	ND	ND	ND	ND	28	ND	ND	ND	ND	ND
NAPHT-C3	ND	ND	ND	ND	ND	ND	110	130	14000	ND	ND	ND	ND	ND	ND	43	ND	ND	ND	ND	ND
NAPHT-C4	90	ND	ND	ND	ND	ND	88	84	8500	ND	ND	ND	ND	100	ND	ND	ND	ND	ND	ND	ND
Phenanthrene	220	200	310	240	320	300	470	550	3900	160	200	76	160	170	140	370	190	130	160	150	5200
Pyrene	400	330	510	360	510	400	650	630	1000	280	330	130	280	300	260	520	310	250	310	320	5200
Total PAHs[a], (16 PAHs, USEPA TCL)	2,813	2,303	3,518	2,582	3,800	2,940	4,772	4,460	19,110	2,152	2,745	1,132	2,080	2,320	2,122	3,427	2,091	1,786	2,210	2,196	41,960
Total PAHs, (All 36 PAHs)	4,313	3,653	5,543	4,081	5,522	4,630	7,444	6,818	110,350	3,537	4,403	2,239	3,320	3,628	3,392	5,105	3,132	2,929	3,395	3,476	58,655

(a) In the summation of Total PAHs, non-detect results were assigned a value of one-half the reporting limit

ft	foot
ug/kg	microgram per kilogram
ND	Non detect
TCL	Target Compound List

Table 2-9
Average Particle Size Distribution
Buffalo River, NY

Location	Number of Samples	Fines (Average %)	Fine Sand (Average %)	Medium Sand (Average %)	Coarse Sand (Average %)	Gravel (Average %)
Buffalo River						
Downstream AOC Boundary - River Mile 0.5	6	94.7	5.0	0.1	0.1	0.0
River Mile 0.5 - 1.0	25	94.3	4.4	0.5	0.5	0.3
River Mile 1.0 - 1.5	33	87.6	5.6	0.9	0.8	5.1
River Mile 1.5 - 2.0	11	86.5	5.1	1.6	1.3	5.5
River Mile 2.0 - 2.5	13	91.8	6.3	0.4	0.3	1.1
River Mile 2.5 - 3.0	18	84.6	11.1	1.4	0.9	2.0
River Mile 3.0 - 3.5	10	84.9	8.7	1.9	1.3	3.2
River Mile 3.5 - 4.0	74	90.6	6.8	1.0	0.5	1.1
River Mile 4.0 - 4.5	54	81.1	13.1	2.1	1.0	2.6
River Mile 4.5 - 5.0	36	79.6	18.1	0.8	0.7	0.8
River Mile 5.0 - 5.5	47	80.4	15.0	3.4	0.6	0.7
River Mile 5.5 - 6.0	20	72.2	16.8	5.4	2.6	3.0
River Mile 6.0 - 6.2	1	4.1	1.0	0.8	4.4	89.8
Upstream of the AOC	2	37.6	11.3	2.2	2.1	47.0
City Ship Canal	42	87.5	9.9	0.9	0.3	1.4
Buffalo Harbor, Downstream of the AOC	11	55.9	26.7	5.4	3.6	8.5
Cazenovia Creek	2	14.9	54.3	9.9	5.6	15.6

% - percent
AOC - area of concern

Table 2-10a
Sediment Geotechnical Results, Moisture Content, Bulk Density, and Consolidation Test
Buffalo, NY

Core	Depth	Location	Soil Classification, ASTM	Moisture Content, percent	Bulk Density, lbs per ft^3	Dry Density, lbs per ft^3	Initial Void Ratio	Final Void Ratio
7	1.0 – 2.0	City Ship Canal	fat clay	77.7	92	51	2.85	0.84
7	3.0 – 4.0	City Ship Canal	lean clay with sand	38.4	104	74	1.01	0.53
25	1.0 – 2.0	River Mile 1.0 – 1.5	fat clay	54.5	112	71	1.87	0.73
25	4.0 – 5.0	River Mile 1.0 – 1.5	silt	61.8	97	64	1.68	0.72
28	1.0 – 2.0	River Mile 1.5 – 2.0	fat clay	64.6	95	57	1.93	0.81
28	4.0 – 5.0	River Mile 1.5 – 2.0	elastic silt	74.3	89	48	2.23	0.76
58	1.0 – 2.0	River Mile 3.5 – 4.0	lean clay	43.1	107	74	1.33	0.65
58	4.0 – 5.0	River Mile 3.5 – 4.0	silt	52.2	108	69	1.66	0.67
59	1.0 – 2.0	River Mile 3.5 – 4.0	fat clay	61.4	99	63	2.10	0.83
59	3.0 – 4.0	River Mile 3.5 – 4.0	lean clay	42.5	100	69	1.57	0.68
61	1.0 – 2.0	River Mile 4.0 – 4.5	elastic silt	57.8	97	59	2.38	0.92
61	4.0 – 5.0	River Mile 4.0 – 4.5	fat clay	51.5	95	61	1.73	0.74
62	1.0 – 2.0	River Mile 4.0 – 4.5	lean clay	54.7	94	60	1.72	0.65
62	4.0 – 5.0	River Mile 4.0 – 4.5	lean clay with sand	40.7	109	81	1.15	0.57
74	1.0 – 2.0	River Mile 4.5 – 5.0	lean clay	41.4	104	73	1.15	0.63
74	4.0 – 5.0	River Mile 4.5 – 5.0	fat clay	57.5	83	50	2.19	0.82
75	1.0 – 2.0	River Mile 4.5 – 5.0	lean clay with sand	52.2	98	64	1.48	0.64
75	3.0 – 4.0	River Mile 4.5 – 5.0	fat clay with sand	58.0	87	55	1.84	0.78
80	1.0 – 2.0	River Mile 4.5 – 5.0	fat clay	57.3	94	59	1.80	0.69
80	4.0 – 5.0	River Mile 4.5 – 5.0	lean clay	44	105	71	1.08	0.57
85	1.0 – 2.0	River Mile 4.5 – 5.0	fat clay	64.1	90	57	1.67	0.68
85	4.0 – 5.0	River Mile 4.5 – 5.0	fat clay	60.7	93	58	2.10	0.80
102	1.0 – 2.0	River Mile 5.0 – 5.5	fat clay	65.1	105	62	2.39	0.99
102	3.0 – 4.0	River Mile 5.0 – 5.5	silt	46.7	93	63	1.45	0.72
104	1.0 – 2.0	River Mile 5.0 – 5.5	elastic silt with sand	64.5	87	53	1.94	0.70
104	3.0 – 4.0	River Mile 5.0 – 5.5	elastic silt	76.3	77	42	2.59	0.84
107	1.0 – 2.0	River Mile 5.5 – 6.0	elastic silt	69.7	92	54	2.36	0.90
107	3.0 – 4.0	River Mile 5.5 – 6.0	sandy elastic silt	61.5	100	71	1.37	0.72

ASTM American Society for Testing and Materials
ft feet
lbs pounds

Table 2-10b
Sediment Geotechnical Results, Atterberg Limits
Buffalo, NY

Core	Depth	Location	Liquid Limit	Plastic Limit	Plasticity Index	Liquidity Index	Dry Strength	Dilantancy	Toughness
7	1.0 – 2.0	City Ship Canal	69	31	38	1	Very High	Slow	Low
7	3.0 – 4.0	City Ship Canal	44	23	21	1	Very High	Slow	Low
25	1.0 – 2.0	River Mile 1.0 – 1.5	57	26	31	1	Very High	Slow	Low
25	4.0 – 5.0	River Mile 1.0 – 1.5	48	28	20	2	Very High	Slow	Low
28	1.0 – 2.0	River Mile 1.5 – 2.0	60	29	31	1	Very High	Slow	Low
28	4.0 – 5.0	River Mile 1.5 – 2.0	67	33	34	1	Very High	Slow	Low
58	1.0 – 2.0	River Mile 3.5 – 4.0	43	25	18	1	High	Slow	Low
58	4.0 – 5.0	River Mile 3.5 – 4.0	43	29	14	2	High	Slow	Low
59	1.0 – 2.0	River Mile 3.5 – 4.0	56	26	30	1	Very High	Slow	Low
59	3.0 – 4.0	River Mile 3.5 – 4.0	43	25	18	1	High	Slow	Low
61	1.0 – 2.0	River Mile 4.0 – 4.5	50	29	21	1	Very High	Slow	Low
61	4.0 – 5.0	River Mile 4.0 – 4.5	52	27	25	1	Very High	Slow	Low
62	1.0 – 2.0	River Mile 4.0 – 4.5	48	27	21	1	Very High	Slow	Low
62	4.0 – 5.0	River Mile 4.0 – 4.5	42	25	17	1	Very High	Slow	Low
74	1.0 – 2.0	River Mile 4.5 – 5.0	39	23	16	1	Very High	Slow	Low
74	4.0 – 5.0	River Mile 4.5 – 5.0	53	27	26	1	Very High	Slow	Low
75	1.0 – 2.0	River Mile 4.5 – 5.0	47	26	21	1	Very High	Slow	Low
75	4.0 – 5.0	River Mile 4.5 – 5.0	59	27	32	1	Very High	Slow	Low
80	1.0 – 2.0	River Mile 4.5 – 5.0	56	29	27	1	Very High	Slow	Low
80	4.0 – 5.0	River Mile 4.5 – 5.0	45	26	19	1	Very High	Slow	Low
85	1.0 – 2.0	River Mile 4.5 – 5.0	65	32	33	1	Very High	Slow	Low
85	4.0 – 5.0	River Mile 4.5 – 5.0	59	28	31	1	Very High	Slow	Low
102	1.0 – 2.0	River Mile 5.0 – 5.5	54	28	26	1	Very High	Slow	Low
102	3.0 – 4.0	River Mile 5.0 – 5.5	45	28	17	1	Very High	Slow	Low
104	1.0 – 2.0	River Mile 5.0 – 5.5	54	33	21	1	Very High	Slow	Low
104	3.0 – 4.0	River Mile 5.0 – 5.5	71	40	31	1	Very High	Slow	Low
107	1.0 – 2.0	River Mile 5.5 – 6.0	71	35	36	1	Very High	Slow	Low
107	3.0 – 4.0	River Mile 5.5 – 6.0	56	32	24	1	Very High	Slow	Low

Table 2-11a
Sediment Pore Water PAH Concentrations
Buffalo, NY

		BR003	BR007	BR017	BR022	BR030	BR036	BR038	BR040	BR049	BR054	BR060	BR66	BR070	BR074	BR080	BR085	BR095	BR098	BR104	BR107
	Detection Limit	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water	Mean Pore Water
	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
Chemical																					
naphthalene	0.1	ND	ND	ND	ND	ND	ND	ND	ND	0.11	0.14	0.13	ND	0.30	ND	ND	ND	ND	ND	ND	ND
2-methylnaphthalene	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.08	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-methylnaphthalene	0.05	ND	ND	ND	0.27	ND	ND	ND	0.23	ND	0.19	0.11	ND	0.05	ND	ND	ND	ND	ND	ND	ND
C2 naphthalenes	0.15	ND	0.20	0.17	0.31	0.19	ND	0.19	0.11	ND	1.58	ND	0.34	0.25	0.18	0.23	ND	ND	0.16	0.21	ND
C3 naphthalenes	0.05	ND	0.16	ND	ND	ND	ND	0.27	ND	ND	5.41	ND	ND	ND	0.12	0.16	ND	ND	0.15	0.25	ND
C4 naphthalenes	0.15	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
acenaphthylene	0.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
acenaphthene	0.1	ND	0.04	ND	ND	ND	ND	ND	ND	ND	0.43	0.12	ND	ND	ND	ND	ND	ND	ND	ND	ND
fluorene	0.04	ND	0.03	ND	0.10	ND	ND	ND	0.07	ND	0.26	0.05	ND	0.04	ND	ND	ND	ND	ND	ND	ND
C1 fluorenes	0.02	ND	0.08	0.07	ND	ND	ND	0.09	ND	ND	0.65	ND	0.08	0.10	ND	ND	ND	ND	0.04	0.10	ND
C2 fluorenes	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.64	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3 fluorenes	0.06	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
phenanthrene	0.1	ND	0.05	ND	ND	ND	ND	ND	ND	ND	0.22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
anthracene	0.05	ND	0.01	ND	ND	ND	ND	ND	ND	ND	0.18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C1 phenanthrenes/anthracenes	0.02	ND	0.09	ND	ND	ND	ND	ND	ND	ND	0.49	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2 phenanthrenes/anthracenes	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.94	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3 phenanthrenes/anthracenes	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4 phenanthrenes/anthracenes	0.02	ND	ND	ND	0.05	ND	ND	ND	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
fluoranthene	0.01	0.03	0.05	0.03	0.05	0.01	0.01	0.03	0.01	0.03	0.15	0.03	0.02	0.04	0.02	0.02	0.01	0.01	0.02	0.01	ND
pyrene	0.01	0.03	0.05	0.02	ND	0.01	ND	0.02	ND	0.02	0.15	0.02	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	ND
C1 fluoranthenes/pyrenes	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benz[a]anthracene	0.001	ND	0.00	0.00	ND	ND	ND	ND	ND	0.00	0.01	0.00	0.00	0.00	ND	ND	ND	ND	ND	ND	ND
chrysene	0.001	ND	0.00	0.00	ND	ND	ND	ND	ND	0.00	0.02	0.00	0.00	0.00	ND	ND	ND	ND	ND	ND	ND
C1 chrysenes	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C2 chrysenes	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C3 chrysenes	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
C4 chrysenes	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo[b+k]fluoranthene	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo[e]pyrene	0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo[a]pyrene	0.008	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
perylene	0.004	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
indeno[1,2,3-cd]pyrene	0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
dibenz[ah]anthracene	0.002	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo[ghi]perylene	0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toxicity Units (total PAHs)		**0.06**	**0.77**	**0.30**	**0.77**	**0.22**	**0.01**	**0.59**	**0.43**	**0.16**	**17.47**	**0.53**	**0.47**	**0.82**	**0.34**	**0.41**	**0.03**	**0.02**	**0.38**	**0.59**	**0.00**

ng/g - Nanogram per gram
PAH - Polycyclic aromatic hydrocarbon

Table 2-11b
Summary of Sediment Pore Water PAH Concentrations and Log Koc Values
Buffalo, NY

Chemical	Number of Detected Samples	Detection Limit	Pore Water Min Detected Sample	Pore Water Max Detected Sample	Pore Water Mean Detected Sample	Log Koc Minimum	Log Koc Maximum	Log Koc Mean
		ng/g	ng/g	ng/g	ng/g			
naphthalene	4	0.1	0.110	0.302	0.172	4.37	5.26	4.69
2-methylnaphthalene	1	0.05	0.078	0.078	0.078	4.86	4.86	4.86
1-methylnaphthalene	5	0.05	0.050	0.268	0.169	3.89	4.72	4.35
C2 naphthalenes	13	0.15	0.108	1.584	0.318	4.71	5.33	5.04
C3 naphthalenes	7	0.05	0.122	5.407	0.930	4.51	5.37	5.07
C4 naphthalenes	1	0.15	5.044	5.044	5.044	4.79	4.79	4.79
acenaphthylene	0	0.2	–	–	–	–	–	–
acenaphthene	3	0.1	0.037	0.430	0.194	4.45	5.11	4.74
fluorene	6	0.04	0.032	0.264	0.092	4.67	5.46	4.99
C1 fluorenes	8	0.02	0.038	0.646	0.151	5.26	5.59	5.44
C2 fluorenes	1	0.05	0.638	0.638	0.638	5.57	5.57	5.57
C3 fluorenes	0	0.06	–	–	–	–	–	–
phenanthrene	2	0.1	0.047	0.224	0.136	5.31	5.96	5.63
anthracene	2	0.05	0.014	0.184	0.099	5.54	6.34	5.94
C1 phenanthrenes/anthracenes	2	0.02	0.094	0.493	0.294	5.42	5.80	5.61
C2 phenanthrenes/anthracenes	1	0.05	0.938	0.938	0.938	5.92	5.92	5.92
C3 phenanthrenes/anthracenes	1	0.04	0.808	0.808	0.808	5.99	5.99	5.99
C4 phenanthrenes/anthracenes	2	0.02	0.014	0.046	0.030	6.05	6.18	6.12
fluoranthene	19	0.01	0.011	0.149	0.030	5.81	6.67	6.38
pyrene	16	0.01	0.010	0.151	0.028	5.77	6.62	6.34
C1 fluoranthenes/pyrenes	1	0.01	0.139	0.139	0.139	6.00	6.00	6.00
benz[a]anthracene	7	0.001	0.001	0.012	0.004	6.62	7.35	7.07
chrysene	7	0.001	0.002	0.016	0.005	6.57	7.74	7.16
C1 chrysenes	0	0.005	–	–	–	–	–	–
C2 chrysenes	0	0.01	–	–	–	–	–	–
C3 chrysenes	0	0.01	–	–	–	–	–	–
C4 chrysenes	0	0.01	–	–	–	–	–	–
benzo[b+k]fluoranthene	0	0.005	–	–	–	–	–	–
benzo[e]pyrene	0	0.005	–	–	–	–	–	–
benzo[a]pyrene	0	0.008	–	–	–	–	–	–
perylene	0	0.004	–	–	–	–	–	–
indeno[1,2,3-cd]pyrene	0	0.001	–	–	–	–	–	–
dibenz[ah]anthracene	0	0.002	–	–	–	–	–	–
benzo[ghi]perylene	0	0.001	–	–	–	–	–	–

ng/g - nanograms per gram

Table 2-12a
Sediment Pore Water PCB Concentrations
Buffalo, NY

PCB Congener	Congener Number	Detection Limit pg/L	BR 03 Mean Pore Water pg/L	BR07 Mean Pore Water pg/L	BR09 Mean Pore Water pg/L	BR17 Mean Pore Water pg/L	BR18 Mean Pore Water pg/L	BR22 Mean Pore Water pg/L	BR30 Mean Pore Water pg/L	BR36 Mean Pore Water pg/L	BR38 Mean Pore Water pg/L	BR40 Mean Pore Water pg/L	BR41 Mean Pore Water pg/L	BR54 Mean Pore Water pg/L	BR60 Mean Pore Water pg/L	BR66 Mean Pore Water pg/L	BR69 Mean Pore Water pg/L	BR70 Mean Pore Water pg/L	BR74 Mean Pore Water pg/L	BR95 Mean Pore Water pg/L	BR98 Mean Pore Water pg/L	BR104 Mean Pore Water pg/L
2,2'-dichlorobiphenyl	4	34	45.6	129.6	50.4	36.5	182.4	128.1	40.7	84.7	233.4	125.8	ND	1065.1	30.6	101.8	72.3	ND	116.7	27.5	939.4	ND
2,3'-dichlorobiphenyl	6	19	35.7	40.5	30.9	27.6	172.1	41.5	35.5	27.8	109.9	66.3	39.9	480.0	46.2	86.0	31.8	ND	74.9	11.7	333.9	ND
2,4'-dichlorobiphenyl	8	17	33.6	59.3	37.5	32.2	184.7	84.9	40.8	58.6	349.3	171.4	58.5	1399.9	36.8	104.7	37.1	ND	203.9	22.3	287.4	ND
4,4'-dichlorobiphenyl	15	8	89.3	108.5	121.3	92.1	180.6	156.1	107.2	97.2	281.3	165.1	133.1	977.6	110.7	120.8	126.3	162.8	207.2	124.6	340.3	209.0
2,2',3 (2,4',6)-trichlorobiphenyl	16+32	4	38.4	50.6	41.8	36.1	156.4	90.8	51.2	51.8	268.5	112.5	37.1	932.4	46.9	94.2	45.5	57.2	152.8	33.7	207.3	43.1
2,2',4-trichlorobiphenyl	17	3	19.2	30.3	21.8	18.0	97.3	51.2	23.2	29.2	165.3	74.8	22.4	602.2	19.3	50.8	24.5	ND	93.8	19.5	177.4	ND
2,2',5-trichlorobiphenyl	18	4	59.9	91.8	65.8	51.2	253.3	154.8	71.5	95.9	518.4	215.7	63.1	1933.2	58.5	149.4	70.2	55.8	290.8	60.1	377.5	40.9
2,3,4'-trichlorobiphenyl	22	2	26.0	24.1	14.8	16.5	82.1	39.0	22.7	27.1	130.6	65.4	19.7	459.9	18.2	67.4	16.7	ND	75.2	14.0	50.4	19.2
2,3',5-trichlorobiphenyl	26	2	10.8	16.4	13.8	10.4	40.2	23.8	10.0	13.5	61.7	28.7	ND	203.0	10.7	44.5	11.9	9.9	30.8	8.2	106.0	22.3
2,4,4'-trichlorobiphenyl	28	1	21.9	27.3	24.2	16.7	64.9	49.7	21.9	26.6	167.2	67.9	19.7	635.8	18.7	50.6	19.6	20.7	93.5	15.4	77.1	14.5
2,4',5-trichlorobiphenyl	31	2	27.7	37.4	32.0	24.2	100.6	67.9	35.1	43.3	242.1	106.8	27.8	898.2	28.5	68.8	33.0	30.8	135.0	29.9	136.9	28.3
2',3,4-trichlorobiphenyl	33	2	21.1	25.7	23.2	18.2	61.5	48.4	26.4	33.2	193.5	91.5	19.8	712.3	26.7	41.7	24.9	18.7	106.6	15.9	55.3	17.4
3,4,4'-trichlorobiphenyl	37	2	6.1	9.6	4.3	5.6	14.5	13.8	6.0	8.0	39.1	20.0	ND	132.9	7.8	19.5	9.2	ND	19.5	9.4	ND	5.6
2,2',3,4'-tetrachlorobiphenyl	42	1	4.6	8.8	6.0	5.5	16.6	16.2	3.2	8.1	36.1	15.4	4.3	119.6	5.8	14.4	7.9	ND	20.2	6.3	28.9	3.5
2,2',3,5'-tetrachlorobiphenyl	44	1	24.4	30.4	27.4	22.0	56.1	49.0	21.6	29.2	146.0	58.1	17.1	497.9	22.5	46.0	28.7	15.8	81.6	23.3	117.3	35.1
2,2',3,6-tetrachlorobiphenyl	45	2	ND	11.2	10.8	4.5	31.6	25.6	6.9	17.2	62.6	28.0	ND	185.0	5.9	16.3	ND	ND	31.3	9.9	39.9	ND
2,2',4,4 (2,2',4,5)'-tetrachlorobiphenyl	47+48	1	15.5	19.4	18.3	20.3	111.0	48.7	7.8	9.0	64.5	23.7	10.2	138.8	12.7	48.5	18.1	11.9	37.3	10.6	58.9	7.4
2,2',4,5'-tetrachlorobiphenyl	49	1	15.7	19.6	16.0	15.2	63.5	33.9	11.4	14.3	80.3	29.4	8.3	264.4	12.8	39.5	17.3	12.6	44.3	12.8	71.4	11.3
2,2',5,5'-tetrachlorobiphenyl	52	1	36.5	41.4	34.0	37.2	84.4	62.6	28.2	32.4	163.8	58.1	25.9	534.7	29.4	72.5	38.3	30.9	94.9	34.4	135.5	26.6
2,3,3',4' (2,3,4,4')-tetrachlorobiphenyl	56+60	0.3	4.0	4.6	4.7	6.2	22.0	7.7	3.6	3.9	17.9	9.0	4.2	66.2	5.3	12.6	4.4	4.6	11.0	4.5	9.6	3.8
2,3,4',6-tetrachlorobiphenyl	64	0.8	16.4	18.0	15.8	13.2	17.9	19.0	14.3	17.3	54.0	22.9	9.7	175.4	15.0	25.9	17.9	14.7	31.8	13.4	35.0	13.0
2,3',4,4'-tetrachlorobiphenyl	66	0.5	7.3	7.9	7.6	5.3	17.2	14.4	4.8	6.3	40.8	14.6	4.2	167.0	5.9	16.8	7.8	6.9	22.5	5.4	21.1	6.1
2,3',4',5-tetrachlorobiphenyl	70	0.5	8.9	10.7	9.4	8.7	20.1	19.5	7.2	8.7	55.3	19.1	5.6	221.3	7.8	20.6	10.9	9.0	30.4	8.3	28.3	6.6
2,4,4',5-tetrachlorobiphenyl	74	0.4	4.6	4.8	4.5	3.5	9.2	8.4	3.3	4.0	24.9	9.3	3.2	97.1	4.2	9.3	5.2	4.2	14.0	3.9	12.7	3.8
2,2',3,3',4-pentachlorobiphenyl	82	0.4	1.9	ND	1.5	2.3	4.6	2.9	1.8	1.7	4.9	2.2	3.1	14.5	1.4	4.2	ND	ND	4.0	2.1	ND	ND
2,2',3,3',6-(2,2',4,4',6pentachlorobiphenyl	84+101	0.2	5.0	5.6	5.3	6.4	14.3	10.4	3.8	3.7	17.0	5.3	3.5	46.4	3.7	12.3	5.8	5.5	10.3	3.0	7.1	3.7
2,2',3,4,4'-pentachlorobiphenyl	85	0.3	1.1	1.2	1.5	1.3	3.2	2.7	0.9	0.9	4.5	2.2	2.1	13.2	1.2	4.5	1.4	1.9	3.3	ND	2.4	0.9
2,2',3,4,5'-pentachlorobiphenyl	87	0.4	3.8	3.8	4.1	5.4	9.9	8.0	3.0	3.1	14.2	6.1	3.7	38.3	2.5	10.2	4.5	5.2	8.9	2.7	5.6	2.2
2,2',3,5',6-pentachlorobiphenyl	95	0.7	15.3	17.6	15.9	17.9	32.5	28.1	11.7	12.4	49.1	17.6	10.7	125.7	12.3	30.5	16.6	13.5	29.9	10.7	23.0	10.1
2,2',3',4,5-pentachlorobiphenyl	97	0.5	3.2	3.3	4.2	4.2	8.0	7.2	2.2	2.5	12.1	4.0	3.7	36.5	2.7	7.7	3.9	4.3	7.9	2.8	8.0	2.1
2,2',4,4',5-pentachlorobiphenyl	99	0.3	3.2	3.3	3.4	3.8	10.1	7.0	2.5	2.2	11.6	3.5	2.5	31.3	2.0	6.8	3.5	4.2	7.0	1.9	6.7	1.5
2,3,3',4,4'-pentachlorobiphenyl	105	0.2	1.5	1.3	1.8	1.9	4.0	2.9	1.2	1.1	4.8	2.5	2.4	15.9	1.4	4.1	1.7	2.5	3.6	1.3	2.8	0.8
2,3,3',4',6-pentachlorobiphenyl	110	0.4	7.7	8.5	8.3	10.0	18.9	15.4	5.9	5.6	28.1	9.1	6.0	79.6	5.9	18.7	9.3	7.9	17.0	5.2	10.9	4.7
2,3',4,4',5-pentachlorobiphenyl	118	0.4	6.1	6.1	6.5	7.4	15.8	11.9	4.6	4.3	20.6	7.3	5.1	63.4	4.6	14.9	5.7	5.9	12.9	3.8	8.0	3.4
2,2',3,3',4,4'-hexachlorobiphenyl	128	0.1	0.5	0.4	0.7	0.4	2.0	1.0	0.3	0.3	1.0	0.7	1.5	2.2	0.3	0.9	0.3	0.8	1.2	0.2	ND	ND
2,2',3,3',4,6'-hexachlorobiphenyl	132	0.3	1.1	1.4	1.6	1.4	4.4	3.1	0.9	0.9	3.2	1.5	2.1	8.5	1.0	3.4	1.4	2.6	2.6	0.9	ND	1.9
2,2',3,3',5,6'-hexachlorobiphenyl	135	0.5	1.5	1.4	1.9	1.5	5.6	3.3	1.1	1.0	2.9	1.5	2.6	7.4	1.1	3.8	1.5	2.6	2.8	0.6	ND	1.2
2,2',3,3',6,6'-hexachlorobiphenyl	136	0.5	0.8	1.6	1.7	1.6	5.5	3.3	1.1	1.1	2.8	2.0	2.2	6.8	1.3	3.2	1.5	1.8	2.5	0.6	ND	1.3
2,2',3,4,4',5'-(2,3,3',4',5,6)hexachlorobiphenyl	138+163	0.1	0.9	1.0	1.3	1.1	3.9	2.5	0.7	0.6	2.5	1.1	1.6	6.3	0.7	2.8	1.1	1.5	2.0	0.7	0.9	0.6
2,2',3,4,5,5'-hexachlorobiphenyl	141	0.2	0.6	0.6	1.0	0.5	2.0	1.5	0.5	0.4	1.2	0.8	1.6	3.4	0.6	2.1	0.5	1.4	1.4	0.2	ND	0.5
2,2',3,4',5,5'-hexachlorobiphenyl	146	0.2	0.6	0.7	1.0	0.8	4.7	1.9	0.6	0.4	1.5	0.8	1.7	3.7	0.5	2.3	0.7	1.2	1.6	0.2	ND	ND
2,2',3,4',5',6-hexachlorobiphenyl	149	0.3	3.2	3.7	3.8	3.4	12.3	8.4	2.3	2.1	8.2	3.1	2.7	21.1	2.5	8.4	3.7	4.1	5.5	1.9	2.2	1.4
2,2',3,5,5',6-hexachlorobiphenyl	151	0.3	1.3	1.4	1.7	1.3	6.1	3.4	0.9	0.9	2.7	1.2	2.0	7.3	1.0	3.4	1.4	1.9	2.4	0.4	ND	0.9
2,2',4,4',5,5'-hexachlorobiphenyl	153	0.1	1.2	1.4	1.6	1.4	5.1	3.4	0.8	0.8	3.3	1.2	1.3	8.4	0.9	3.6	1.4	1.7	2.3	0.8	1.0	0.9
2,3,3',4,4',5-hexachlorobiphenyl	156	0.1	0.3	ND	0.7	0.3	1.4	0.6	ND	0.2	0.4	0.4	1.1	1.4	0.2	0.9	0.1	0.7	0.8	0.1	ND	ND
2,2',3,3',4,4',5-heptachlorobiphenyl	170	0.1	0.4	0.5	ND	0.3	3.2	1.9	0.5	0.3	1.1	ND	2.7	3.4	0.5	1.5	0.4	1.6	1.9	0.2	ND	ND
2,2',3,3',4,4',6-heptachlorobiphenyl	171	0.1	0.2	0.2	0.4	0.1	1.3	0.6	0.3	ND	0.3	0.6	1.3	1.0	0.1	0.8	0.2	0.8	0.8	ND	ND	ND
2,2',3,3',4,5,6'-heptachlorobiphenyl	174	0.2	0.6	0.6	1.0	0.6	3.3	1.9	0.6	0.4	1.1	1.0	2.0	3.5	0.3	1.8	0.6	1.8	1.5	0.2	1.2	1.1
2,2',3,3',4',5,6-heptachlorobiphenyl	177	0.1	0.4	0.3	0.5	0.3	2.2	1.1	0.4	0.2	0.6	0.7	1.5	1.8	0.2	1.3	0.3	1.1	1.0	0.2	ND	ND
2,2',3,3',5,6,6'-heptachlorobiphenyl	179	0.3	0.3	0.4	0.8	0.4	2.6	1.4	0.3	ND	0.8	0.6	1.6	2.0	ND	1.3	0.5	1.0	1.2	0.2	ND	ND
2,2',3,4,4',5,5'-heptachlorobiphenyl	180	0.1	0.6	0.7	1.0	0.6	3.6	2.3	0.7	0.4	1.4	0.9	2.2	4.0	0.4	2.0	0.8	1.7	1.8	0.6	0.6	0.3
2,2',3,4,4',5',6-heptachlorobiphenyl	183	0.2	0.3	0.3	0.5	0.3	1.9	1.1	0.3	0.2	0.6	0.6	1.6	1.8	0.2	1.2	0.3	0.9	1.1	0.4	ND	ND
2,2',3,4',5,5',6-heptachlorobiphenyl	187	0.2	0.8	1.0	1.0	0.7	3.9	2.4	0.8	0.5	1.4	1.0	1.7	3.5	0.6	2.0	1.0	1.3	1.5	0.8	0.8	0.9
2,3,3',4,4',5',6-heptachlorobiphenyl	191	0.1	0.3	ND	ND	ND	1.1	0.7	0.3	ND	ND	ND	1.6	0.7	ND	0.9	ND	0.7	0.8	ND	ND	ND
2,2',3,3',4,4',5,5'-octachlorobiphenyl	194	0.2	ND	0.2	0.7	ND	1.7	0.7	0.3	ND	ND	ND	1.5	1.0	ND	0.4	ND	ND	0.7	ND	ND	ND
2,2',3,3',4,5,6,6'-octachlorobiphenyl	199	0.4	ND	0.6	1.6	ND	4.0	1.8	0.6	ND	1.3	ND	2.9	2.3	ND	0.8	ND	ND	2.1	ND	ND	ND
2,2',3,4,4',5,5',6-octachlorobiphenyl	203	0.2	ND	0.3	0.7	ND	1.7	0.8	0.3	ND	ND	ND	1.4	1.0	ND	0.4	ND	ND	0.7	ND	ND	ND

PCB - Polychlorinated Biphenyl
pg/L - Picogram per Liter

Table 2-12b
Summary of Buffalo River Sediment Log Koc Values for PCB Congeners
Buffalo, NY

PCB Congener	Congener Number	Number of Calculated Log Koc Values[a]	Log Koc Minimum	Log Koc Maximum	Log Koc Mean
2,2'-dichlorobiphenyl	4	3	5.6	6.4	6.1
2,3'-dichlorobiphenyl	6	14	5.7	6.9	6.2
2,4'-dichlorobiphenyl	8	13	5.5	6.5	6.0
4,4'-dichlorobiphenyl	15	20	6.1	6.9	6.5
2,2',3 (2,4',6)-trichlorobiphenyl	16+32	10	6.1	6.8	6.4
2,2',4-trichlorobiphenyl	17	8	5.9	6.7	6.3
2,2',5-trichlorobiphenyl	18	15	5.6	6.7	6.2
2,3,4'-trichlorobiphenyl	22	8	6.2	7.1	6.5
2,3',5-trichlorobiphenyl	26	7	6.2	6.8	6.5
2,4,4'-trichlorobiphenyl	28	18	6.1	7.1	6.8
2,4',5-trichlorobiphenyl	31	17	6.0	6.9	6.6
2',3,4-trichlorobiphenyl	33	12	6.0	7.0	6.6
3,4,4'-trichlorobiphenyl	37	10	6.6	8.0	7.5
2,2',3,4'-tetrachlorobiphenyl	42	12	6.5	7.7	7.3
2,2',3,5'-tetrachlorobiphenyl	44	20	6.3	7.3	6.9
2,2',3,6-tetrachlorobiphenyl	45	7	6.3	7.4	6.9
2,2',4,4 (2,2',4,5)'-tetrachlorobiphenyl	47+48	12	6.2	7.3	6.9
2,2',4,5'-tetrachlorobiphenyl	49	15	6.4	7.7	7.1
2,2',5,5'-tetrachlorobiphenyl	52	20	6.7	7.6	7.1
2,3,3',4' (2,3,4,4')-tetrachlorobiphenyl	56+60	5	6.9	7.9	7.4
2,3,4',6-tetrachlorobiphenyl	64	5	6.2	7.2	6.8
2,3',4,4'-tetrachlorobiphenyl	66	19	6.9	7.6	7.4
2,3',4',5-tetrachlorobiphenyl	70	20	6.5	7.5	7.2
2,4,4',5-tetrachlorobiphenyl	74	18	7.1	7.7	7.5
2,2',3,3',4-pentachlorobiphenyl	82	4	7.4	7.9	7.6
2,2',3,3',6-(2,2',4,4',6pentachlorobiphenyl	84+101	20	7.4	8.0	7.8
2,2',3,4,4'-pentachlorobiphenyl	85	6	7.4	7.9	7.6
2,2',3,4,5'-pentachlorobiphenyl	87	19	7.2	8.1	7.8
2,2',3,5',6-pentachlorobiphenyl	95	20	6.8	7.3	7.1
2,2',3',4,5-pentachlorobiphenyl	97	13	7.0	8.0	7.5
2,2',4,4',5-pentachlorobiphenyl	99	18	7.2	7.8	7.6
2,3,3',4,4'-pentachlorobiphenyl	105	9	7.5	8.1	7.8
2,3,3',4',6-pentachlorobiphenyl	110	19	7.1	7.7	7.5
2,3',4,4',5-pentachlorobiphenyl	118	20	7.5	8.4	8.2
2,2',3,3',4,4'-hexachlorobiphenyl	128	1	8.5	8.5	8.5
2,2',3,3',4,6'-hexachlorobiphenyl	132	11	7.4	8.1	7.8
2,2',3,3',5,6'-hexachlorobiphenyl	135	6	7.4	8.1	7.7
2,2',3,3',6,6'-hexachlorobiphenyl	136	6	7.2	7.8	7.5
2,2',3,4,4',5'-(2,3,3',4',5,6)hexachlorobiphenyl	138+163	18	7.3	8.6	8.2
2,2',3,4,5.5'-hexachlorobiphenyl	141	7	7.5	8.2	7.8
2,2',3,4',5,5'-hexachlorobiphenyl	146	6	7.4	8.1	7.8
2,2',3,4',5',6-hexachlorobiphenyl	149	19	7.4	8.0	7.7
2,2',3,5,5',6-hexachlorobiphenyl	151	8	7.4	8.1	7.8
2,2',4,4',5,5'-hexachlorobiphenyl	153	20	7.7	8.5	8.1
2,3,3',4,4',5-hexachlorobiphenyl	156	3	8.4	8.8	8.6
2,2',3,3',4,4',5-heptachlorobiphenyl	170	2	8.5	8.8	8.6
2,2',3,3',4,4',6-heptachlorobiphenyl	171	2	8.1	8.7	8.4
2,2',3,3',4,5,6'-heptachlorobiphenyl	174	4	7.9	8.4	8.2
2,2',3,3',4',5,6-heptachlorobiphenyl	177	3	8.1	8.6	8.4
2,2',3,3',5,6,6'-heptachlorobiphenyl	179	10	7.4	8.6	8.1
2,2',3,4,4',5,5'-heptachlorobiphenyl	180	2	8.3	8.8	8.5
2,2',3,4,4',5',6-heptachlorobiphenyl	183	5	7.6	8.5	8.1
2,2',3,4',5,5',6-heptachlorobiphenyl	187	16	7.7	8.4	8.2
2,3,3',4,4',5',6-heptachlorobiphenyl	191	0	NA[b]	NA	NA
2,2',3,3',4,4',5,5'-octachlorobiphenyl	194	2	8.3	8.3	8.3
2,2',3,3',4,5,6,6'-octachlorobiphenyl	199	3	7.8	8.3	8.1
2,2',3,4,4',5,5'.6-octachlorobiphenyl	203	2	8.1	8.5	8.3

(a) Log Koc values were not calculated for samples in which PCB congener concentrations were below the detection limit in either pore water or sediment.

(b) 2,2',3,3',4,4',5,5'-octachlorobiphenyl was not detected in any of the sediment extracts (detection limit =1.0 ng/g). Therefore log Koc values were not calculated for this chemical.

PCB - Polychlorinated biphenyl
pg/L - Picogram per liter
NA - Not Available

Table 3-1a
Downstream ADP Summary Statistics
Buffalo, NY

	Date Time	Downstream Water VelocityX ft/s	Cross-channel Water VelocityY ft/s	Water Level Above ADP ft	Water Temperature F	Measured Cell Begin ft	Measured Cell End ft	Water Velocity Magnitude ft/s	Water Velocity Direction degrees
Minimum	10/1/2008 13:30	-2.3	-0.34	2.3	39.9	4.9	93.5	0	0
Maximum	11/19/2008 11:35	3.25	0.22	6.9	66.2	4.9	165.7	3.25	352.9
Average		0.09	-0.02	3.6	50.1	4.9	164.5	0.3	164.6
St. Dev.		0.42	0.04	0.5	6.4	0	1.1	0.32	80.5

Table 3-1b
Midstream ADP Summary Statistics
Buffalo, NY

	Date Time	Downstream Water VelocityX ft/s	Cross-channel Water VelocityY ft/s	Water Level Above ADP ft	Water Temperature F	Measured Cell Begin ft	Measured Cell End ft	Water Velocity Magnitude ft/s	Water Velocity Direction degrees
Minimum	10/1/2008 18:00	-1.4	-0.34	2	38.2	4.9	90.2	0	0
Maximum	11/19/2008 15:20	1.89	0.46	7	64.9	4.9	210	1.95	354.3
Average		0.09	0.004	3.5	47.9	4.9	209.1	0.2	140.3
St. Dev.		0.26	0.061	0.6	6	0	1.6	0.2	77.4

Table 3-1c
Upstream ADP Summary Statistics
Buffalo, NY

	Date Time	Downstream Water VelocityX ft/s	Cross-channel Water VelocityY ft/s	Water Level Above ADP ft	Water Temperature F	Measured Cell Begin ft	Measured Cell End ft	Water Velocity Magnitude ft/s	Water Velocity Direction degrees
Min.	9/30/2008 6:00:00 PM	-1.3	-0.11	4.6	35.1	4.9	178.8	0	0
Max.	11/19/2008 1:40:00 PM	2.12	0.09	10	65.6	4.9	229.7	2.12	346
Avg.		0.17	-0.01	6.2	47.9	4.9	179.8	0.23	127
StDev.		0.28	0.01	0.6	6.42	7.00E-13	5.7	0.24	68

ft - feet
ft/s - feet per second
F - Fahrenheit

Table 3-2
Long Term Turbidity Result Summary
Buffalo, NY

	OBS Turbidity NTU	YSI - 25% Depth Temperature °C	YSI - 25% Depth Turbidity NTU	YSI - 75% Depth Temperature °C	YSI - 75% Depth Turbidity NTU
			DOWNSTREAM		
Average	34.82	11.23	21.57	10.60	24.32
Maximum	362.30	16.96	140.70	16.78	240.55
Minimum	-0.59	4.49	-5.24	4.45	-4.81
Median	19.96	10.46	16.31	9.95	18.81
Standard Deviation	46.67	3.51	20.81	3.32	20.06
			MIDSTREAM		
Average	----	9.75	27.49	9.53	25.32
Maximum	----	15.84	178.97	15.84	165.11
Minimum	----	3.59	-1.88	3.69	-2.43
Median	----	9.29	17.22	9.25	19.97
Standard Deviation	----	3.18	28.31	2.99	21.57
			UPSTREAM		
Average	67.43	9.76	25.99	9.35	49.89
Maximum	518.48	16.45	867.99	15.92	1049.27
Minimum	5.41	3.17	-2.25	3.28	-6.82
Median	40.53	9.45	13.26	8.93	19.97
Standard Deviation	83.08	3.27	50.26	3.08	98.51

% - percent
° - degree
C - Celsius
NTU - Nephelometric Turbidity Units

Table 3-3
Short Term Hydrodynamic Study-Cross Sectional Flow Measurements
Buffalo, NY

Date	Transect	Start Time	End Time	Transect Width ft	Transect Area ft^2	Mean Depth ft	Mean Velocity fps	Flow Direction º	Discharge cfs
10/23/2008	Downstream Round 1	11:06:30	11:18:46	218	4,889	22.4	0.23	332	1,093
10/23/2008	Downstream Round 2	11:46:10	12:03:48	217	4,835	22.2	0.33	328	1,497
10/23/2008	Downstream Round 3	13:02:19	13:21:45	216	4,750	22.0	0.29	325	1,368
11/5/2008	Downstream Round 4	11:27:54	11:38:58	213	4,888	22.9	0.04	209	57
10/23/2008	Middle (d.s. of buoy btwn buoy and uplooker)	14:39:35	14:59:37	267	5,793	21.7	0.24	259	1,337
10/23/2008	Middle (at buoy)	15:11:45	15:20:18	273	5,664	20.7	0.20	258	1,119
10/23/2008	Upstream	15:41:57	15:57:56	227	3,571	15.8	0.14	313	490
10/23/2008	Upstream (500 ft u.s. of buoy round 1)	16:14:41	16:21:38	233	3,888	16.7	0.10	124	-330
10/23/2008	Upstream (500 ft u.s. of buoy round 2)	16:40:06	16:46:48	231	3,819	16.5	0.27	314	971

Notes:
Each row represents the average values from multiple runs across a transect
Flow direction is in compass degrees with north equal to 0 & 360 degrees
Downstream directions (parallel to channel) are approximately as follows:
312 degrees at downstream location
212 degrees at middle location
300 degrees at upstream location

º - degree
cfs - cubic feet per second
fps - feet per second
ft - feet

Table 3-4
Short Term Turbidity/Temp/DO/pH Data Summary
Buffalo, NY

	Temperature ^{o}C	**DO** mg/L	**pH**	**Turbidity** NTU
DOWNSTREAM - LEFT CHANNEL				
Average	11.67	7.72	7.65	27.74
Max	12.15	7.87	7.68	30.00
Min	10.18	7.48	7.62	26.80
Median	11.80	7.73	7.65	27.70
St Dev	0.52	0.13	0.02	0.82
DOWNSTREAM - CENTER CHANNEL				
Average	10.88	7.60	7.64	28.15
Max	11.90	8.26	7.68	30.30
Min	9.77	7.26	7.61	27.00
Median	11.29	7.40	7.63	27.50
St Dev	0.91	0.36	0.02	1.19
DOWNSTREAM-RIGHT CHANNEL				
Average	10.64	7.78	7.66	26.68
Max	11.58	8.24	7.69	28.90
Min	9.79	7.51	7.64	24.60
Median	10.43	7.68	7.65	26.90
St Dev	0.74	0.26	0.02	1.59
MIDSTREAM-LEFT CHANNEL				
Average	9.18	9.76	7.84	30.28
Max	9.24	10.50	7.85	35.50
Min	8.89	9.55	7.82	29.50
Median	9.21	9.65	7.84	30.10
St Dev	0.09	0.25	0.01	0.91
MIDSTREAM - CENTER CHANNEL				
Average	9.06	9.75	7.96	28.86
Max	9.29	10.39	8.02	33.20
Min	8.72	9.59	7.93	27.40
Median	9.11	9.64	7.95	28.00
St Dev	0.19	0.21	0.02	1.49
MIDSTREAM-RIGHT CHANNEL				
Average	9.18	9.63	7.94	27.99
Max	9.89	9.78	7.96	32.90
Min	8.86	9.54	7.93	26.20
Median	9.06	9.61	7.94	27.50
St Dev	0.35	0.08	0.01	1.70
UPSTREAM-LEFT CHANNEL				
Average	7.36	11.73	8.10	16.73
Max	7.68	12.19	8.17	19.40
Min	7.10	11.55	8.08	13.10
Median	7.38	11.69	8.09	18.20
St Dev	0.21	0.14	0.02	2.52
UPSTREAM-CENTER CHANNEL				
Average	7.31	11.77	8.16	24.14
Max	7.55	12.03	8.24	25.80
Min	7.18	11.54	8.13	23.60
Median	7.24	11.79	8.15	23.80
St Dev	0.15	0.14	0.03	0.61
UPSTREAM-RIGHT CHANNEL				
Average	7.41	11.62	8.15	23.13
Max	7.67	11.93	8.21	24.90
Min	7.22	11.44	8.13	22.70
Median	7.37	11.61	8.15	23.00
St Dev	0.13	0.13	0.01	0.49

^{o} - degree
C - celsius
mg/L - milligrams per liter
NTU - Nephelometric Turbidity Units

Table 3-5
USGS Gages for Model Boundary Conditions
Buffalo, NY

Gage Number	Location	Drainage Area sq mi	Correction Factor --
4214500	Buffalo Creek at Gardenville	142	1.027 [1]
4215000	Cayuga Creek at Lancaster	96.4	1.027
4215500	Cazenovia Creek at Ebenezer	135	1.011

NOTE:
1) The model boundary is downstream of the confluence of Buffalo and Cayuga Creeks, so the drainage area ratio is based on their combined area and is applied to each.

sq - sqaure
mi - mile

Table 3-6
Data Periods Selected for Model Calibration
Buffalo, NY

Period	Description	Dates (2008)	Peak / Average Discharge cfs
A	High Flow, Moderate Seiche	10/15 - 10/18	6500 / 1510
B	Moderate Flow, Moderate Seiche	10/24 - 10/29	2380 / 711
C	Low Flow, High Seiche	11/6 - 11/9	401 / 153
D	Moderate Flow, High Seiche	11/15 - 11/17	2770 / 1440

cfs - cubic feet per second

Table 4-1
Submerged Aquatic Vegetation from the Buffalo River AOC
Buffalo River, NY

Species Name	Common Name	Submerged Aquatic Vegetation (SAV) Beds																												
		SAV-1	SAV-2	SAV-3	SAV-4	SAV-5	SAV-6	SAV-7	SAV-8	SAV-9	SAV-10	SAV-11	SAV-12	SAV-13	SAV-14	SAV-15	SAV-16	SAV-17	SAV-18	SAV-19	SAV-20	SAV-21	SAV-22	SAV-23	SAV-24	SAV-25	SAV-26	SAV-27	SAV-28	SAV-29
Ceratophyllum demersum	coontail	X	X			X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X				X
Elodea canadensis	Canadian waterweed		X		X		X		X			X	X			X	X											X		
Justicia americana	American waterwillow		X				X					X																		
Myriophyllum spicatum	Eurasian watermilfoil				X	X	X	X	X	X						X	X		X	X	X			X	X	X	X	X	X	X
Potamogeton crispus	curlyleaf pondweed	X		X	X			X	X	X	X		X	X	X	X	X		X	X				X			X	X		X
Potamogeton nodosus	American pondweed	X	X	X								X		X	X	X	X	X	X	X	X	X		X	X		X	X	X	X
Potamogeton pectinatus	sago pondweed	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X
Vallisneria americana	wild celery	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X			X	X	X	X	X
Water Depth (ft)		9	3	3	3.5	3	4.5	6	9	7	2	8	2.5	7	8	8	3	3	3	4.5	4	3	3	3	7	4.5	8	10	4	4
Approximate Bed Width (ft)		5	9	18	10	10	7	12	7	6	25	13	14	15	10	10	16	5	12	10	12	4	8	8	5	7	8	8	10	14

Source:
Results from the September 2008 survey; illustrated on Figure 4-1.

Notes:

AOC	Area of concern
ft	feet
SAV	Submerged aquatic vegetation

Table 4-2
Emergent Vegetation from the Buffalo River AOC
Buffalo River, NY

		Emergent Vegetation (EV) Stands														
Species Name	Common Name	EV-1	EV-2	EV-3	EV-4	EV-5	EV-6	EV-7	EV-8	EV-9	EV-10	EV-11	EV-12	EV-13	EV-14	EV-15
Lythrum salicaria	purple loosestrife	X	X	X	X	X			X	X			X	X		
Phragmites australis	common reed	X	X	X	X	X				X			X			X
Polygonum cuspidatum	Japanese knotweed		X			X	X	X	X	X	X			X	X	
Sagittaria latifolia	broadleaf arrowhead													X		
Scirpus validus	softstem bulrush		X									X		X		
Typha latifolia	broadleaf cattail	X	X											X		X
Pontederia cordata	pickerelweed													X		

Source:
Results from the September 2008 survey; illustrated on Figure 4-1.

Notes:

AOC	Area of concern
EV	Emergent vegetation

Table 4-3
Indirect Metrics for Benthic Community Assessment
Buffalo River, NY

Benthic Macroinvertebrate Metric	Formula
1. Species Richness	Number of species
2. Abundance	Total number of organisms
3. EPT richness	Number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera)
4. Biotic index	$\sum \frac{x_i \times t_i}{n}$ Where: xi=The number of organisms within species ti=The tolerance value of species (b) n=Total number of organisms in sample
5. Percent Model Affinity	For ponar samples, the model is: 20% Oligochaeta, 15% Mollusca, 15% Crustacea, 20% Non-Chironomidae Insecta, and 20% Chironomidae, and 10% Other.
6. Species diversity	$H = -\sum_{i=1}^{s}(pi \times \ln pi)$ Where: H = Shannon diversity index s = total number of species in the community (richness) p_i = proportion of individuals of a given species to the total number of species in the community
7. Dominance	Number of individuals in most dominant taxon/ total number of organisms
8. Non-chironomid/oligochaetes (NCO) richness	Number of species of non-chironomid (fly) and non oligochaete (worm) organisms.
9. Chironomid mouthpart deformities	Percentage of chironomids with mouthpart deformities.

Source:
Based on USEPA (1989, 1999), NYSDEC (1991, 2002), and Weber (1973).

Table 4-4
Water Quality Measurements for Benthic Community Locations
Buffalo River, NY

Location	River Mile	Temperature (°C)	Specific Conductance (µmhos/cm)	Dissolved Oxygen (mg/L)	pH (s.u.)	Turbidity NTUs	Secchi Disk (m)
BR01	7.25	16.7	626	8.7	7.67	NA	1
BR02	6.8	17	624	7.71	7.78	NA	1
BR03	6.25	17.9	629	7.57	7.99	NA	1.2
BR04	5.5	20	497	7.29	7.96	NA	1.5
BR05	4.75	20.6	495	7.87	7.84	NA	2
BR06	2.1	20.5	378	5.59	7.62	NA	0.7
BR07	1.0	20.8	348	6.56	7.84	NA	1.5
BR08	0.3	20.4	291	8.56	8.36	NA	3.5
CC01	---	17.4	586	9.8	8.23	NA	2.5
RSC01	---	20.5	456	8.76	7.68	3.3	0.5
RSC02	---	20.3	452	9.1	7.95	10	1.5
RSC03	---	18.6	457	9.8	7.99	8	1.5
RST01	---	20.2	295	8.19	7.33	1	3
RST02	---	20.4	295	8.31	7.85	0	3
RST03	---	20.4	315	8.33	7.94	0	NA
BR (mean)	---	19.2	486	7.5	7.9	NA	1.6
CC	---	17.4	586	9.8	8.2	NA	2.5
RSC (mean)	---	19.8	455	9.2	7.9	7.1	1.2
RST (mean)	---	20.3	302	8.3	7.7	0.3	3.0

Notes:
Flow ranged from 0.05-0.2 feet/second in the Buffalo River at the time of sampling.

°C	Degrees Celcius
BR	Buffalo River
CC	Cazenovia Creek
m	Meter
mg/L	Milligram per liter
NA	Not analyzed
NTUs	Nephelometric turbidity units
RSC	Reference Site Cattaraugas Creek
RST	Reference Site Tonawanda Creek
s.u.	Standard unit

Table 4-5
Habitat Assessment Scores for Benthic Community Locations
Buffalo River, NY

Location	River Mile	Epifaunal Substrate/Avalable Cover	Pool Substrate Characterization	Pool Variability	Sediment Deposition	Channel Flow Status	Channel Alteration	Channel Sinuosity	Bank Stability (LB)	Bank Stability (RB)	Vegetative Protection (LB)	Vegetative Protection (RB)	Riparian Vegetative Zone Width (LB)	Riparian Vegetative Zone Width (RB)	Sum	Ranking*
BR01	7.25	6	9	2	4	15	6	5	9	3	8	3	9	3	82	Marginal
BR02	6.8	14	15	6	18	18	11	10	8	8	5	5	8	8	134	Suboptimal
BR03	6.25	12	6	11	13	18	5	2	9	9	6	6	4	4	105	Suboptimal
BR04	5.5	0	6	8	1	18	7	4	6	5	6	6	9	9	85	Marginal
BR05	4.75	1	8	2	1	19	3	6	9	8	1	3	7	5	73	Marginal
BR06	2.1	0	6	2	0	19	3	7	9	9	0	1	1	1	58	Marginal
BR07	1.0	0	6	6	2	19	1	2	9	9	1	1	0	0	56	Marginal
BR08	0.3	1	7	7	1	19	2	2	9	9	1	1	1	1	61	Marginal
CC01	---	13	6	11	8	18	5	3	9	9	6	6	5	6	105	Suboptimal
RSC01	---	3	6	8	5	17	6	5	9	7	2	4	2	5	79	Marginal
RSC02	---	3	7	8	3	18	11	7	5	4	7	7	5	8	93	Marginal
RSC03	---	12	7	10	11	18	13	7	7	7	4	7	4	7	114	Suboptimal
RST01	---	1	6	6	1	19	1	4	9	9	1	1	2	2	62	Marginal
RST02	---	8	6	6	8	19	1	5	9	9	2	2	3	3	81	Marginal
RST03	---	6	7	6	7	18	5	3	8	8	3	2	2	2	77	Marginal

Source:
USEPA (1999)

Notes:
* The habitat assessment process involves rating 10 parameters as optimal, suboptimal, marginal, or poor based on the criteria included in USEPA 1999 Habitat Assessment Field Data Sheets. Total Score Rankings: Poor: 0-50, Marginal: 60-100, Suboptimal: 110-150, Optimal: 160-200

BR	Buffalo River
CC	Cazenovia Creek
LB	Left bank
RB	Right bank
RSC	Reference Site Cattaraugas Creek
RST	Reference Site Tonawanda Creek

Table 4-6a
Summary of Benthic Metrics Calculated for Sediment Grab Samples
Buffalo River, NY

Location	River Mile	Species Richness	Abundance	EPT Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance-3	Non-chironomid / Oligochaetes Richness	Number of Deformities
BR01-PP1	7.25	17	137	0	9.15	43%	2.22	64%	77%	8	0/35
BR01-PP2	7.25	11	36	0	8.44	26%	2.72	36%	69%	5	0/16
BR01-PP3	7.25	14	150	0	9.2	45%	2.22	62%	74%	5	0/41
BR01-PP4	7.25	20	217	2	9.49	44%	2.29	61%	80%	10	0/58
BR01-PP5	7.25	9	89	0	9.65	35%	1.79	67%	83%	4	0/21
BR02-PP1	6.8	13	55	4	8.85	35%	2.42	56%	73%	7	2/15
BR02-PP2	6.8	5	14	0	8.86	10%	1.63	64%	86%	3	0/2
BR02-PP3	6.8	3	12	0	9.83	9%	1.04	75%	100%	1	0/3
BR02-PP4	6.8	3	8	0	9.25	6%	1.06	75%	100%	1	0/2
BR02-PP5	6.8	4	11	0	8.36	8%	1.68	45%	91%	3	0/1
BR03-PP1	6.25	9	45	0	9.62	29%	1.53	73%	87%	2	2/11
BR03-PP2	6.25	10	42	1	7.45	31%	2.21	45%	83%	5	0/7
BR03-PP3	6.25	12	205	0	9.85	35%	0.792	90%	94%	5	1/16
BR03-PP4	6.25	7	27	0	9.22	20%	1.72	67%	85%	4	0/5
BR03-PP5	6.25	13	100	1	9.64	34%	1.44	78%	88%	6	0/16
BR04-PP1	5.5	22	494	14	9.35	78%	2.67	46%	76%	16	2/53
BR04-PP2	5.5	10	125	1	9.89	27%	2.2	42%	86%	7	1/5
BR04-PP3	5.5	8	100	1	9.88	29%	1.39	76%	89%	5	0/10
BR04-PP4	5.5	4	127	0	10	22%	1.64	47%	98%	3	1/3
BR04-PP5	5.5	22	351	1	9.56	52%	1.93	68%	85%	11	0/37
BR05-PP1	4.75	5	153	0	9.99	24%	0.878	84%	97%	3	1/5
BR05-PP2	4.75	5	387	0	9.98	22%	0.566	91%	99%	3	0/3
BR05-PP3	4.75	6	184	0	9.95	26%	0.589	91%	98%	3	0/7
BR05-PP4	4.75	8	282	0	9.97	27%	0.807	85%	98%	4	0/8
BR05-PP5	4.75	5	146	0	9.9	24%	0.326	96%	99%	1	0/6
BR06-PP1	2.1	5	270	0	9.93	24%	1.55	56%	98%	5	0/0
BR06-PP2	2.1	7	162	0	9.85	27%	1.16	74%	96%	6	1/1
BR06-PP3	2.1	4	173	0	9.91	24%	1.1	65%	99%	3	1/1
BR06-PP4	2.1	2	122	0	9.93	21%	0.121	98%	100%	2	0/0
BR06-PP5	2.1	8	210	0	9.86	27%	1.68	57%	95%	5	0/4
BR07-PP1	1.0	8	108	1	9.78	25%	0.585	93%	95%	7	0/1
BR07-PP2	1.0	7	89	0	9.78	24%	0.906	84%	96%	6	0/1
BR07-PP3	1.0	7	230	0	9.85	27%	1.48	58%	96%	6	0/1
BR07-PP4	1.0	5	93	0	9.87	22%	1.45	65%	97%	5	0/0
BR07-PP5	1.0	6	85	0	9.76	25%	1.64	52%	92%	4	0/3
BR08-PP1	0.3	5	172	0	9.85	32%	0.748	88%	95%	2	1/16
BR08-PP2	0.3	9	360	0	9.91	38%	1.43	47%	97%	5	5/21
BR08-PP3	0.3	9	291	0	9.83	28%	1.99	53%	88%	6	1/9
BR08-PP4	0.3	9	239	0	9.88	31%	1.63	54%	94%	6	0/11
BR08-PP5	0.3	10	203	0	9.8	37%	1.67	53%	92%	7	3/16
CC01-PP1	---	8	156	0	9.75	29%	1.23	74%	95%	4	1/6
CC01-PP2	---	7	99	0	9.69	28%	0.759	89%	96%	4	1/5
CC01-PP3	---	2	21	0	9.62	15%	0.454	90%	100%	1	0/2
CC01-PP4	---	13	75	1	9.44	33%	1.9	69%	81%	4	1/16
CC01-PP5	---	6	117	2	9.86	27%	1.24	72%	96%	3	0/7

Table 4-6a
Summary of Benthic Metrics Calculated for Sediment Grab Samples
Buffalo River, NY

Location	River Mile	Species Richness	Abundance	EPT Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance-3	Non-chironomid / Oligochaetes Richness	Number of Deformities
RSC01-PP1	---	10	86	3	9.55	40%	1.89	58%	90%	6	2/23
RSC01-PP2	---	5	21	0	9.62	15%	1.93	38%	90%	4	0/8
RSC01-PP3	---	4	41	0	9.9	22%	0.814	85%	98%	3	0/2
RSC01-PP4	---	2	16	0	10	12%	0.954	63%	100%	1	0/6
RSC01-PP5	---	9	126	0	9.82	41%	1.4	66%	94%	4	10/40
RSC02-PP1	---	5	45	0	9.09	33%	1.67	53%	96%	2	0/20
RSC02-PP2	---	14	46	0	6.91	27%	3.29	24%	52%	4	0/37
RSC02-PP3	---	12	252	0	7.31	43%	1.66	62%	93%	5	0/180
RSC02-PP4	---	7	98	0	7.39	40%	1.69	58%	92%	2	1/70
RSC02-PP5	---	6	22	0	8.91	16%	2.06	50%	82%	2	1/10
RSC03-PP1	---	3	12	0	9.08	9%	1.04	75%	100%	1	0/3
RSC03-PP2	---	3	6	0	8.67	4%	1.25	67%	100%	1	0/2
RSC03-PP3	---	5	33	0	9.45	24%	1.14	79%	94%	2	0/6
RSC03-PP4	---	5	12	0	7.5	9%	2.05	42%	83%	1	0/7
RSC03-PP5	---	2	8	0	9	6%	0.811	75%	100%	1	0/2
RST01-PP1	---	6	15	0	9.33	11%	2.04	53%	80%	2	1/6
RST01-PP2	---	7	14	0	9.79	10%	2.5	36%	71%	4	0/5
RST01-PP3	---	5	13	0	9.23	9%	2.2	31%	77%	3	0/5
RST01-PP4	---	2	6	0	10	4%	0.65	83%	100%	2	0/0
RST01-PP5	---	6	13	0	9.46	9%	2.19	38%	77%	3	0/3
RST02-PP1	---	3	3	0	10	2%	1.58	33%	100%	3	0/0
RST02-PP2	---	4	29	0	10	21%	1.7	52%	93%	3	0/2
RST02-PP3	---	7	31	0	9.42	23%	2.17	45%	84%	4	0/4
RST02-PP4	---	3	7	0	8.71	5%	1.15	71%	100%	2	0/1
RST02-PP5	---	2	7	0	10	5%	0.863	71%	100%	1	0/2
RST03-PP1	---	6	34	0	9.82	24%	2.13	41%	82%	4	0/5
RST03-PP2	---	3	10	0	9.6	7%	1.3	60%	100%	2	0/3
RST03-PP3	---	4	69	0	10	37%	1.73	33%	97%	3	2/23
RST03-PP4	---	11	74	0	9.35	38%	2.25	51%	82%	7	0/19
RST03-PP5	---	9	56	0	9.2	35%	1.91	63%	84%	4	2/17

Table 4-6a
Summary of Benthic Metrics Calculated for Sediment Grab Samples
Buffalo River, NY

Location	River Mile	Species Richness	Abundance	EPT Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance-3	Non-chironomid / Oligochaetes Richness	Number of Deformities
BR01 Mean	7.25	14.2	126	0.4	9.19	39%	2.25	58%	77%	6.4	0/171
BR02 Mean	6.8	5.6	20	0.8	9.03	14%	1.57	63%	90%	3	2/23
BR03 Mean	6.25	10.2	83.8	0.4	9.16	30%	1.54	71%	87%	4.4	3/55
BR04 Mean	5.5	13.2	239	3.4	9.74	42%	1.97	56%	87%	8.4	4/108
BR05 Mean	4.75	5.8	230	0	9.96	25%	0.633	89%	98%	2.8	1/29
BR06 Mean	2.1	5.2	187	0	9.9	25%	1.12	70%	98%	4.2	2/6
BR07 Mean	1.0	6.6	121	0.2	9.81	25%	1.21	70%	95%	5.6	0/6
BR08 Mean	0.3	8.4	253	0	9.85	33%	1.49	59%	93%	5.2	10/73
CC01 Mean	---	7.2	93.6	0.6	9.67	26%	1.12	79%	94%	3.2	3/36
RSC01 Mean	---	5.2	12.2	0	9.56	9%	1.92	48%	81%	2.8	12/79
RSC02 Mean	---	8.8	92.6	0	7.92	32%	2.07	49%	83%	3	2/317
RSC03 Mean	---	3.6	14.2	0	8.74	10%	1.26	68%	95%	1.2	0/20
RST01 Mean	---	5.2	12.2	0	9.56	9%	1.92	48%	81%	2.8	1/19
RST02 Mean	---	3.8	15.4	0	9.63	11%	1.49	54%	95%	2.6	0/9
RST03 Mean	---	6.6	48.6	0	9.59	28%	1.86	50%	89%	4	4/67

Notes:

BR Buffalo River
CC Cazenovia Creek
EPT Ephemeroptera, Plecoptera, and Trichoptera
PP Petite Ponar
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawanda Creek

Table 4-6b
Summary of Mean Metrics Calculated for Sediment Grab Samples
Buffalo River, NY

	All Buffalo River Stations	Buffalo River Upstream Stations	Buffalo River Downstream Stations	Cazenovia Creek	Cattaraugus Creek Reference Site	Tonawanda Creek Reference Site
Number of Stations	8	3	5	1	3	3
Species Richness	8.65	10	7.84	7.2	6.13	5.2
Abundance	158	76.5	206	93.6	54.9	25.4
EPT Richness	0.65	0.533	0.72*	0.6	0.2	0
Hilsenhoff Biotic Index	9.58	9.12	9.85	9.67	8.81	9.59
Percent Model Affinity	29%	27%	30%	26%	23%	16%
Species Diversity (base 2)	1.47	1.78	1.29	1.12	1.58	1.76
Dominance	67%	64%	69%	79%	60%	51%
Dominance-3	91%	85%	94%	94%	91%	89%
Non-Chironomid / Oligochaete Richness	5	4.6	5.24	3.2	2.6	3.13
Number of Deformities	22/471	5/249	17/222	3/36	14/416	5/95
	4.7%	2.0%	7.7%	8.3%	3.4%	5.3%

Notes:

*This EPT score includes the BR4-PP1 replicate which contained a large number of mayflies in comparison to the other replicates at that location.

EPT	Ephemeroptera, Plecoptera, and Trichoptera
Dominance-3	Dominance of the three most numerous organisms

Table 4-7a
NYSDEC Index for Sediment Grab Samples
Buffalo River, NY

		Water Quality Scale (0-10) - Actual Metrics Presented Previously								
Location	River Mile	Species Richness	Species Diversity (base 2)	Hilsenhoff Biotic Index	Dominance-3	Percent Model Affinity	Average Value	Water Quality Impact	Average Value	Water Quality Impact
BR01-PP1	7.25	6.4	3.6	2.0	4.7	2.6	3.8	moderate		
BR01-PP2	7.25	3.1	6.1	3.8	6.0	0.0	3.8	moderate		
BR01-PP3	7.25	4.7	3.6	2.0	5.2	3.0	3.7	moderate	3.4	moderate
BR01-PP4	7.25	7.9	4.0	1.4	4.2	2.7	4.0	moderate		
BR01-PP5	7.25	1.8	1.5	1.1	3.7	1.1	1.8	severe		
BR02-PP1	6.8	4.2	4.6	3.1	5.3	1.1	3.7	moderate		
BR02-PP2	6.8	0.0	0.6	2.9	3.2	0.0	1.3	severe		
BR02-PP3	6.8	0.0	0.0	0.4	0.0	0.0	0.1	severe	1.4	severe
BR02-PP4	6.8	0.0	0.0	1.9	0.0	0.0	0.4	severe		
BR02-PP5	6.8	0.0	0.9	4.3	2.3	0.0	1.5	severe		
BR03-PP1	6.25	1.8	0.2	1.0	3.0	0.0	1.2	severe		
BR03-PP2	6.25	2.3	3.6	6.4	3.7	0.1	3.2	moderate		
BR03-PP3	6.25	3.6	0.0	0.4	1.5	0.9	1.3	severe	1.8	severe
BR03-PP4	6.25	0.9	1.1	2.0	3.3	0.0	1.5	severe		
BR03-PP5	6.25	4.2	0.0	1.0	2.8	0.8	1.7	severe		
BR04-PP1	5.5	8.7	5.9	1.7	4.8	9.5	6.1	slight		
BR04-PP2	5.5	2.3	3.5	0.4	3.2	0.0	1.9	severe		
BR04-PP3	5.5	1.4	0.0	0.3	2.7	0.0	0.9	severe	2.6	moderate
BR04-PP4	5.5	0.0	0.7	0.0	0.5	0.0	0.2	severe		
BR04-PP5	5.5	8.7	2.2	1.3	3.3	4.5	4.0	moderate		
BR05-PP1	4.75	0.0	0.0	0.0	0.8	0.0	0.2	severe		
BR05-PP2	4.75	0.0	0.0	0.0	0.3	0.0	0.1	severe		
BR05-PP3	4.75	0.5	0.0	0.1	0.5	0.0	0.2	severe	0.2	severe
BR05-PP4	4.75	1.4	0.0	0.1	0.5	0.0	0.4	severe		
BR05-PP5	4.75	0.0	0.0	0.2	0.3	0.0	0.1	severe		
BR06-PP1	2.1	0.0	0.3	0.2	0.5	0.0	0.2	severe		
BR06-PP2	2.1	0.9	0.0	0.4	1.0	0.0	0.5	severe		
BR06-PP3	2.1	0.0	0.0	0.2	0.3	0.0	0.1	severe	0.3	severe
BR06-PP4	2.1	0.0	0.0	0.2	0.0	0.0	0.0	severe		
BR06-PP5	2.1	1.4	0.9	0.4	1.3	0.0	0.8	severe		
BR07-PP1	1.0	1.4	0.0	0.6	1.3	0.0	0.6	severe		
BR07-PP2	1.0	0.9	0.0	0.6	1.0	0.0	0.5	severe		
BR07-PP3	1.0	0.9	0.0	0.4	1.0	0.0	0.5	severe	0.5	severe
BR07-PP4	1.0	0.0	0.0	0.3	0.8	0.0	0.2	severe		
BR07-PP5	1.0	0.5	0.7	0.6	2.0	0.0	0.8	severe		
BR08-PP1	0.3	0.0	0.0	0.4	1.3	0.3	0.4	severe		
BR08-PP2	0.3	1.8	0.0	0.2	0.8	1.5	0.9	severe		
BR08-PP3	0.3	1.8	2.5	0.6	2.8	0.0	1.5	severe	1.0	severe
BR08-PP4	0.3	1.8	0.6	0.3	1.5	0.2	0.9	severe		
BR08-PP5	0.3	2.3	0.9	0.5	2.0	1.4	1.4	severe		

Table 4-7a
NYSDEC Index for Sediment Grab Samples
Buffalo River, NY

		Water Quality Scale (0-10) - Actual Metrics Presented Previously								
Location	River Mile	Species Richness	Species Diversity (base 2)	Hilsenhoff Biotic Index	Dominance-3	Percent Model Affinity	Average Value	Water Quality Impact	Average Value	Water Quality Impact
CC01-PP1	---	1.4	0.0	0.6	1.3	0.0	0.7	severe		
CC01-PP2	---	0.9	0.0	0.7	1.0	0.0	0.5	severe		
CC01-PP3	---	0.0	0.0	1.0	0.0	0.0	0.2	severe	0.8	severe
CC01-PP4	---	4.2	2.0	1.4	4.0	0.6	2.4	severe		
CC01-PP5	---	0.5	0.0	0.4	1.0	0.0	0.4	severe		
RSC01-PP1	---	2.3	2.0	2.2	2.5	1.9	2.2	severe		
RSC01-PP2	---	0.0	2.2	2.9	2.5	0.0	1.5	severe		
RSC01-PP3	---	0.0	0.0	1.0	0.5	0.0	0.3	severe	1.0	severe
RSC01-PP4	---	0.0	0.0	0.0	0.0	0.0	0.0	severe		
RSC01-PP5	---	1.8	0.0	0.4	1.5	2.3	1.2	severe		
RSC02-PP1	---	0.0	0.9	2.3	1.0	0.6	0.9	severe		
RSC02-PP2	---	4.7	8.2	7.3	8.8	0.0	5.8	slight		
RSC02-PP3	---	3.6	0.8	6.9	1.8	2.6	3.1	moderate	2.9	moderate
RSC02-PP4	---	0.9	1.0	6.5	2.0	2.1	2.5	severe		
RSC02-PP5	---	0.5	2.8	3.2	3.8	0.0	2.1	severe		
RSC03-PP1	---	0.0	0.0	2.7	0.0	0.0	0.5	severe		
RSC03-PP2	---	0.0	0.0	3.3	0.0	0.0	0.7	severe		
RSC03-PP3	---	0.0	0.0	1.8	1.5	0.0	0.7	severe	1.0	severe
RSC03-PP4	---	0.0	2.8	6.3	3.7	0.0	2.5	severe		
RSC03-PP5	---	0.0	0.0	2.5	0.0	0.0	0.5	severe		
RST01-PP1	---	0.5	2.7	1.3	4.2	0.0	1.7	severe		
RST01-PP2	---	0.9	5.0	0.5	5.7	0.0	2.4	severe		
RST01-PP3	---	0.0	3.5	1.2	4.7	0.0	1.9	severe	1.6	severe
RST01-PP4	---	0.0	0.0	0.0	0.0	0.0	0.0	severe		
RST01-PP5	---	0.5	3.5	1.4	4.7	0.0	2.0	severe		
RST02-PP1	---	0.0	0.4	0.0	0.0	0.0	0.1	severe		
RST02-PP2	---	0.0	1.0	0.0	1.8	0.0	0.6	severe		
RST02-PP3	---	0.9	3.4	1.1	3.5	0.0	1.8	severe	0.6	severe
RST02-PP4	---	0.0	0.0	2.5	0.0	0.0	0.5	severe		
RST02-PP5	---	0.0	0.0	0.0	0.0	0.0	0.0	severe		
RST03-PP1	---	0.5	3.2	0.4	3.8	0.0	1.6	severe		
RST03-PP2	---	0.0	0.0	1.0	0.0	0.0	0.2	severe		
RST03-PP3	---	0.0	1.2	0.0	0.8	1.4	0.7	severe	1.4	severe
RST03-PP4	---	3.1	3.8	1.4	3.8	1.6	2.7	moderate		
RST03-PP5	---	1.8	2.1	1.7	3.5	0.9	2.0	severe		

Notes:

BR Buffalo River
CC Cazenovia Creek
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawanda Creek

Water Quality Scale and Impact Values are from NYSDEC 2002. These values are calculated by taking the metrics and scaling them from 0-10, as detailed in Appendix V "Biological Assessment Profile Of Index Values For Ponar Samples From Soft Sediments."

Table 4-7b
USEPA Bioassessment Approach for Rapid Bioassessment Protocol III
Buffalo River, NY

	Biological Condition Scoring Criteria (a)			
Benthic Macroinvertebrate Metric (a)	6	4	2	0
A. Taxa Richness (b)	> 80 %	60-80 %	40-60 %	< 40 %
B. Biotic Index (modified) (c)	> 85 %	70-85 %	50-70 %	< 50 %
C. Ratio of Scrapers/Filterers Collectors (b,d)	> 50 %	35-50 %	20-35 %	< 20 %
D. Ratio of EPT and Chironomidae Abundances (b)	> 75 %	50-75 %	25-50 %	< 25 %
E. Percent Contribution of Dominant Taxon (e)	< 20 %	20-30 %	30-40 %	> 40 %
F. EPT Index (b)	> 90 %	80-90 %	70-80 %	< 70 %
G. Community Loss Index (f)	< 0.5	0.5-1.5	1.5-4.0	> 4.0
H. Ratio of Shredders/Total (b,d)	> 50 %	35-50 %	20-35 %	< 20 %

Notes:
(a) USEPA Rapid Bioassessment Protocols III (USEPA 1989)
(b) Score is a ratio of study site to reference site x 100.
(c) Score is a ratio of reference site to study site x 100.
(d) Determination of Functional Feeding Group is independent of taxonomic grouping.
(e) Scoring criteria evaluate actual percent contribution, not percent comparability to the reference station.
(f) Range of values obtained. A comparison to the reference station is incorporated in this index.

Comparison to Reference Score (g)	Biological Condition Category (g)	Support Status (g)
> 83 %	Nonimpaired	Comparable to a reference station (upstream location).
54-79 %	Slightly impaired	Community structure less than expected compared to the reference station. Composition (species richness) lower than expected due to loss of some intolerant forms. Percent contribution of tolerant forms increases.
21-50 %	Moderately	Fewer species due to loss of most intolerant forms. Reduction in EPT Index.
< 17 %	Severely impaired	Few species present. If high densities of organisms, then dominated by one or two taxa.

Notes:
(g) Percentage values obtained that are intermediate to the above ranges will require subjective judgement as to the correct placement. Use of the habitat assessment and physiochemical data may be necessary to aid in the decision process (USEPA 1989)
EPT Ephemeroptera, Plecoptera, Trichoptera

Table 4-7c
USEPA Index for Sediment Grab Samples
Buffalo River, NY

						Biological Condition Score as a % of Tonawanda Creek (Reference)									Scaled Metric												
Location	River Mile	Ratio of Scrapers/ Filterers Collectors (a)	Ratio of EPT and Chironomidae Abundances (a)	Community Loss Index (a)	Ratio of Shredders/ Total (a)	Taxa Richness (b)	Biotic Index (b)	Ratio of Scrapers/Fi lterers Collectors (b)	Ratio of EPT and Chironomidae Abundances (c)	Percent Contribution of Dominant Taxon (b)	EPT Index (c)	Community Loss Index (b)	Ratio of Shredders/ Total (b)	Average of Comparison to Reference (d)	Taxa Richness (e)	Biotic Index (e)	Ratio of Scrapers/ Filterers Collectors (e)	Ratio of EPT and Chironomidae Abundances (e)	Percent Contribution of Dominant Taxon (e)	EPT Index (e)	Community Loss Index (e)	Ratio of Shredders/ Total (e)	Total (f)	% of Reference (f)	Biological Condition Category (f)	% of Reference (g)	Biological Condition Category (g)
BR01-PP1	7.25	0	0	0.71	0.02	327%	105%	0%	0%	64%	0%	0.71	1613%	301%	6	6	0	0	0	0	4	6	22	73%	Slight		
BR01-PP2	7.25	0	0	1.36	0.03	212%	114%	0%	0%	36%	0%	1.36	3011%	482%	6	6	0	0	2	0	4	6	24	80%	Non to slight		
BR01-PP3	7.25	0	0	1.00	0.04	269%	105%	0%	0%	62%	0%	1.00	4301%	677%	6	6	0	0	0	0	4	6	22	73%	Slight	69%	Slight
BR01-PP4	7.25	0	0.03	0.50	0.01	385%	103%	0%	0%	61%	0%	0.50	1505%	293%	6	6	0	0	0	0	4	6	22	73%	Slight		
BR01-PP5	7.25	0	0	2.00	0	173%	101%	0%	0%	67%	0%	2.00	0%	49%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR02-PP1	6.8	0.33	0.27	1.23	0	250%	111%	493%	0%	56%	0%	1.23	0%	130%	6	6	6	0	0	0	4	0	22	73%	Slight		
BR02-PP2	6.8	1.00	0	3.40	0	96%	109%	1493%	0%	64%	0%	3.40	0%	252%	6	6	6	0	0	0	2	0	20	67%	Slight		
BR02-PP3	6.8	0	0	6.67	0	58%	99%	0%	0%	75%	0%	6.67	0%	33%	2	6	0	0	0	0	0	0	8	27%	Moderate	45%	Moderate
BR02-PP4	6.8	0	0	7.00	0	58%	105%	0%	0%	75%	0%	7.00	0%	34%	2	6	0	0	0	0	0	0	8	27%	Moderate		
BR02-PP5	6.8	0	0	4.75	0	77%	117%	0%	0%	45%	0%	4.75	0%	34%	4	6	0	0	0	0	0	0	10	33%	Moderate		
BR03-PP1	6.25	0	0	2.00	0.04	173%	101%	0%	0%	73%	0%	2.00	4731%	725%	6	6	0	0	0	0	2	6	20	67%	Slight		
BR03-PP2	6.25	6.30	0.14	1.90	0.02	192%	131%	9403%	0%	45%	0%	1.90	2581%	1764%	6	6	6	0	0	0	2	6	26	87%	Non		
BR03-PP3	6.25	0	0	1.42	0.01	231%	99%	0%	0%	90%	0%	1.42	1054%	210%	6	6	0	0	0	0	4	6	22	73%	Slight	69%	Slight
BR03-PP4	6.25	0	0	2.71	0	135%	105%	0%	0%	67%	0%	2.71	0%	44%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR03-PP5	6.25	0	0.06	1.31	0.03	250%	101%	0%	0%	78%	0%	1.31	3226%	522%	6	6	0	0	0	0	4	6	22	73%	Slight		
BR04-PP1	5.5	0.14	0.26	0.64	0	423%	104%	209%	0%	46%	0%	0.64	0%	112%	6	6	6	0	0	0	4	0	22	73%	Slight		
BR04-PP2	5.5	0	0.20	1.60	0	192%	98%	0%	0%	42%	0%	1.60	0%	48%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR04-PP3	5.5	0	0.10	2.13	0	154%	98%	0%	0%	76%	0%	2.13	0%	47%	6	6	0	0	0	0	2	0	14	47%	Moderate	59%	Slight
BR04-PP4	5.5	0	0	4.75	0	77%	97%	0%	0%	47%	0%	4.75	0%	32%	4	6	0	0	0	0	0	0	10	33%	Moderate		
BR04-PP5	5.5	0.33	0.03	0.68	0.01	423%	102%	493%	0%	68%	0%	0.68	1505%	370%	6	6	6	0	0	0	4	6	28	93%	Non		
BR05-PP1	4.75	0	0	3.60	0	96%	97%	0%	0%	84%	0%	3.60	0%	40%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR05-PP2	4.75	0	0	3.60	0	96%	97%	0%	0%	91%	0%	3.60	0%	41%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR05-PP3	4.75	0	0	2.83	0	115%	97%	0%	0%	91%	0%	2.83	0%	43%	6	6	0	0	0	0	2	0	14	47%	Moderate	47%	Moderate
BR05-PP4	4.75	0	0	2.13	0	154%	97%	0%	0%	85%	0%	2.13	0%	48%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR05-PP5	4.75	0	0	3.60	0	96%	98%	0%	0%	96%	0%	3.60	0%	41%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR06-PP1	2.1	0	0	3.60	0	96%	98%	0%	0%	56%	0%	3.60	0%	36%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR06-PP2	2.1	0	0	2.43	0	135%	98%	0%	0%	74%	0%	2.43	0%	44%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR06-PP3	2.1	0	0	4.75	0	77%	98%	0%	0%	65%	0%	4.75	0%	34%	4	6	0	0	0	0	0	0	10	33%	Moderate	39%	Moderate
BR06-PP4	2.1	0	0	10.00	0	38%	98%	0%	0%	98%	0%	10.00	0%	33%	0	6	0	0	0	0	0	0	6	20%	derate to Sev		
BR06-PP5	2.1	0	0	1.88	0	154%	98%	0%	0%	57%	0%	1.88	0%	44%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR07-PP1	1.0	0.50	1.00	2.25	0	154%	99%	746%	0%	93%	0%	2.25	0%	156%	6	6	6	0	0	0	2	0	20	67%	Slight		
BR07-PP2	1.0	0.50	0	2.57	0	135%	99%	746%	0%	84%	0%	2.57	0%	152%	6	6	6	0	0	0	2	0	20	67%	Slight		
BR07-PP3	1.0	0	0	2.14	0	135%	98%	0%	0%	58%	0%	2.14	0%	42%	6	6	0	0	0	0	2	0	14	47%	Moderate	55%	Slight
BR07-PP4	1.0	0	0	3.60	0	96%	98%	0%	0%	65%	0%	3.60	0%	37%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR07-PP5	1.0	0	0	2.67	0	115%	99%	0%	0%	52%	0%	2.67	0%	38%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR08-PP1	0.3	0	0	3.60	0	96%	99%	0%	0%	88%	0%	3.60	0%	40%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR08-PP2	0.3	0	0	1.67	0	173%	98%	0%	0%	47%	0%	1.67	0%	45%	6	6	0	0	0	0	2	0	14	47%	Moderate		
BR08-PP3	0.3	0	0	1.56	0	173%	99%	0%	0%	53%	0%	1.56	0%	46%	6	6	0	0	0	0	2	0	14	47%	Moderate	55%	Slight
BR08-PP4	0.3	0.50	0	1.67	0	173%	98%	746%	0%	54%	0%	1.67	0%	153%	6	6	6	0	0	0	2	0	20	67%	Slight		
BR08-PP5	0.3	0.20	0	1.50	0	192%	99%	299%	0%	53%	0%	1.50	0%	92%	6	6	6	0	0	0	2	0	20	67%	Slight		
CC01-PP1	---	0	0	2.25	0	154%	100%	0%	0%	74%	0%	2.25	0%	47%	6	6	0	0	0	0	2	0	14	47%	Moderate		
CC01-PP2	---	0	0	2.57	0	135%	100%	0%	0%	89%	0%	2.57	0%	46%	6	6	0	0	0	0	2	0	14	47%	Moderate		
CC01-PP3	---	0	0	10.50	0	38%	101%	0%	0%	90%	0%	10.50	0%	33%	0	6	0	0	0	0	0	0	6	20%	derate to Sev	43%	Moderate
CC01-PP4	---	0	0.06	1.23	0	250%	103%	0%	0%	69%	0%	1.23	0%	60%	6	6	0	0	0	0	4	0	16	53%	ight to modera		
CC01-PP5	---	0	0.29	2.83	0	115%	98%	0%	0%	72%	0%	2.83	0%	41%	6	6	0	0	0	0	2	0	14	47%	Moderate		

Table 4-7c
USEPA Index for Sediment Grab Samples
Buffalo River, NY

Location	River Mile	Ratio of Scrapers/ Filterers Collectors (a)	Ratio of EPT and Chironomidae Abundances (a)	Community Loss Index (a)	Ratio of Shredders/ Total (a)	Biological Condition Score as a % of Tonawanda Creek (Reference): Taxa Richness (b)	Biotic Index (b)	Ratio of Scrapers/Filterers Collectors (b)	Ratio of EPT and Chironomidae Abundances (c)	Percent Contribution of Dominant Taxon (b)	EPT Index (c)	Community Loss Index (b)	Ratio of Shredders/ Total (b)	Average of Comparison to Reference (d)	Scaled Metric: Taxa Richness (e)	Biotic Index (e)	Ratio of Scrapers/ Filterers Collectors (e)	Ratio of EPT and Chironomidae Abundances (e)	Percent Contribution of Dominant Taxon (e)	EPT Index (e)	Community Loss Index (e)	Ratio of Shredders/ Total (e)	Total (f)	% of Reference (f)	Biological Condition Category (f)	% of Reference (g)	Biological Condition Category (g)
RSC01-PP1	---	0	0.13	1.70	0.01	192%	106%	0%	0%	58%	0%	1.70	1290%	235%	6	6	0	0	0	0	2	6	20	67%	Slight		
RSC01-PP2	---	0	0	3.80	0	96%	109%	0%	0%	38%	0%	3.80	0%	35%	6	6	0	0	2	0	2	0	16	53%	ight to modera		
RSC01-PP3	---	0	0	4.75	0	77%	101%	0%	0%	85%	0%	4.75	0%	38%	4	6	0	0	0	0	0	0	10	33%	Moderate	48%	Moderate
RSC01-PP4	---	0	0	10.00	0	38%	97%	0%	0%	63%	0%	10.00	0%	28%	0	6	0	0	0	0	0	0	6	20%	derate to Sev		
RSC01-PP5	---	0	0	1.56	0.01	173%	99%	0%	0%	66%	0%	1.56	849%	170%	6	6	0	0	0	0	2	6	20	67%	Slight		
RSC02-PP1	---	0	0	3.40	0.22	96%	107%	0%	0%	53%	0%	3.40	23656%	3416%	6	6	0	0	0	0	2	6	20	67%	Slight		
RSC02-PP2	---	0	0	1.07	0.35	269%	137%	0%	0%	24%	0%	1.07	37634%	5438%	6	6	0	0	4	0	4	6	26	87%	Non		
RSC02-PP3	---	0	0	1.25	0.62	231%	134%	0%	0%	62%	0%	1.25	66667%	9585%	6	6	0	0	0	0	4	6	22	73%	Slight	72%	Slight
RSC02-PP4	---	0	0	2.43	0.58	135%	131%	0%	0%	58%	0%	2.43	62366%	8956%	6	6	0	0	0	0	2	6	20	67%	Slight		
RSC02-PP5	---	0	0	3.00	0.23	115%	111%	0%	0%	50%	0%	3.00	24731%	3573%	6	6	0	0	0	0	2	6	20	67%	Slight		
RSC03-PP1	---	0	0	7.00	0	58%	109%	0%	0%	75%	0%	7.00	0%	34%	2	6	0	0	0	0	0	0	8	27%	Moderate		
RSC03-PP2	---	0	0	7.00	0.17	58%	112%	0%	0%	67%	0%	7.00	18280%	2645%	2	6	0	0	0	0	0	6	14	47%	Moderate		
RSC03-PP3	---	0	0	4.00	0	96%	105%	0%	0%	79%	0%	4.00	0%	40%	6	6	0	0	0	0	0	0	12	40%	Moderate	43%	Moderate
RSC03-PP4	---	0	0	4.00	0.08	96%	129%	0%	0%	42%	0%	4.00	8925%	1313%	6	6	0	0	0	0	0	6	18	60%	Slight		
RSC03-PP5	---	0	0	10.00	0.25	38%	108%	0%	0%	75%	0%	10.00	26882%	3872%	0	6	0	0	0	0	0	6	12	40%	Moderate		
RST Mean	---	0.07	0.00	0.00	0.001	100%	100%	100%	0%	51%	0%	0.00	100%		6	6	6	0	0	0	6	6	30			Reference	

Notes:

BR Buffalo River
CC Cazenovia Creek
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawanda Creek

(a) These values are calculated using USEPA 1989 and USEPA 1999 for feeding strategy designations and methods. Species Richness, Hilsenhoff Biotic Index, and Dominance have been presented on previous tables.
(b) These values are calculated as a percentage using the average value from Tonowanda Creek as the reference station (station value/mean Tonowanda creek value). A value >100% indicates that it is higher than the reference.
(c) Tonowanda Creek scored a 0 on these metrics, so they are not used here (station value/0 = error).
(d) This value is the average of ratio of the station to the reference but does not include Ratio of EPT and Chironomidae Abundances, EPT Index, or Ratio of Shredders/ Total because these values are essentially unused in this calculation because these metrics
(e) These values have been scaled from 0 to 6 compared to Tonawanda Creek using Figure 6.3-4 in USEPA 1989. Ratio of EPT and Chironomidae Abundances, EPT Index, or Ratio of Shredders/ Total are all considered to be zero, as they are also zero in the referenc
(f) The scaled metrics are summed and then compared to the sum at the reference station and then classified according to USEPA 1989 (non>slight>moderate>severe).
(g) These are the values averaged for each station.

Table 4-8
Hester-Dendy Samplers Deployed and Retrieved
Buffalo River, NY

	River	Number of Hester Dendy Samplers		
Location	Mile	Deployed	Retrieved	Sent to Lab
BR01	7.25	8	6	5
BR02	6.8	8	6	5
BR03	6.25	8	5	5
BR04	5.5	8	4	4
BR05	4.75	8	6	5
BR06	2.1	8	8	5
BR07	1.0	8	8	5
BR08	0.3	8	5	5
CC01	---	8	7	5
RSC01	---	7	4	4
RSC02	---	7	4	4
RST01	---	7	7	5
RST02	---	7	7	5
RST03	---	7	4	4

Notes:

BR Buffalo River
CC Cazenovia Creek
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawnda Creek

Table 4-9
Summary of Benthic Metrics Calculated for Hester-Dendy Samplers
Buffalo River, NY

Sample ID	River Mile	Number of Famillies	Number of Species	Number of Organisms	EPT Species Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance of top 3 organisms	Non-Chironomid / Oligochaetes Richness	Number of Chironomid Deformities
INV-BR-01-B	7.25	8	21	160	3	8.07	49%	3.47	21%	51%	7	0/92
INV-BR-01-C	7.25	5	22	284	2	7.74	42%	3.65	21%	48%	3	4/212
INV-BR-01-D	7.25	3	7	14	0	8.29	47%	2.66	29%	57%	1	0/3
INV-BR-01-E	7.25	3	14	42	0	8.71	42%	2.98	33%	69%	1	0/19
INV-BR-01-F	7.25	3	11	331	1	9.5	40%	2.13	60%	76%	1	0/106
INV-BR-02-A	6.8	6	13	436	0	7.61	42%	2.61	45%	69%	4	11/212
INV-BR-02-B	6.8	7	19	475	1	7.86	42%	2.53	43%	74%	5	16/243
INV-BR-02-C	6.8	6	9	387	1	8.19	42%	2.15	38%	83%	4	6/268
INV-BR-02-E	6.8	6	17	424	1	8.18	42%	2.79	42%	71%	4	0/272
INV-BR-02-F	6.8	8	20	210	0	8.02	40%	2.28	57%	81%	7	0/17
INV-BR-03-A	6.25	8	23	329	2	8.26	42%	3.93	13%	38%	6	0/236
INV-BR-03-B	6.25	4	18	484	0	7.74	35%	3.28	35%	57%	2	0/412
INV-BR-03-C	6.25	4	19	294	0	8.05	45%	3.46	27%	55%	2	4/204
INV-BR-03-D	6.25	6	22	605	1	7.71	41%	3.57	17%	46%	4	0/424
INV-BR-03-E	6.25	4	15	600	2	8.37	41%	2.6	29%	78%	3	0/424
INV-BR-04-E	5.5	10	16	212	2	8.02	31%	2.49	51%	72%	9	0/188
INV-BR-04-F	5.5	3	14	396	0	8.04	30%	3.11	34%	56%	1	0/356
INV-BR-04-G	5.5	7	24	499	3	7.89	37%	3.34	26%	60%	5	13/416
INV-BR-04-H	5.5	7	23	304	3	8.28	42%	3.25	30%	63%	5	0/236
INV-BR-05-A	4.75	6	15	274	2	8.06	26%	2.83	28%	70%	4	0/257
INV-BR-05-B	4.75	4	15	95	1	8.55	37%	3.07	32%	63%	2	0/79
INV-BR-05-D	4.75	5	15	621	0	8.25	34%	2.62	37%	76%	4	0/536
INV-BR-05-E	4.75	5	11	280	1	8.29	36%	2.11	54%	80%	3	0/236
INV-BR-05-F	4.75	4	13	534	1	7.9	45%	3.04	28%	59%	2	0/360
INV-BR-06-A	2.1	9	23	273	2	7.96	67%	3.71	20%	48%	7	0/136
INV-BR-06-B	2.1	8	12	79	2	7.58	63%	2.93	28%	65%	6	0/32
INV-BR-06-C	2.1	8	16	97	1	8.8	64%	3.03	36%	63%	6	0/34
INV-BR-06-F	2.1	9	18	157	2	7.89	60%	3.4	20%	48%	7	0/84
INV-BR-06-H	2.1	10	23	358	2	8.11	48%	3.01	41%	69%	8	0/137
INV-BR-07-A	1.0	11	28	421	3	7.97	56%	3.66	25%	51%	9	0/129
INV-BR-07-C	1.0	6	17	612	1	7.59	40%	1.9	65%	87%	5	0/105
INV-BR-07-D	1.0	8	15	158	2	7.27	60%	2.74	39%	75%	6	0/29
INV-BR-07-F	1.0	8	27	451	2	7.78	61%	3.57	25%	54%	6	0/133
INV-BR-07-H	1.0	7	23	238	1	8.01	46%	2.83	49%	71%	5	0/59
INV-BR-08-A	0.3	8	18	402	1	7.81	57%	2.79	45%	71%	8	0/72
INV-BR-08-B	0.3	6	22	198	2	7.35	50%	3.54	27%	53%	4	0/92
INV-BR-08-C	0.3	6	18	91	1	6.84	47%	3.66	18%	44%	5	0/66
INV-BR-08-F	0.3	5	21	219	1	7.79	50%	2.49	60%	73%	3	0/65
INV-BR-08-H	0.3	6	22	300	2	7.53	61%	3.55	30%	56%	4	0/123
INV-CC-01-A	---	8	25	248	3	6.79	38%	3.51	37%	54%	6	0/203
INV-CC-01-B	---	5	18	281	0	7.44	45%	2.83	25%	70%	3	20/198
INV-CC-01-E	---	6	21	217	2	6.95	42%	3.33	22%	59%	4	0/170
INV-CC-01-F	---	8	23	118	0	7.54	60%	3.88	15%	43%	6	0/67
INV-CC-01-G	---	7	20	136	2	6.93	50%	3.53	23%	54%	5	0/90

Table 4-9
Summary of Benthic Metrics Calculated for Hester-Dendy Samplers
Buffalo River, NY

Sample ID	River Mile	Number of Famillies	Number of Species	Number of Organisms	EPT Species Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance of top 3 organisms	Non-Chironomid / Oligochaetes Richness	Number of Chironomid Deformities
INV-RSC-01-B	---	12	22	336	7	6.84	59%	2.53	37%	79%	10	0/75
INV-RSC-01-E	---	6	13	379	1	6.28	44%	2.21	46%	84%	4	0/168
INV-RSC-01-F	---	5	12	626	0	6.13	29%	0.914	86%	96%	3	1/42
INV-RSC-01-G	---	8	21	506	4	6.11	41%	3.22	41%	57%	6	12/268
INV-RSC-02-D	---	9	21	377	2	7.19	43%	3.6	21%	46%	7	0/280
INV-RSC-02-E	---	8	21	611	4	6.13	24%	3.05	38%	60%	6	0/584
INV-RSC-02-F	---	11	24	455	7	6.46	30%	3.69	22%	46%	10	0/408
INV-RSC-02-G	---	9	19	668	6	6.65	36%	2.57	51%	72%	10	0/563
INV-RST-01-B	---	12	23	313	1	6.7	48%	3.46	27%	52%	10	0/216
INV-RST-01-C	---	8	21	115	2	7.52	48%	3.05	47%	65%	6	0/38
INV-RST-01-D	---	7	25	161	2	7.43	46%	4.01	25%	39%	5	0/86
INV-RST-01-E	---	8	19	161	2	6.84	58%	3.62	16%	45%	6	0/87
INV-RST-01-F	---	13	35	404	1	6.43	55%	3.78	23%	55%	11	0/160
INV-RST-02-A	---	8	21	249	2	7.4	46%	3.66	26%	45%	6	0/136
INV-RST-02-B	---	9	19	143	3	7.31	48%	3.45	21%	54%	7	0/91
INV-RST-02-D	---	7	20	386	1	7.16	42%	3.66	20%	44%	5	0/292
INV-RST-02-F	---	8	18	254	0	7.8	30%	2.73	50%	66%	6	20/228
INV-RST-02-G	---	7	18	294	0	7.49	33%	3.29	33%	56%	5	0/256
INV-RST-03-A	---	8	13	51	0	6.59	54%	2.77	41%	71%	7	0/10
INV-RST-03-D	---	6	18	108	0	7.24	46%	3.68	17%	44%	4	0/80
INV-RST-03-E	---	6	20	256	0	6.68	39%	3.53	22%	47%	4	0/208
INV-RST-03-G	---	7	18	237	1	7.7	42%	2.9	39%	69%	5	0/184

Table 4-9
Summary of Benthic Metrics Calculated for Hester-Dendy Samplers
Buffalo River, NY

Sample ID	River Mile	Number of Famillies	Number of Species	Number of Organisms	EPT Species Richness	Hilsenhoff Biotic Index	Percent Model Affinity	Species Diversity (Base 2)	Dominance	Dominance of top 3 organisms	Non-Chironomid / Oligochaetes Richness	Number of Chironomid Deformities
BR Mean	---	6.3	18	320	1.3	8	46%	3	35%	64%	4.6	54/7104
BR US Mean	---	5.4	17	340	0.93	8.2	42%	2.9	34%	64%	3.6	41/3144
BR DS Mean	---	7.4	20	320	2.1	7.4	47%	3.1	34%	62%	5.7	13/3960
CC01 Mean	---	6.8	21	200	1.4	7.1	47%	3.4	24%	56%	4.8	20/728
RSC Mean	---	8.5	19	490	3.9	6.5	38%	2.7	43%	68%	7	13/2388
RST Mean	---	8.1	21	220	1.1	7.2	45%	3.4	29%	54%	6.2	20/2072
BR01 Avg	7.25	4.4	15	170	1.2	8.5	44%	3	33%	60%	2.6	4/432
BR02 Avg	6.8	6.6	16	390	0.6	8	41%	2.5	45%	76%	4.8	33/1012
BR03 Avg	6.25	5.2	19	460	1	8	41%	3.4	24%	55%	3.4	4/1700
BR04 Avg	5.5	6.8	19	350	2	8.1	35%	3	35%	63%	5	13/1196
BR05 Avg	4.75	4.8	14	360	1	8.2	35%	2.7	36%	70%	3	0/1468
BR06 Avg	2.1	8.8	18	190	1.8	8.1	60%	3.2	29%	59%	6.8	0/423
BR07 Avg	1.0	8	22	380	1.8	7.7	53%	2.9	41%	68%	6.2	0/455
BR08 Avg	0.3	6.2	20	240	1.4	7.5	53%	3.2	36%	59%	4.8	0/418
CC01 Avg	---	6.8	21	200	1.4	7.1	47%	3.4	24%	56%	4.8	20/728
RSC01 Avg	---	7.8	17	460	3	6.3	43%	2.2	53%	79%	5.8	13/553
RSC02 Avg	---	9.3	21	530	4.8	6.6	33%	3.2	33%	56%	8.3	0/1835
RST01 Avg	---	9.6	25	230	1.6	7	51%	3.6	28%	51%	7.6	0/587
RST02 Avg	---	7.8	19	270	1.2	7.4	40%	3.4	30%	53%	5.8	20/1003
RST03 Avg	---	6.8	17	160	0.25	7.1	45%	3.2	30%	58%	5	0/482

Notes:

BR	Buffalo River
CC	Cazenovia Creek
EPT	Ephemeroptera, Plecoptera, and Trichoptera
RSC	Reference Site Cattaraugas Creek
RST	Reference Site Tonawanda Creek

Table 4-10
Summary of Mean Metrics Calculated for Hester-Dendy Samplers
Buffalo River, NY

	All Buffalo River Stations	Buffalo River Upstream Stations	Buffalo River Downstream Stations	Cazenovia Creek	Cattaraugus Creek Reference Site	Tonawanda Creek Reference Site
Mean Number of Famillies	6.3	5.4	7.4	6.8	8.5	8.1
Mean Number of Species	18	17	20	21	19	21
Mean Number of Organisms	320	340	320	200	490	220
Mean EPT Species Richness	1.3	0.93	2.1	1.4	3.9	1.1
Mean Hilsenhoff Biotic Index	8	8.2	7.4	7.1	6.5	7.2
Mean Percent Model Affinity	46%	42%	47%	47%	38%	45%
Mean Species Diversity (Base 2)	3	2.9	3.1	3.4	2.7	3.4
Mean Dominance	35%	34%	34%	24%	43%	29%
Mean Dominance of top 3 organisms	64%	64%	62%	56%	68%	54%
Mean Non-Chironomid / Oligochaetes Richness	4.6	3.6	5.7	4.8	7	6.2
Total Number of Chironomid Deformities	54/7104	41/3144	13/3960	20/728	13/2388	20/2072
Percentage of deformed chironomids	0.8%	1.3%	0.3%	2.7%	0.5%	1.0%

Notes:

EPT Ephemeroptera, Plecoptera, and Trichoptera

Table 4-11a
NYSDEC Index for Hester-Dendy Samples
Buffalo River, NY

		Water Quality Scale (0-10) - Actual Metrics Presented Previously							
Location	River Mile	Species Richness	Hilsenhoff Biotic Index	EPT	Species Diversity (base 2)	Average Value	Water Quality Impact	Average Value	Water Quality Impact
INV-BR-01-B	7.25	7.3	4.8	4.5	9.9	6.6	slight		
INV-BR-01-C	7.25	8.0	5.7	3.5	10.0	6.8	slight		
INV-BR-01-D	7.25	0.0	4.3	0.0	5.8	2.5	severe	4.3	moderate
INV-BR-01-E	7.25	3.9	3.2	0.0	7.4	3.6	moderate		
INV-BR-01-F	7.25	2.1	1.3	1.5	3.2	2.0	severe		
INV-BR-02-A	6.8	3.4	6.0	0.0	5.6	3.7	moderate		
INV-BR-02-B	6.8	6.4	5.4	1.5	5.2	4.6	moderate		
INV-BR-02-C	6.8	0.7	4.5	1.5	3.3	2.5	severe	3.8	moderate
INV-BR-02-E	6.8	5.5	4.6	1.5	6.5	4.5	moderate		
INV-BR-02-F	6.8	6.8	5.0	0.0	3.9	3.9	moderate		
INV-BR-03-A	6.25	8.5	4.4	3.5	10.0	6.6	slight		
INV-BR-03-B	6.25	5.9	5.7	0.0	8.9	5.1	slight		
INV-BR-03-C	6.25	6.4	4.9	0.0	9.8	5.3	slight	5.5	slight
INV-BR-03-D	6.25	8.0	5.7	1.5	10.0	6.3	slight		
INV-BR-03-E	6.25	4.3	4.1	3.5	5.5	4.3	moderate		
INV-BR-04-E	5.5	4.8	5.0	3.5	5.0	4.5	moderate		
INV-BR-04-F	5.5	3.9	4.9	0.0	8.1	4.2	moderate	5.6	slight
INV-BR-04-G	5.5	9.0	5.3	4.5	9.2	7.0	slight		
INV-BR-04-H	5.5	8.5	4.3	4.5	8.8	6.5	slight		
INV-BR-05-A	4.75	4.3	4.9	3.5	6.7	4.8	moderate		
INV-BR-05-B	4.75	4.3	3.6	1.5	7.9	4.3	moderate		
INV-BR-05-D	4.75	4.3	4.4	0.0	5.6	3.6	moderate	4.0	moderate
INV-BR-05-E	4.75	2.1	4.3	1.5	3.1	2.7	moderate		
INV-BR-05-F	4.75	3.4	5.3	1.5	7.7	4.5	moderate		
INV-BR-06-A	2.1	8.5	5.1	3.5	10.0	6.8	slight		
INV-BR-06-B	2.1	3.0	6.1	3.5	7.2	4.9	moderate		
INV-BR-06-C	2.1	4.8	3.0	1.5	7.7	4.2	moderate	5.6	slight
INV-BR-06-F	2.1	5.9	5.3	3.5	9.5	6.0	slight		
INV-BR-06-H	2.1	8.5	4.7	3.5	7.6	6.1	slight		
INV-BR-07-A	1.0	10.0	5.1	4.5	10.0	7.4	slight		
INV-BR-07-C	1.0	5.5	6.0	1.5	2.0	3.7	moderate		
INV-BR-07-D	1.0	4.3	6.8	3.5	6.2	5.2	slight	5.8	slight
INV-BR-07-F	1.0	10.0	5.6	3.5	10.0	7.3	slight		
INV-BR-07-H	1.0	8.5	5.0	1.5	6.7	5.4	slight		
INV-BR-08-A	0.3	5.9	5.5	1.5	6.5	4.8	moderate		
INV-BR-08-B	0.3	8.0	6.6	3.5	10.0	7.0	slight		
INV-BR-08-C	0.3	5.9	7.9	1.5	10.0	6.3	slight	6.0	slight
INV-BR-08-F	0.3	7.3	5.5	1.5	5.0	4.8	moderate		
INV-BR-08-H	0.3	8.0	6.2	3.5	10.0	6.9	slight		
INV-CC-01-A	---	9.5	8.0	4.5	10.0	8.0	non-		
INV-CC-01-B	---	5.9	6.4	0.0	6.7	4.7	moderate		
INV-CC-01-E	---	7.3	7.6	3.5	9.2	6.9	slight	6.6	slight
INV-CC-01-F	---	8.5	6.2	0.0	10.0	6.2	slight		
INV-CC-01-G	---	6.8	7.7	3.5	10.0	7.0	slight		

Table 4-11a
NYSDEC Index for Hester-Dendy Samples
Buffalo River, NY

Location	River Mile	Species Richness	Hilsenhoff Biotic Index	EPT	Species Diversity (base 2)	Average Value	Water Quality Impact	Average Value	Water Quality Impact
		Water Quality Scale (0-10) - Actual Metrics Presented Previously							
INV-RSC-01-B	---	8.0	7.9	8.5	5.2	7.4	slight	5.7	slight
INV-RSC-01-E	---	3.4	9.3	1.5	3.6	4.4	moderate		
INV-RSC-01-F	---	3.0	9.7	0.0	0.0	3.2	moderate		
INV-RSC-01-G	---	7.3	9.7	6.0	8.6	7.9	non-		
INV-RSC-02-D	---	7.3	7.0	3.5	10.0	6.9	slight	7.7	non-
INV-RSC-02-E	---	7.3	9.7	6.0	7.8	7.7	non-		
INV-RSC-02-F	---	9.0	8.9	8.5	10.0	9.1	non-		
INV-RSC-02-G	---	6.4	8.4	8.0	5.4	7.0	slight		
INV-RST-01-B	---	8.5	8.3	1.5	9.8	7.0	slight	7.0	slight
INV-RST-01-C	---	7.3	6.2	3.5	7.8	6.2	slight		
INV-RST-01-D	---	9.5	6.4	3.5	10.0	7.4	slight		
INV-RST-01-E	---	6.4	7.9	3.5	10.0	6.9	slight		
INV-RST-01-F	---	10.0	8.9	1.5	10.0	7.6	non-		
INV-RST-02-A	---	7.3	6.5	3.5	10.0	6.8	slight	5.9	slight
INV-RST-02-B	---	6.4	6.7	4.5	9.8	6.8	slight		
INV-RST-02-D	---	6.8	7.1	1.5	10.0	6.4	slight		
INV-RST-02-F	---	5.9	5.5	0.0	6.2	4.4	moderate		
INV-RST-02-G	---	5.9	6.3	0.0	9.0	5.3	slight		
INV-RST-03-A	---	3.4	8.5	0.0	6.4	4.6	moderate	5.4	slight
INV-RST-03-D	---	5.9	6.9	0.0	10.0	5.7	slight		
INV-RST-03-E	---	6.8	8.3	0.0	10.0	6.3	slight		
INV-RST-03-G	---	5.9	5.8	1.5	7.0	5.0	moderate		

Notes:

BR Buffalo River
CC Cazenovia Creek
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawanda Creek

Water Quality Scale and Impact Values are from NYSDEC 2002. These values are calculated by taking the metrics and scaling them from 0-10, as detailed in Appendix V "Formulas For Calculating Biological Assessment Profile Values For Multiplate Samples From Soft Sediments."

Table 4-11b
USEPA Index for Hester Dendy Samples
Buffalo River, NY

		Calculated Metric				Biological Condition Score as a % of Tonawanda Creek (Reference)									Scaled Metric											Station Average	
Location	River Mile	Ratio of Scrapers/ Filterers Collectors (a)	Ratio of EPT and Chironomidae Abundances (a)	Community Loss Index (a)	Ratio of Shredders/ Total (a)	Taxa Richness (b)	Biotic Index (b)	Ratio of Scrapers/Fi lterers Collectors (b)	Ratio of EPT and Chironomidae Abundances (c)	Percent Contribution of Dominant Taxon (b)	EPT Index (c)	Community Loss Index (b)	Ratio of Shredders/ Total (b)	Average of Comparison to Reference (d)	Taxa Richness (e)	Biotic Index (e)	Ratio of Scrapers/ Filterers Collectors (e)	Ratio of EPT and Chironomidae Abundances (e)	Percent Contribution of Dominant Taxon (e)	EPT Index (e)	Community Loss Index (e)	Ratio of Shredders/ Total (e)	Total (f)	% of Reference (f)	Biological Condition Category (f)	% of Reference (g)	Biological Condition Category (g)
INV-BR-01-B	7.25	0	8%	2.71	6%	100%	89%	0%	230%	21%	273%	2.71	97%	116%	6	6	0	6	4	6	2	6	36	78%	Slight		
INV-BR-01-C	7.25	17%	2%	2.68	7%	105%	93%	35%	58%	21%	182%	2.68	121%	88%	6	6	4	4	4	6	2	6	38	83%	Non to slight		
INV-BR-01-D	7.25	0	0	9.86	7%	33%	87%	0%	0%	29%	0%	9.86	122%	39%	0	6	0	0	4	0	0	6	16	35%	Moderate	52%	Slight to moderate
INV-BR-01-E	7.25	0	0	4.57	0	67%	83%	0%	0%	33%	0%	4.57	0%	26%	4	4	0	0	2	0	0	0	10	22%	Moderate		
INV-BR-01-F	7.25	0	1%	6.09	5%	52%	76%	0%	28%	60%	91%	6.09	88%	56%	2	4	0	2	0	6	0	6	20	43%	Moderate		
INV-BR-02-A	6.8	0	0	4.77	6%	62%	95%	0%	0%	45%	0%	4.77	110%	45%	4	6	0	0	0	0	0	6	16	35%	Moderate		
INV-BR-02-B	6.8	2%	2%	3.00	0%	90%	92%	5%	48%	43%	91%	3.00	4%	53%	6	6	0	2	0	6	2	0	22	48%	Moderate		
INV-BR-02-C	6.8	6%	2%	7.33	0	43%	88%	13%	45%	38%	91%	7.33	0%	45%	2	6	0	2	2	6	0	0	18	39%	Moderate	41%	Moderate
INV-BR-02-E	6.8	0	0%	3.47	0	81%	88%	0%	11%	42%	91%	3.47	0%	45%	6	6	0	0	0	6	2	0	20	43%	Moderate		
INV-BR-02-F	6.8	20%	0	3.00	0%	95%	90%	42%	0%	57%	0%	3.00	8%	42%	6	6	4	0	0	0	2	0	18	39%	Moderate		
INV-BR-03-A	6.25	0	1%	2.43	4%	110%	87%	0%	26%	13%	182%	2.43	69%	69%	6	6	0	2	6	6	2	6	34	74%	Slight		
INV-BR-03-B	6.25	0	0	3.28	0	86%	93%	0%	0%	35%	0%	3.28	0%	31%	6	6	0	0	2	0	2	0	16	35%	Moderate		
INV-BR-03-C	6.25	0	0	2.95	3%	90%	89%	0%	0%	27%	0%	2.95	47%	36%	6	6	0	0	4	0	2	4	22	48%	Moderate	51%	Slight to moderate
INV-BR-03-D	6.25	1%	0%	2.55	0	105%	93%	1%	7%	17%	91%	2.55	0%	45%	6	6	0	0	6	6	2	0	26	57%	Slight		
INV-BR-03-E	6.25	0	1%	4.20	0	71%	86%	0%	22%	29%	182%	4.20	0%	56%	4	6	0	0	4	6	0	0	20	43%	Moderate		
INV-BR-04-E	5.5	4%	1%	3.94	0	76%	90%	9%	33%	51%	182%	3.94	0%	63%	4	6	0	2	0	6	2	0	20	43%	Moderate		
INV-BR-04-F	5.5	0	0	4.43	0	67%	90%	0%	0%	34%	0%	4.43	0%	27%	4	6	0	0	2	0	0	0	12	26%	Moderate	48%	Moderate
INV-BR-04-G	5.5	0	2%	2.33	0	114%	91%	0%	52%	26%	273%	2.33	0%	79%	6	6	0	4	4	6	2	0	28	61%	Slight		
INV-BR-04-H	5.5	0	3%	2.35	1%	110%	87%	0%	76%	30%	273%	2.35	11%	84%	6	6	0	6	2	6	2	0	28	61%	Slight		
INV-BR-05-A	4.75	0	2%	4.20	4%	71%	89%	0%	58%	28%	182%	4.20	62%	70%	4	6	0	4	4	6	0	6	30	65%	Slight		
INV-BR-05-B	4.75	9%	3%	4.13	2%	71%	84%	19%	76%	32%	91%	4.13	36%	58%	4	4	0	6	2	6	0	4	26	57%	Slight		
INV-BR-05-D	4.75	10%	0	4.13	7%	71%	87%	20%	0%	37%	0%	4.13	122%	48%	4	6	0	0	2	0	0	6	18	39%	Moderate	49%	Moderate
INV-BR-05-E	4.75	0	0%	6.00	0	52%	87%	0%	13%	54%	91%	6.00	0%	42%	2	6	0	0	0	6	0	0	14	30%	Moderate		
INV-BR-05-F	4.75	0	2%	4.77	0	62%	91%	0%	58%	28%	91%	4.77	0%	47%	4	6	0	4	4	6	0	0	24	52%	Slight to moderate		
INV-BR-06-A	2.1	3%	23%	2.43	4%	110%	90%	7%	697%	20%	182%	2.43	64%	167%	6	6	0	6	4	6	2	6	36	78%	Slight		
INV-BR-06-B	2.1	0	22%	5.42	0	57%	95%	0%	667%	28%	182%	5.42	0%	147%	2	6	0	6	4	6	0	0	24	52%	Slight to moderate		
INV-BR-06-C	2.1	0	24%	3.81	0	76%	82%	0%	727%	36%	91%	3.81	0%	145%	4	4	0	6	2	6	2	0	24	52%	Slight to moderate	63%	Slight
INV-BR-06-F	2.1	0	11%	3.28	3%	86%	91%	0%	333%	20%	182%	3.28	55%	110%	6	6	0	6	4	6	2	6	36	78%	Slight		
INV-BR-06-H	2.1	6%	10%	2.43	1%	110%	89%	12%	288%	41%	182%	2.43	14%	105%	6	6	0	6	0	6	2	0	26	57%	Slight		
INV-BR-07-A	1.0	2%	5%	1.71	0	133%	90%	5%	142%	25%	273%	1.71	0%	96%	6	6	0	6	4	6	2	0	30	65%	Slight		
INV-BR-07-C	1.0	0	2%	3.71	0	81%	95%	0%	58%	65%	91%	3.71	0%	56%	6	6	0	4	0	6	2	0	24	52%	Slight to moderate		
INV-BR-07-D	1.0	0	21%	4.20	1%	71%	99%	0%	636%	39%	182%	4.20	22%	150%	4	6	0	6	2	6	0	2	26	57%	Slight	58%	Slight
INV-BR-07-F	1.0	1%	2%	1.96	1%	129%	93%	3%	70%	25%	182%	1.96	12%	73%	6	6	0	4	4	6	2	0	28	61%	Slight		
INV-BR-07-H	1.0	0	5%	2.35	0%	110%	90%	0%	155%	49%	91%	2.35	7%	72%	6	6	0	6	0	6	2	0	26	57%	Slight		
INV-BR-08-A	0.3	3%	4%	3.33	0	86%	92%	7%	127%	45%	91%	3.33	0%	64%	6	6	0	6	0	6	2	0	26	57%	Slight		
INV-BR-08-B	0.3	0	4%	2.55	3%	105%	98%	0%	130%	27%	182%	2.55	43%	84%	6	6	0	6	4	6	2	4	34	74%	Slight		
INV-BR-08-C	0.3	14%	2%	3.17	0	86%	105%	29%	45%	18%	91%	3.17	0%	54%	6	6	2	2	6	6	2	0	30	65%	Slight	65%	Slight
INV-BR-08-F	0.3	0	3%	2.67	0	100%	92%	0%	94%	60%	91%	2.67	0%	62%	6	6	0	6	0	6	2	0	26	57%	Slight		
INV-BR-08-H	0.3	2%	8%	2.59	5%	105%	96%	4%	245%	30%	182%	2.59	91%	108%	6	6	0	6	2	6	2	6	34	74%	Slight		
INV-CC-01-A	---	1%	2%	2.28	5%	119%	106%	2%	45%	37%	273%	2.28	83%	95%	6	6	0	2	2	6	2	6	30	65%	Slight		
INV-CC-01-B	---	0	0	3.33	1%	86%	97%	0%	0%	25%	0%	3.33	12%	31%	6	6	0	0	4	0	2	0	18	39%	Moderate		
INV-CC-01-E	---	2%	2%	2.81	1%	100%	104%	4%	55%	22%	182%	2.81	24%	70%	6	6	0	4	4	6	2	2	30	65%	Slight	59%	Slight
INV-CC-01-F	---	23%	0	2.57	2%	110%	95%	48%	0%	15%	0%	2.57	29%	42%	6	6	4	0	6	0	2	2	26	57%	Slight		
INV-CC-01-G	---	0	2%	2.85	3%	95%	104%	0%	67%	23%	182%	2.85	50%	74%	6	6	0	4	4	6	2	4	32	70%	Slight		

Table 4-11b
USEPA Index for Hester Dendy Samples
Buffalo River, NY

Calculated Metric

Location	River Mile	Ratio of Scrapers/ Filterers Collectors (a)	Ratio of EPT and Chironomidae Abundances (a)	Community Loss Index (a)	Ratio of Shredders/ Total (a)
INV-RSC-01-B	---	27%	12%	2.77	6%
INV-RSC-01-E	---	17%	2%	4.77	3%
INV-RSC-01-F	---	30%	0	5.33	0%
INV-RSC-01-G	---	1%	3%	2.95	7%
INV-RSC-02-D	---	160%	1%	2.95	24%
INV-RSC-02-E	---	0	2%	2.90	4%
INV-RSC-02-F	---	0%	5%	2.42	5%
INV-RSC-02-G	---	4%	3%	3.26	0
INV-RST-01-B	---	3%	1%	REF	8%
INV-RST-01-C	---	0	5%	REF	2%
INV-RST-01-D	---	4%	2%	REF	3%
INV-RST-01-E	---	0	8%	REF	0
INV-RST-01-F	---	5%	3%	REF	1%
INV-RST-02-A	---	0	2%	REF	8%
INV-RST-02-B	---	13%	7%	REF	9%
INV-RST-02-D	---	12%	1%	REF	0
INV-RST-02-F	---	21%	0	REF	0
INV-RST-02-G	---	3%	0	REF	0
INV-RST-03-A	---	440%	0	REF	2%
INV-RST-03-D	---	11%	0	REF	10%
INV-RST-03-E	---	8%	0	REF	11%
INV-RST-03-G	---	8%	1%	REF	5%
RST Mean	---	48%	3%	0	6%

Biological Condition Score as a % of Tonawanda Creek (Reference)

Location	Taxa Richness (b)	Biotic Index (b)	Ratio of Scrapers/Filterers Collectors (b)	Ratio of EPT and Chironomidae Abundances (c)	Percent Contribution of Dominant Taxon (b)	EPT Index (c)	Community Loss Index (b)	Ratio of Shredders/ Total (b)	Average of Comparison to Reference (d)
INV-RSC-01-B	105%	105%	56%	364%	37%	636%	2.77	109%	202%
INV-RSC-01-E	62%	115%	35%	55%	46%	91%	4.77	50%	65%
INV-RSC-01-F	57%	117%	63%	0%	86%	0%	5.33	6%	47%
INV-RSC-01-G	100%	118%	2%	103%	41%	364%	2.95	122%	121%
INV-RSC-02-D	100%	100%	333%	22%	21%	182%	2.95	414%	167%
INV-RSC-02-E	100%	117%	0%	45%	38%	364%	2.90	71%	105%
INV-RSC-02-F	114%	111%	1%	142%	22%	636%	2.42	79%	158%
INV-RSC-02-G	90%	108%	9%	82%	51%	545%	3.26	0%	127%
RST Mean	100%	100%	100%	100%	29%	100%	0	100%	

Scaled Metric / Station Average

Location	Taxa Richness (e)	Biotic Index (e)	Ratio of Scrapers/ Filterers Collectors (e)	Ratio of EPT and Chironomidae Abundances (e)	Percent Contribution of Dominant Taxon (e)	EPT Index (e)	Community Loss Index (e)	Ratio of Shredders/ Total (e)	Total (f)	% of Reference (f)	Biological Condition Category (f)	Station Average % of Reference (g)	Station Average Biological Condition Category (g)
INV-RSC-01-B	6	6	6	6	2	6	2	6	40	87%	Non		
INV-RSC-01-E	4	6	4	4	0	6	0	4	28	61%	Slight	62%	Slight
INV-RSC-01-F	2	6	6	0	0	0	0	0	14	30%	Moderate		
INV-RSC-01-G	6	6	0	6	0	6	2	6	32	70%	Slight		
INV-RSC-02-D	6	6	6	0	4	6	2	6	36	78%	Slight		
INV-RSC-02-E	6	6	0	2	2	6	2	6	30	65%	Slight	70%	Slight
INV-RSC-02-F	6	6	0	6	4	6	2	6	36	78%	Slight		
INV-RSC-02-G	6	6	0	6	0	6	2	0	26	57%	Slight		
RST Mean	6	6	6	6	4	6	6	6	46				Reference

Notes:

BR Buffalo River
CC Cazenovia Creek
REF Reference
RSC Reference Site Cattaraugas Creek
RST Reference Site Tonawanda Creek

(a) These values are calculated using USEPA 1989 and USEPA 1999 for feeding strategy designations and methods. Species Richness, Hilsenhoff Biotic Index, and Dominance have been presented on previous tables.
(b) These values are calculated as a percentage using the average value from Tonowanda Creek as the reference station (station value/mean Tonowanda creek value). A value >100% indicates that it is higher than the reference.
(c) Tonowanda Creek scored a 0 on these metrics, so they are not used here (station value/0 = error).
(d) This value is the average of ratio of the station to the reference but does not include Ratio of EPT and Chironomidae Abundances, EPT Index, or Ratio of Shredders/ Total because these values are essentially unused in this calculation because these metrics
(e) These values have been scaled from 0 to 6 compared to Tonawanda Creek using Figure 6.3-4 in USEPA 1989. Ratio of EPT and Chironomidae Abundances, EPT Index, or Ratio of Shredders/ Total are all considered to be zero, as they are also zero in the referenc
(f) The scaled metrics are summed and then compared to the sum at the reference station and then classified according to USEPA 1989 (non>slight>moderate>severe).
(g) These are the values averaged for each station.

Table 4-12
Indirect Metrics for Fish Community Assessment
Buffalo River, NY

Fish Metric	Formula
1. Total Taxa	Total number of each species identified
2. Percent Centrarchids	Number of Centrarchids/ Total Number of Organisms
3. Percent Catostomidae	Number of Catostomidae/ Total Number of Organisms
4. Percent Cyprinidae	Number of Cyprinidae/ Total Number of Organisms
5. Percent Dominant Species	Number of Individuals in Dominant Species/ Total Number of Organisms
6. Similarity Index	$J(A,B) = \frac{\lvert A \cap B \rvert}{\lvert A \cup B \rvert}$ Where: J = Jaccard similarity index A and B = sample sets
7. Shannon Diversity Index	$H = -\sum_{i=1}^{s} \left(pi \times \ln pi \right)$ Where: H = Shannon diversity index s = total number of species in the community (richness) p_i = proportion of individuals of a given species to the total number of species in the community
8. Percent Tolerant/Intolerant Species	Number of Individuals in Tolerant/Intolerant Taxon/ Total Number of Organisms
9. Percent Omnivores	Number of Omnivores/ Total Number of Organisms
10. Percent Top Carnivores	Number of top carnivores/ Total Number of Organisms
11. Abundance	Number fish caught per unit effort
12. Condition Factor (K)	$K = \frac{100{,}000W}{L^3}$ Where: W = the weight of fish in grams L = the length of fish in millimeters

Source:
Based on Rapid Bioassessment Protocol III (USEPA 1989, 1999).

Table 4-13a
Water Quality and Habitat Assessment Scores for Fish Community Locations
Buffalo River, NY

Location	River Mile	pH (s.u.)	Dissolved Oxygen (mg/L)	Specific Conductance (umho/cm)	Temperature (°C)	Secchi Disk (m)	QHEI Score*	QHEI Score	Ranking*
CC-1	---	7.93	8.74	597	16.8	1.8	54	54	Fair
BR1	7.25	7.25	7.05	682	17.7	0.5	51	51	Fair
BR2	6.6	7.66	6.93	667	17.9	0.5	55	55	Fair
BR3	6.25	7.70	6.86	675	17.9	0.6	51	51	Fair
BR4	5.5	6.58	6.82	570	19.0	1.5	59	59	Fair
BR5	4.5	7.60	7.7	517	19.5	0.7	55.5	55.5	Fair

Notes:

* Rankings correspond to the following larger stream QHEI scores: Very Poor: >30, Poor: 30-44, Fair: 45-59, Good: 60-74, Excellent: >75

°C	Degrees Celcius
BR	Buffalo River
CC	Cazenovia Creek
m	Meter
mg/L	Milligram per liter
QHEI	Qualitiative habitat evaluation index
s.u.	Standard unit

Table 4-13b
Individual Habitat Assessment Scores for Fish Community Locations
Buffalo River, NY

Location	River Mile	Substrate	Instream Cover	Channel Morphology	Bank Erosion and Riparian Zone	Pool/Glide and Riffle/Run Quality	Gradient	Sum	Ranking*
BR1	7.25	1	12	11	10	9	8	51	Fair
BR2	6.6	4	14	10	10	9	8	55	Fair
BR3	6.25	4	10	10	10	9	8	51	Fair
BR4	5.5	12	13	10	7	9	8	59	Fair
BR5	4.5	7.5	11	11	10	9	8	56.5	Fair
CC1	---	4	13	10	10	9	8	54	Fair

Source:
Rankin (1989)

Notes:
* The habitat assessment process involves rating the sum of several parameters based on the criteria included in QHEI field sheet. Total Score Rankings: Very poor: <30, Poor: 30-44, Fair: 45-59, Good: 60-74, Excellent: >75.

BR Buffalo River
CC Cazenovia Creek

Table 4-14a
Electrofishing Catch per Unit Effort (CPUE) on the Buffalo River and Cazenovia Creek during the Fish Community Assessment
Buffalo River, NY

		Electrofishing Catch per Unit Effort (CPUE)					
Scientific Name*	Common Name	BR1 RM 7.25	BR2 RM 6.6	BR3 RM 6.25	BR4 RM 5.5	BR5 RM 4.5	CC
Hybopsis amblops	Bigeye chub						3.9
Lepomis macrochirus	Bluegill	3.9	7.9	3.9	10	47.5	7.9
Pimephales notatus	Bluntnose minnow	3.9	4	3.9	4	15.8	102.1
Ameiurus nebulosus	Brown bullhead	3.9					
Cyprinus carpio	Common carp	11.7	11.9	11.6	8	11.9	
Luxilus cornutus	Common shiner	19.5	4	11.6	4	4	11.8
Dorosoma cepedianum	Gizzard shad	3.9	27.7	19.3		27.7	
Moxostoma erythrurum	Golden redhorse	3.9			4		3.9
Notemigonus crysoleucas	Golden shiner	3.9			14	79.2	
Etheostoma nigrum	Johnny darter				2	7.9	
Micropterus salmoides	Largemouth bass	7.8	15.8	23.1	44.1	67.3	27.5
Hypentelium nigricans	Northern hogsucker					4	3.9
Lepomis gibbosus	Pumpkinseed	11.7	27.7	27	10	35.6	3.9
Oncorhynchus mykiss	Rainbow trout	3.9					3.9
Ambloplites rupestris	Rock bass	3.9		11.6		4	11.8
Micropterus dolomieui	Smallmouth bass	3.9					
Ictiobus bubalus	Smallmouth buffalo					4	
Notropis hudsonius	Spottail shiner			3.9			
Minytrema melanops	Spotted sucker					4	
Catostomus commersonii	White sucker		4	7.7		7.9	3.9
Ameiurus natalis	Yellow bullhead					4	
Perca flavescens	Yellow perch				8		3.9
CPUE Totals		**86**	**103**	**124**	**108**	**325**	**188**

Source:
MACTEC (2008)

Notes:
* Only fish species that were collected via electrofishing are included.

BR	Buffalo River
CC	Cazenovia Creek
CPUE	Catch per unit effort (# / hour)
RM	River mile

Table 4-14b
Summary of DELT Abnormalities in Fish Collected during the Fish Community Survey on the Buffalo River and Cazenovia Creek
Buffalo River, NY

Location	River Mile	Species	Length (mm)	Weight (g)	Abnormality Description
BR2	6.6	Common shiner	83	5	Eroded caudal fin
BR4	5.5	Largemouth bass	110	17	Lesion on abdomen
BR4	5.5	Largemouth bass	70	4	Mouth lesion
BR5	4.5	Largemouth bass	105	14	Dorsal & anal fin fungus
BR5	4.5	Largemouth bass	130	24	Missing portion of upper jaw
BR5	4.5	Golden shiner	115	14	Mouth lesion

Source:
MACTEC (2008)
Ohio EPA (1987)

Notes:
BR Buffalo River
DELT Deformities, eroded fins, lesions, and tumors
g Gram
mm Millimeter

Table 4-15a
Fish Community Metrics for Locations within the Buffalo River and Cazenovia Creek[(a)]
Buffalo River, NY

	CC	BR1 RM 7.25	BR2 RM 6.6	BR3 RM 6.25	BR4 RM 5.5	BR5 RM 4.5
Total Taxa	12	15	8	10	10	15
Percent Centrarchids	27%	13%	50%	53%	59%	48%
Percent Catostomidae	6.3%	3.3%	3.8%	6.3%	3.7%	6.1%
Percent Cyprinidae	63%	80%	19%	25%	28%	34%
Percent Dominant Species	54%	49%	27%	22%	41%	24%
Similarity Index	NA	60%	75%	80%	70%	53%
Shannon-Wiener Diversity Index	1.7	1.7	1.8	2.1	1.9	2.2
Percent Tolerant Species	56%	56%	19%	19%	24%	37%
Percent Intolerant Species	2.1%	2.2%	0%	0%	0%	1.2%
Percent Omnivores	56%	56%	46%	34%	24%	44%
Percent Top Carnivores	23%	8.8%	15%	28%	41%	22%
Abundance (b)	0.052	0.099	0.029	0.034	0.060	0.090
Mean Condition Factor (K) (c)	0.98	1.1	1.3	1.4	1.3	1.3

Notes:
(a) Includes fish caught via electrofishing and seining.
(b) Only includes fish caught via electrofishing.
(c) Calculated based on Williams (2000).

AOC	Area of Concern
BR	Buffalo River
CC	Cazenovia Creek
NA	Not applicable
RM	River mile

Table 4-15b
Summary of Fish Community Metrics: Buffalo River AOC, Buffalo River - Upstream, Cazenovia Creek[(a)]
Buffalo River, NY

	Cazenovia Creek	Buffalo River AOC Mean	Buffalo River Upstream Mean
Number of Stations	1	2	3
Total Taxa	12	13	11
Percent Centrarchids	27%	54%	39%
Percent Catostomidae	6.3%	4.9%	4.5%
Percent Cyprinidae	63%	31%	41%
Percent Dominant Species	54%	33%	33%
Similarity Index	NA	62%	72%
Shannon-Wiener Diversity Index	1.7	2.0	1.9
Percent Tolerant Species	56%	31%	31%
Percent Intolerant Species	2.1%	0.60%	0.73%
Percent Omnivores	56%	34%	45%
Percent Top Carnivores	23%	32%	17%
Abundance (b)	0.052	0.075	0.054
Mean Condition Factor (K) (c)	0.98	1.3	1.3

Notes:

(a) Includes fish caught via electrofishing and seining.
(b) Only includes fish caught via electrofishing.
(c) Calculated based on Williams (2000).

AOC	Area of Concern
NA	Not applicable

Table 4-16a
NYSDEC Approach for Assessment of Water Quality Using Fish
Buffalo River, NY

	Buffalo River Location					Cazenovia Creek
	BR1 RM 7.25	BR2 RM 6.6	BR3 RM 6.25	BR4 RM 5.5	BR5 RM 4.5	
Fish Metric*						
A. Species Richness, weighted (a)	11	4	6	6	11	8
B. Percent Non-tolerant Individuals (b)	44%	81%	81%	76%	63%	44%
C. Percent Non-tolerant Species (b)	73%	63%	70%	70%	67%	83%
D. Percent Model Affinity, by trophic class (c)	64%	68%	68%	81%	64%	63%
Profile Value (d)	2.8	1.1	1.6	1.6	2.8	2.0
Rating	Moderately Impaired	Severely Impaired	Severely Impaired	Severely Impaired	Moderately Impaired	Severely Impaired

Notes:
* Includes fish caught via electrofishing and seining.
(a) Weighted by stream size (> 20 meters = x - 4, where x = richness).
(b) Individuals or species considered intolerant or intermediate to environmental perturbations, based on Barbour et al. (1999).
(c) The highest percentage similarity to any of five models of non-impacted fish communities, by trophic class (Halliwell et al., 1999).
(d) Value = (weighted richness value + 0.1(percent non-tolerant individuals) + 0.1(percent non-tolerant species) + 0.1(percent model affinity))/4
RM River mile

Profile Score (e)	Rating
7.5-10	Nonimpaired
5-7.5	Slightly Impaired
2.5-5	Moderately Impaired
0-2.5	Severely Impaired

Notes:
(e) Categories defined per personal communication between Katrina Leigh, ENVIRON senior associate, and Alexander J. Smith, NYSDEC Stream Biomonitoring Unit, on December 23, 2008.

Table 4-16b
Index of Biotic Integrity Calculated for Fish
Buffalo River, NY

	Buffalo River Location (a)					Cazenovia Creek (b)
	BR1 RM 7.25	BR2 RM 6.6	BR3 RM 6.25	BR4 RM 5.5	BR5 RM 4.5	
Fish Metric*						
A. Total Number of Fish Species	15	8	10	10	15	12
B. Total Number of Individuals Caught	91	26	32	54	82	48
C. Percent of Individuals with DELT	0%	4%	0%	4%	4%	0%
D. Percent of Omnivorous Individuals	56%	46%	34%	24%	44%	56%
E. Percent of Insectivorous Individuals	35%	38%	38%	35%	34%	21%
F. Percent of Individuals as Top Carnivores	9%	15%	28%	41%	22%	23%
G. Percent of Tolerant Individuals	56%	19%	19%	24%	37%	56%
H. Number of Intolerant Species	NA	NA	NA	NA	NA	1
I. Number of Benthic Species	NA	NA	NA	NA	NA	3
J. Total Number of Insectivorous Species	7	3	4	6	8	NA
K. Total Number of Sunfish/Cyprinid Species	7	3	4	6	8	NA
Total IBI Score (d)	27	23	29	25	29	21
Quality Rating	Fair	Poor	Fair	Poor	Fair	Poor

Notes:
* Includes fish caught via electrofishing and seining.
(a) Determined based on Irvine et al. (2005).
(b) Determined based on Greer et al. (2002).
(c) Carp and goldfish were excluded.
(d) Based on Scoring Criteria below.

DELT Deformities, Erosions, Lesions, Tumors
IBI Index of Biotic Integrity
NA Not applicable
RM River mile

Category	Metric	Scoring Criteria 5	3	1
Species Richness	A	>15	8-15	<8
Fish Abundance	B	>250	75-250	<75
Fish Condition	C	0-2%	2-5%	>5%
Trophic Composition	D	<20%	20-45%	>45%
	E	>65%	30-65%	<30%
	F	>5%	1-5%	<1%
Species Composition	H	>5	2-5	<2
	I	>7	3-7	<3
	J	>7	3-7	<3
	K	>7	3-7	<3

Notes:
% Percent

IBI Score (e)	Quality Rating
41-45	Excellent
34-40	Good
27-33	Fair
20-26	Poor
9-19	Very Poor

Notes:
(e) Defined in Irvine et al. (2005).

Table 4-17a
Histopathological Evaluation of Liver Lesions in Brown Bullhead
Buffalo River, NY

n	37
Foci of Cellular Alteration (%)	29.8
Hepatocellular Carcinomas (%)	5.4
Cholangiocarcinomas (%)	0
Hepatocellular Tumors (%)	2.7
Bile Ductular Tumors (%)	0
Total Liver Tumors (%)	**8.1**

Notes:
% Percent
n Number of samples

Table 4-17b
Body Length, Mass, Condition Factor, and Hepatosomatic Index in Brown Bullhead
Buffalo River, NY

ID number	Length (cm)	Weight (g)	Liver Weight (g)	Condition Factor	Hepatosomatic Index
Reach 1 (RM 5.6 - 6.25)					
1-1-9-29-08	26.6	442	12.64	2.35	2.86
1-2-9-29-08	25	358	7.26	2.29	2.03
1-3-9-29-28	25.5	351	8.41	2.12	2.4
1-4-9-29-08	25	334	9.03	2.14	2.7
1-5-9-29-08	24.5	343	10.39	2.33	3.03
1-6-9-29-08	27.2	480	14.64	2.39	3.05
1-7-9-29-08	25.1	328	10.66	2.07	3.25
1-8-9-29-08	27	414	11.63	2.1	2.81
1-9-9-29-08	24.5	300	6.9	2.04	2.3
1-10-10-01-08	30	482.2	9.01	1.79	1.87
1-11-10-03-08	26.04	281.79	6.66	1.6	2.36
1-12-10-03-08	24.13	267.9	7.96	1.91	2.97
1-13-10-03-08	22.86	225.17	7.89	1.88	3.5
Mean	**25.6**	**354.4**	**9.5**	**2.1**	**2.7**
Reach 2 (RM 3.4 - 4.6)					
2-1-9-30-08	26.67	315	7.02	1.66	2.23
2-2-9-30-08	26.04	354	NA	2	NA
2-3-9-30-08	28.58	424.6	10.77	1.82	2.54
2-4-9-30-08	24.13	255.7	4.81	1.82	1.88
2-5-9-30-08	26.04	347.5	7.96	1.97	2.29
2-6-9-30-08	26.67	327.5	8.28	1.73	2.53
2-7-9-30-08	23.5	219.4	4.73	1.69	2.16
2-8-9-30-08	32.39	519.26	10.76	1.53	2.07
2-9-9-30-08	29.21	379.98	12.66	1.52	3.33
2-10-9-30-08	24.13	278	5.81	1.98	2.09
2-11-10-01-08	27	389.4	9.26	1.98	2.38
2-12-10-01-08	24.5	320.2	6.65	2.18	2.08
2-13-10-01-08	28	452.8	11.18	2.06	2.47
2-14-10-02-08	27.62	224.5	4.9	1.07	2.18
2-15-10-03-08	24.13	292.81	10.16	2.08	3.47
2-16-10-03-08	24.13	262.39	8.83	1.87	3.37
Mean	**26.4**	**335.2**	**8.3**	**1.8**	**2.5**
Reach 3 (RM 1.25 - 1.9)					
3-1-9-29-08	NA	405	10.45	NA	2.58
3-2-10-01-08	25	327.9	7.72	2.1	2.35
3-3-10-01-08	25.5	316.8	8.48	1.91	2.68
3-4-10-01-08	25.3	355	9.92	2.19	2.79
3-5-10-01-08	28.5	386.8	8.59	1.67	2.22
3-6-10-01-08	31.2	572.4	13.79	1.88	2.41
3-7-10-01-08	23.5	246.9	8.97	1.9	3.63
3-8-10-01-08	27.5	495.2	16.7	2.38	3.37
Mean	**26.6**	**388.3**	**10.6**	**2.0**	**2.8**

Notes:

cm	Centimeter
g	Gram
NA	Not analyzed
RM	River mile

Table 4-17c
Incidence of External Lesions in Brown Bullhead by Reach
Buffalo River, NY

		Lesion Severity[a]				
Date collected	ID number	Barbels	General Skin	Oral	Melanistic Areas	Ulcers
Reach 1 (RM 5.6 - 6.25)						
9/29/2008	1-1-9-29-08	0	0	1	0	0
9/29/2008	1-2-9-29-08	0	0	0	0	0
9/29/2008	1-3-9-29-28	0	0	0	0	0
9/29/2008	1-4-9-29-08	0	0	0	0	0
9/29/2008	1-5-9-29-08	0	0	0	0	0
9/29/2008	1-6-9-29-08	0	0	0	2	0
9/29/2008	1-7-9-29-08	0	0	0	0	0
9/29/2008	1-8-9-29-08	0	0	0	0	0
9/29/2008	1-9-9-29-08	0	0	0	1	0
9/30/2008	1-10-10-01-08	0	1	2	1	2
10/2/2008	1-11-10-03-08	0	0	0	0	0
10/2/2008	1-12-10-03-08	0	0	0	0	0
10/2/2008	1-13-10-03-08	0	0	2	0	0
Percent Affected		**0**	**7.7**	**23.1**	**23.1**	**7.7**
Reach 2 (RM 3.4 - 4.6)						
9/29/2008	2-1-9-30-08	0	0	0	0	0
9/29/2008	2-2-9-30-08	0	0	0	0	0
9/29/2008	2-3-9-30-08	0	0	0	2	0
9/29/2008	2-4-9-30-08	0	0	0	0	0
9/29/2008	2-5-9-30-08	0	0	2	0	2
9/29/2008	2-6-9-30-08	0	0	0	0	3
9/29/2008	2-7-9-30-08	0	0	0	0	0
9/29/2008	2-8-9-30-08	2	0	3	2	2
9/29/2008	2-9-9-30-08	1	0	0	0	0
9/29/2008	2-10-9-30-08	2	0	1	0	0
9/30/2008	2-11-10-01-08	2	1	0	1	0
10/1/2008	2-12-10-01-08	2	0	0	1	0
10/1/2008	2-13-10-01-08	0	0	0	3	0
10/1/2008	2-14-10-02-08	0	0	0	0	0
10/2/2008	2-15-10-03-08	0	0	0	0	0
10/2/2008	2-16-10-03-08	0	0	0	0	0
Percent Affected		**31.3**	**6.3**	**18.8**	**31.3**	**18.8**
Reach 3 (RM 1.25 - 1.9)						
9/29/2008	3-1-9-29-08	0	0	0	2	0
9/30/2008	3-2-10-01-08	1	0	0	0	0
9/30/2008	3-3-10-01-08	0	0	0	0	0
9/30/2008	3-4-10-01-08	0	0	0	0	0
9/30/2008	3-5-10-01-08	0	0	2	0	1
9/30/2008	3-6-10-01-08	0	0	0	0	1
10/1/2008	3-7-10-01-08	0	0	0	0	0
10/1/2008	3-8-10-01-08	0	0	0	0	0
Percent Affected		**12.5**	**0**	**12.5**	**12.5**	**25.0**
Overall Percent Mean =		**16.2**	**5.4**	**18.9**	**24.3**	**16.2**

Notes:
(a) Lesion severity is listed on a scale of 0-3 where 3 is the most severe

ID	Identification
RM	Rive mile

Table 5-1
Physical and Chemical Characteristics of the Buffalo River by River Mile
Buffalo, NY

	RM 0.0 - 1.0	RM 1.0 - 2.0	RM 2.0 - 3.5	RM 3.5 - 5.0	RM 5.0+	City Ship Canal
Bathymetry / Cross-section	Shallower, with defined nav channel and shoulders	Narrow reach with deeper channel and narrow shoulders	Depths vary with bends; point bars and holes	Depths vary with bends; point bars and holes	Defined nav channel and shoulders	Shallower, U-shaped section
Hydrodynamics	Low velocity, lake impacted	High velocities	Moderate velocities	Moderate velocities	Low-moderate velocities	Low velocities
Bottom Stress	Low stress, moderated by lake	High event stress	Variable, zones of higher stress	Variable, generally lower stress	Low stress	Very low stress
Substrate Type	Fines (95%)	Fines/sand/gravel mix	Fines/ sand/ some gravel	Fines / sands/ limited gravel	Sand and fines	Fines
River Geomorphology	Mouth: wide, shallow	Straight, narrow reach	Highly sinuous	Highly sinuous	Lower sinuosity	
Sedimentation Rates	Deposition of fines from lake	Minimal deposition	Some deposition	Higher deposition of fines, some sands	Bedload deposition and some fines	Fines deposition, local biotic solids
Surficial Contaminant Distribution	Relatively low levels	Low to moderate levels	Moderate levels	Higher levels	Low to moderate levels	Moderate levels

RM - River Mile

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	007-MA1-C-C-Z1a 2.4 % Organic Carbon				007-MA1-C-C-Z1b 2.7 % Organic Carbon				007-MA1-C-C-Z1b/D 2.8 % Organic Carbon				026-HB1-C-C-Z1a 1.7 % Organic Carbon			
		PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.16		6.78E+00	1.4E-02	0.12	J	4.51E+00	9.2E-03	0.077	J	2.72E+00	5.5E-03	0.041	U	2.43E+00	4.9E-03
Acenaphthylene	452	0.096	J	4.07E+00	9.0E-03	0.11	J	4.14E+00	9.1E-03	0.089	J	3.14E+00	7.0E-03	0.041	U	2.43E+00	5.4E-03
Anthracene	594	0.44		1.86E+01	3.1E-02	0.45		1.69E+01	2.8E-02	0.24		8.48E+00	1.4E-02	0.041	U	2.43E+00	4.1E-03
Benzo (a) anthracene	841	0.99		4.19E+01	5.0E-02	1.2		4.51E+01	5.4E-02	0.65		2.30E+01	2.7E-02	0.041	U	2.43E+00	2.9E-03
Benzo (a) pyrene	965	0.93		3.94E+01	4.1E-02	1.1		4.14E+01	4.3E-02	0.62		2.19E+01	2.3E-02	0.041	U	2.43E+00	2.5E-03
Benzo (b) fluoranthene	979	1.2		5.08E+01	5.2E-02	1.6		6.02E+01	6.1E-02	0.94		3.32E+01	3.4E-02	0.041	U	2.43E+00	2.5E-03
Benzo (e) pyrene	967	0.74		3.14E+01	3.2E-02	0.9		3.38E+01	3.5E-02	0.52		1.84E+01	1.9E-02	0.041	U	2.43E+00	2.5E-03
Benzo (g,h,i) perylene	1,095	0.17		7.20E+00	6.6E-03	0.14		5.26E+00	4.8E-03	0.1	J	3.53E+00	3.2E-03	0.041	U	2.43E+00	2.2E-03
Benzo (k) fluoranthene	981	1.2		5.08E+01	5.2E-02	1.7	J	6.39E+01	6.5E-02	0.81	J	2.86E+01	2.9E-02	0.041	U	2.43E+00	2.5E-03
Chrysene	844	1.2		5.08E+01	6.0E-02	1.5		5.64E+01	6.7E-02	0.92		3.25E+01	3.9E-02	0.041	U	2.43E+00	2.9E-03
Dibenz (a,h) anthracene	1,123	0.073	J	3.09E+00	2.8E-03	0.053	J	1.99E+00	1.8E-03	0.037	J	1.31E+00	1.2E-03	0.041	U	2.43E+00	2.2E-03
Fluoranthene	707	2.4		1.02E+02	1.4E-01	2.9		1.09E+02	1.5E-01	1.5		5.30E+01	7.5E-02	0.041	U	2.43E+00	3.4E-03
Fluorene	538	0.21		8.90E+00	1.7E-02	0.22		8.27E+00	1.5E-02	0.11	J	3.89E+00	7.2E-03	0.041	U	2.43E+00	4.5E-03
Indeno (1,2,3-cd) pyrene	1,115	0.21		8.90E+00	8.0E-03	0.16		6.02E+00	5.4E-03	0.12	J	4.24E+00	3.8E-03	0.041	U	2.43E+00	2.2E-03
Naphthalene	385	0.043	J	1.82E+00	4.7E-03	0.056	J	2.11E+00	5.5E-03	0.047	J	1.66E+00	4.3E-03	0.041	U	2.43E+00	6.3E-03
Phenanthrene	596	1.3		5.51E+01	9.2E-02	1.4	J	5.26E+01	8.8E-02	0.61	J	2.16E+01	3.6E-02	0.041	U	2.43E+00	4.1E-03
Pyrene	697	2		8.47E+01	1.2E-01	2.1		7.89E+01	1.1E-01	1.2		4.24E+01	6.1E-02	0.041	U	2.43E+00	3.5E-03
Alkylated PAHs																	
1-Methylnaphthalene	446	0.07	U	2.97E+00	6.7E-03	0.054	J	2.03E+00	4.6E-03	0.036	J	1.27E+00	2.9E-03	0.041	U	2.43E+00	5.4E-03
2-Methylnaphthalene	447	0.071	J	3.01E+00	6.7E-03	0.096	J	3.61E+00	8.1E-03	0.086	J	3.04E+00	6.8E-03	0.041	U	2.43E+00	5.4E-03
C1-Anthracenes/ Phenanthrenes	670	0.47		1.99E+01	3.0E-02	0.66		2.48E+01	3.7E-02	0.36		1.27E+01	1.9E-02	0.041	U	2.43E+00	3.6E-03
C1-Chrysenes	929	0.99		4.19E+01	4.5E-02	1.2		4.51E+01	4.9E-02	0.75		2.65E+01	2.9E-02	0.041	U	2.43E+00	2.6E-03
C1-Fluoranthenes/ Pyrenes	770	0.99		4.19E+01	5.4E-02	1.3		4.89E+01	6.3E-02	0.85		3.00E+01	3.9E-02	0.041	U	2.43E+00	3.2E-03
C1-Fluorenes	611	0.091	J	3.86E+00	6.3E-03	0.11	J	4.14E+00	6.8E-03	0.076	J	2.69E+00	4.4E-03	0.041	U	2.43E+00	4.0E-03
C2-Anthracenes/ Phenanthrenes	746	0.47		1.99E+01	2.7E-02	0.67		2.52E+01	3.4E-02	0.45		1.59E+01	2.1E-02	0.041	U	2.43E+00	3.3E-03
C2-Chrysenes	1,008	0.83		3.52E+01	3.5E-02	0.73		2.74E+01	2.7E-02	0.59		2.08E+01	2.1E-02	0.041	U	2.43E+00	2.4E-03
C2-Fluorenes	686	0.055	J	2.33E+00	3.4E-03	0.069	J	2.59E+00	3.8E-03	0.049	J	1.73E+00	2.5E-03	0.041	U	2.43E+00	3.5E-03
C2-Napthalenes	510	0.089	J	3.77E+00	7.4E-03	0.15		5.64E+00	1.1E-02	0.098	J	3.46E+00	6.8E-03	0.041	U	2.43E+00	4.8E-03
C3-Anthracenes/ Phenanthrenes	829	0.39		1.65E+01	2.0E-02	0.57		2.14E+01	2.6E-02	0.43		1.52E+01	1.8E-02	0.041	U	2.43E+00	2.9E-03
C3-Chrysenes	1,112	0.41		1.74E+01	1.6E-02	0.54		2.03E+01	1.8E-02	0.39		1.38E+01	1.2E-02	0.041	U	2.43E+00	2.2E-03
C3-Fluorenes	769	0.07	U	2.97E+00	3.9E-03	0.065	U	2.44E+00	3.2E-03	0.07	U	2.47E+00	3.2E-03	0.041	U	2.43E+00	3.2E-03
C3-Napthalenes	581	0.13	J	5.51E+00	9.5E-03	0.22		8.27E+00	1.4E-02	0.14		4.95E+00	8.5E-03	0.041	U	2.43E+00	4.2E-03
C4-Anthracenes/ Phenanthrenes	913	0.2		8.47E+00	9.3E-03	0.3		1.13E+01	1.2E-02	0.23		8.13E+00	8.9E-03	0.041	U	2.43E+00	2.7E-03
C4-Chrysenes	1,214	0.19		8.05E+00	6.6E-03	0.23		8.65E+00	7.1E-03	0.17		6.01E+00	4.9E-03	0.041	U	2.43E+00	2.0E-03
C4-Napthalenes	657	0.1	J	4.24E+00	6.4E-03	0.2		7.52E+00	1.1E-02	0.11	J	3.89E+00	5.9E-03	0.041	U	2.43E+00	3.7E-03
Total Toxic Units					**1**				**1**				**0.6**				**0.1**

Notes:

%	Percent
mg/kg	Milligrams per kilogram
µg/goc	Micrograms per gram organic carbon
J	Estimated value
PAH	Polycyclic aromatic hydrocarbon
U	Not-detected, value shown is one-half the non-detect value
	A toxic unit value exceeding 1 indicates the potential for toxicity to benthic organisms.

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

		026-HB1-C-C-Z1b				030-HB1-R-C-Z1a				030-HB1-R-C-Z1b				038-HB1-L-C-Z1a			
		1.5		% Organic Carbon		3.1		% Organic Carbon		2.3		% Organic Carbon		1.8		% Organic Carbon	
Compound	Final Chronic Value (µg/goc)	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.039	U	2.69E+00	5.5E-03	0.042	U	1.35E+00	2.8E-03	0.0435	U	1.92E+00	3.9E-03	0.25		1.37E+01	2.8E-02
Acenaphthylene	452	0.039	U	2.69E+00	6.0E-03	0.042	U	1.35E+00	3.0E-03	0.0435	U	1.92E+00	4.3E-03	0.099	J	5.44E+00	1.2E-02
Anthracene	594	0.039	U	2.69E+00	4.5E-03	0.042	U	1.35E+00	2.3E-03	0.0435	U	1.92E+00	3.2E-03	0.9		4.95E+01	8.3E-02
Benzo (a) anthracene	841	0.039	U	2.69E+00	3.2E-03	0.042	U	1.35E+00	1.6E-03	0.0435	U	1.92E+00	2.3E-03	0.56		3.08E+01	3.7E-02
Benzo (a) pyrene	965	0.039	U	2.69E+00	2.8E-03	0.042	U	1.35E+00	1.4E-03	0.0435	U	1.92E+00	2.0E-03	0.49		2.69E+01	2.8E-02
Benzo (b) fluoranthene	979	0.039	U	2.69E+00	2.7E-03	0.042	U	1.35E+00	1.4E-03	0.0435	U	1.92E+00	2.0E-03	0.56		3.08E+01	3.1E-02
Benzo (e) pyrene	967	0.039	U	2.69E+00	2.8E-03	0.042	U	1.35E+00	1.4E-03	0.0435	U	1.92E+00	2.0E-03	0.37		2.03E+01	2.1E-02
Benzo (g,h,i) perylene	1,095	0.039	U	2.69E+00	2.5E-03	0.042	U	1.35E+00	1.2E-03	0.0435	U	1.92E+00	1.8E-03	0.062	J	3.41E+00	3.1E-03
Benzo (k) fluoranthene	981	0.039	U	2.69E+00	2.7E-03	0.042	U	1.35E+00	1.4E-03	0.0435	U	1.92E+00	2.0E-03	0.6		3.30E+01	3.4E-02
Chrysene	844	0.039	U	2.69E+00	3.2E-03	0.042	U	1.35E+00	1.6E-03	0.027	J	1.19E+00	1.4E-03	0.64		3.52E+01	4.2E-02
Dibenz (a,h) anthracene	1,123	0.039	U	2.69E+00	2.4E-03	0.042	U	1.35E+00	1.2E-03	0.0435	U	1.92E+00	1.7E-03	0.055	U	3.02E+00	2.7E-03
Fluoranthene	707	0.039	U	2.69E+00	3.8E-03	0.042	U	1.35E+00	1.9E-03	0.0435	U	1.92E+00	2.7E-03	1.6		8.79E+01	1.2E-01
Fluorene	538	0.039	U	2.69E+00	5.0E-03	0.042	U	1.35E+00	2.5E-03	0.0435	U	1.92E+00	3.6E-03	0.64		3.52E+01	6.5E-02
Indeno (1,2,3-cd) pyrene	1,115	0.039	U	2.69E+00	2.4E-03	0.042	U	1.35E+00	1.2E-03	0.0435	U	1.92E+00	1.7E-03	0.077	J	4.23E+00	3.8E-03
Naphthalene	385	0.039	U	2.69E+00	7.0E-03	0.042	U	1.35E+00	3.5E-03	0.028	J	1.24E+00	3.2E-03	0.14		7.69E+00	2.0E-02
Phenanthrene	596	0.039	U	2.69E+00	4.5E-03	0.026	J	8.36E-01	1.4E-03	0.036	J	1.59E+00	2.7E-03	1.6		8.79E+01	1.5E-01
Pyrene	697	0.039	U	2.69E+00	3.9E-03	0.042	U	1.35E+00	1.9E-03	0.027	J	1.19E+00	1.7E-03	1		5.49E+01	7.9E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.039	U	2.69E+00	6.0E-03	0.042	U	1.35E+00	3.0E-03	0.0435	U	1.92E+00	4.3E-03	0.24		1.32E+01	3.0E-02
2-Methylnaphthalene	447	0.039	U	2.69E+00	6.0E-03	0.042	U	1.35E+00	3.0E-03	0.0435	U	1.92E+00	4.3E-03	0.22		1.21E+01	2.7E-02
C1-Anthracenes/ Phenanthrenes	670	0.039	U	2.69E+00	4.0E-03	0.023	J	7.40E-01	1.1E-03	0.031	J	1.37E+00	2.0E-03	0.9		4.95E+01	7.4E-02
C1-Chrysenes	929	0.039	U	2.69E+00	2.9E-03	0.042	U	1.35E+00	1.5E-03	0.0435	U	1.92E+00	2.1E-03	0.81		4.45E+01	4.8E-02
C1-Fluoranthenes/ Pyrenes	770	0.039	U	2.69E+00	3.5E-03	0.042	U	1.35E+00	1.8E-03	0.0435	U	1.92E+00	2.5E-03	0.92		5.05E+01	6.6E-02
C1-Fluorenes	611	0.039	U	2.69E+00	4.4E-03	0.042	U	1.35E+00	2.2E-03	0.0435	U	1.92E+00	3.2E-03	0.23		1.26E+01	2.1E-02
C2-Anthracenes/ Phenanthrenes	746	0.039	U	2.69E+00	3.6E-03	0.029	J	9.32E-01	1.2E-03	0.046	J	2.04E+00	2.7E-03	1.1		6.04E+01	8.1E-02
C2-Chrysenes	1,008	0.039	U	2.69E+00	2.7E-03	0.042	U	1.35E+00	1.3E-03	0.0435	U	1.92E+00	1.9E-03	0.53		2.91E+01	2.9E-02
C2-Fluorenes	686	0.039	U	2.69E+00	3.9E-03	0.042	U	1.35E+00	2.0E-03	0.0435	U	1.92E+00	2.8E-03	0.25		1.37E+01	2.0E-02
C2-Napthalenes	510	0.039	U	2.69E+00	5.3E-03	0.042	U	1.35E+00	2.6E-03	0.0435	U	1.92E+00	3.8E-03	0.55		3.02E+01	5.9E-02
C3-Anthracenes/ Phenanthrenes	829	0.039	U	2.69E+00	3.2E-03	0.042	U	1.35E+00	1.6E-03	0.041	J	1.81E+00	2.2E-03	0.87		4.78E+01	5.8E-02
C3-Chrysenes	1,112	0.039	U	2.69E+00	2.4E-03	0.042	U	1.35E+00	1.2E-03	0.0435	U	1.92E+00	1.7E-03	0.34		1.87E+01	1.7E-02
C3-Fluorenes	769	0.039	U	2.69E+00	3.5E-03	0.042	U	1.35E+00	1.8E-03	0.0435	U	1.92E+00	2.5E-03	0.42		2.31E+01	3.0E-02
C3-Napthalenes	581	0.039	U	2.69E+00	4.6E-03	0.042	U	1.35E+00	2.3E-03	0.0435	U	1.92E+00	3.3E-03	0.64		3.52E+01	6.1E-02
C4-Anthracenes/ Phenanthrenes	913	0.039	U	2.69E+00	2.9E-03	0.042	U	1.35E+00	1.5E-03	0.0435	U	1.92E+00	2.1E-03	0.3		1.65E+01	1.8E-02
C4-Chrysenes	1,214	0.039	U	2.69E+00	2.2E-03	0.042	U	1.35E+00	1.1E-03	0.0435	U	1.92E+00	1.6E-03	0.21		1.15E+01	9.5E-03
C4-Napthalenes	657	0.039	U	2.69E+00	4.1E-03	0.042	U	1.35E+00	2.1E-03	0.0435	U	1.92E+00	2.9E-03	0.45		2.47E+01	3.8E-02
Total Toxic Units					**0.1**				**0.06**				**0.09**				**1**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	038-HB1-L-C-Z1b PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	041-HB1-L-C-Z1a PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	041-HB1-L-C-Z1b PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	043-HB1-L-C-Z1a PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
% Organic Carbon		2.2				2.1				2.0				1.9			
Unsubstituted PAHs																	
Acenaphthene	491	1		4.55E+01	9.3E-02	0.06	U	2.90E+00	5.9E-03	0.06	U	2.97E+00	6.0E-03	0.33		1.77E+01	3.6E-02
Acenaphthylene	452	0.21		9.55E+00	2.1E-02	0.06	U	2.90E+00	6.4E-03	0.06	U	2.97E+00	6.6E-03	0.05	U	2.69E+00	5.9E-03
Anthracene	594	2		9.09E+01	1.5E-01	0.039	J	1.88E+00	3.2E-03	0.032	J	1.58E+00	2.7E-03	0.37		1.99E+01	3.3E-02
Benzo (a) anthracene	841	1.4		6.36E+01	7.6E-02	0.16		7.73E+00	9.2E-03	0.14		6.93E+00	8.2E-03	0.71		3.82E+01	4.5E-02
Benzo (a) pyrene	965	1		4.55E+01	4.7E-02	0.18		8.70E+00	9.0E-03	0.16		7.92E+00	8.2E-03	0.25		1.34E+01	1.4E-02
Benzo (b) fluoranthene	979	1.8		8.18E+01	8.4E-02	0.23		1.11E+01	1.1E-02	0.23		1.14E+01	1.2E-02	0.49		2.63E+01	2.7E-02
Benzo (e) pyrene	967	0.73		3.32E+01	3.4E-02	0.16		7.73E+00	8.0E-03	0.15		7.43E+00	7.7E-03	0.33		1.77E+01	1.8E-02
Benzo (g,h,i) perylene	1,095	0.077	J	3.50E+00	3.2E-03	0.049	J	2.37E+00	2.2E-03	0.045	J	2.23E+00	2.0E-03	0.03	J	1.61E+00	1.5E-03
Benzo (k) fluoranthene	981	1.2		5.45E+01	5.6E-02	0.26		1.26E+01	1.3E-02	0.2		9.90E+00	1.0E-02	0.32		1.72E+01	1.8E-02
Chrysene	844	1.3		5.91E+01	7.0E-02	0.24		1.16E+01	1.4E-02	0.22		1.09E+01	1.3E-02	0.73		3.92E+01	4.7E-02
Dibenz (a,h) anthracene	1,123	0.031	J	1.41E+00	1.3E-03	0.06	U	2.90E+00	2.6E-03	0.06	U	2.97E+00	2.6E-03	0.05	U	2.69E+00	2.4E-03
Fluoranthene	707	3.9	D	1.77E+02	2.5E-01	0.46		2.22E+01	3.1E-02	0.4		1.98E+01	2.8E-02	1.2		6.45E+01	9.1E-02
Fluorene	538	2.1		9.55E+01	1.8E-01	0.06	U	2.90E+00	5.4E-03	0.06	U	2.97E+00	5.5E-03	0.4		2.15E+01	4.0E-02
Indeno (1,2,3-cd) pyrene	1,115	0.084	J	3.82E+00	3.4E-03	0.057	J	2.75E+00	2.5E-03	0.051	J	2.52E+00	2.3E-03	0.026	J	1.40E+00	1.3E-03
Naphthalene	385	0.41		1.86E+01	4.8E-02	0.06	U	2.90E+00	7.5E-03	0.06	U	2.97E+00	7.7E-03	0.087	J	4.68E+00	1.2E-02
Phenanthrene	596	4.8	D	2.18E+02	3.7E-01	0.2		9.66E+00	1.6E-02	0.17		8.42E+00	1.4E-02	1.4		7.53E+01	1.3E-01
Pyrene	697	1.9		8.64E+01	1.2E-01	0.35		1.69E+01	2.4E-02	0.3		1.49E+01	2.1E-02	0.82		4.41E+01	6.3E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	1		4.55E+01	1.0E-01	0.06	U	2.90E+00	6.5E-03	0.06	U	2.97E+00	6.7E-03	0.3		1.61E+01	3.6E-02
2-Methylnaphthalene	447	1.4		6.36E+01	1.4E-01	0.06	U	2.90E+00	6.5E-03	0.06	U	2.97E+00	6.6E-03	0.15		8.06E+00	1.8E-02
C1-Anthracenes/ Phenanthrenes	670	2.7		1.23E+02	1.8E-01	0.1	J	4.83E+00	7.2E-03	0.096	J	4.75E+00	7.1E-03	1.6		8.60E+01	1.3E-01
C1-Chrysenes	929	1.8		8.18E+01	8.8E-02	0.17		8.21E+00	8.8E-03	0.15		7.43E+00	8.0E-03	1.9		1.02E+02	1.1E-01
C1-Fluoranthenes/ Pyrenes	770	2.8		1.27E+02	1.7E-01	0.18		8.70E+00	1.1E-02	0.17		8.42E+00	1.1E-02	1.9		1.02E+02	1.3E-01
C1-Fluorenes	611	0.73		3.32E+01	5.4E-02	0.06	U	2.90E+00	4.7E-03	0.06	U	2.97E+00	4.9E-03	0.35		1.88E+01	3.1E-02
C2-Anthracenes/ Phenanthrenes	746	2.8		1.27E+02	1.7E-01	0.13		6.28E+00	8.4E-03	0.13		6.44E+00	8.6E-03	3		1.61E+02	2.2E-01
C2-Chrysenes	1,008	1.1		5.00E+01	5.0E-02	0.083	J	4.01E+00	4.0E-03	0.055	J	2.72E+00	2.7E-03	1.5		8.06E+01	8.0E-02
C2-Fluorenes	686	0.96		4.36E+01	6.4E-02	0.06	U	2.90E+00	4.2E-03	0.06	U	2.97E+00	4.3E-03	0.72		3.87E+01	5.6E-02
C2-Napthalenes	510	2		9.09E+01	1.8E-01	0.06	U	2.90E+00	5.7E-03	0.06	U	2.97E+00	5.8E-03	0.99		5.32E+01	1.0E-01
C3-Anthracenes/ Phenanthrenes	829	2.4		1.09E+02	1.3E-01	0.12		5.80E+00	7.0E-03	0.12		5.94E+00	7.2E-03	3.3		1.77E+02	2.1E-01
C3-Chrysenes	1,112	0.31		1.41E+01	1.3E-02	0.06	U	2.90E+00	2.6E-03	0.06	U	2.97E+00	2.7E-03	0.55		2.96E+01	2.7E-02
C3-Fluorenes	769	1.1		5.00E+01	6.5E-02	0.06	U	2.90E+00	3.8E-03	0.06	U	2.97E+00	3.9E-03	1.2		6.45E+01	8.4E-02
C3-Napthalenes	581	1.9		8.64E+01	1.5E-01	0.06	U	2.90E+00	5.0E-03	0.06	U	2.97E+00	5.1E-03	1.4		7.53E+01	1.3E-01
C4-Anthracenes/ Phenanthrenes	913	0.83		3.77E+01	4.1E-02	0.06	U	2.90E+00	3.2E-03	0.06	U	2.97E+00	3.3E-03	2.4		1.29E+02	1.4E-01
C4-Chrysenes	1,214	0.2		9.09E+00	7.5E-03	0.06	U	2.90E+00	2.4E-03	0.06	U	2.97E+00	2.4E-03	0.27		1.45E+01	1.2E-02
C4-Napthalenes	657	1.4		6.36E+01	9.7E-02	0.06	U	2.90E+00	4.4E-03	0.06	U	2.97E+00	4.5E-03	1.2		6.45E+01	9.8E-02
Total Toxic Units					**3**				**0.3**				**0.3**				**2**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	043-HB1-L-C-Z1b 1.6 % Organic Carbon				047-HB1-C-C-Z1a 2.5 % Organic Carbon				047-HB1-C-C-Z1b 3.2 % Organic Carbon				054-MA1-R-C-Z1a 3.2 % Organic Carbon			
		PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.31		1.89E+01	3.8E-02	0.26		1.06E+01	2.2E-02	0.2		6.17E+00	1.3E-02	4.4		1.39E+02	2.8E-01
Acenaphthylene	452	0.046	U	2.80E+00	6.2E-03	0.098	J	4.00E+00	8.8E-03	0.099	J	3.06E+00	6.8E-03	0.6	U	1.90E+01	4.2E-02
Anthracene	594	0.33		2.01E+01	3.4E-02	0.77		3.14E+01	5.3E-02	0.57		1.76E+01	3.0E-02	5.6		1.77E+02	3.0E-01
Benzo (a) anthracene	841	0.61		3.72E+01	4.4E-02	0.87		3.55E+01	4.2E-02	0.75		2.31E+01	2.8E-02	2.6		8.23E+01	9.8E-02
Benzo (a) pyrene	965	0.24		1.46E+01	1.5E-02	0.77		3.14E+01	3.3E-02	0.74		2.28E+01	2.4E-02	1.5		4.75E+01	4.9E-02
Benzo (b) fluoranthene	979	0.49		2.99E+01	3.1E-02	1.6		6.53E+01	6.7E-02	1.2		3.70E+01	3.8E-02	1.6		5.06E+01	5.2E-02
Benzo (e) pyrene	967	0.28		1.71E+01	1.8E-02	0.58		2.37E+01	2.4E-02	0.57		1.76E+01	1.8E-02	0.92	J	2.91E+01	3.0E-02
Benzo (g,h,i) perylene	1,095	0.046	U	2.80E+00	2.6E-03	0.097	J	3.96E+00	3.6E-03	0.08	J	2.47E+00	2.3E-03	0.95	J	3.01E+01	2.7E-02
Benzo (k) fluoranthene	981	0.22		1.34E+01	1.4E-02	0.94		3.84E+01	3.9E-02	1.1		3.40E+01	3.5E-02	1.2		3.80E+01	3.9E-02
Chrysene	844	0.67		4.09E+01	4.8E-02	0.89		3.63E+01	4.3E-02	0.82		2.53E+01	3.0E-02	2.5		7.91E+01	9.4E-02
Dibenz (a,h) anthracene	1,123	0.046	U	2.80E+00	2.5E-03	0.055	U	2.24E+00	2.0E-03	0.055	U	1.70E+00	1.5E-03	0.33	J	1.04E+01	9.3E-03
Fluoranthene	707	0.97		5.91E+01	8.4E-02	2.6		1.06E+02	1.5E-01	2.2		6.79E+01	9.6E-02	9.9		3.13E+02	4.4E-01
Fluorene	538	0.34		2.07E+01	3.9E-02	0.3		1.22E+01	2.3E-02	0.25		7.72E+00	1.4E-02	3.7		1.17E+02	2.2E-01
Indeno (1,2,3-cd) pyrene	1,115	0.046	U	2.80E+00	2.5E-03	0.096	J	3.92E+00	3.5E-03	0.073	J	2.25E+00	2.0E-03	0.79	J	2.50E+01	2.2E-02
Naphthalene	385	0.068	J	4.15E+00	1.1E-02	0.12		4.90E+00	1.3E-02	0.086	J	2.65E+00	6.9E-03	0.73	J	2.31E+01	6.0E-02
Phenanthrene	596	1.2		7.32E+01	1.2E-01	1.5		6.12E+01	1.0E-01	1.1		3.40E+01	5.7E-02	16		5.06E+02	8.5E-01
Pyrene	697	0.67		4.09E+01	5.9E-02	1.3		5.31E+01	7.6E-02	1.1		3.40E+01	4.9E-02	7.4		2.34E+02	3.4E-01
Alkylated PAHs																	
1-Methylnaphthalene	446	0.18		1.10E+01	2.5E-02	0.15		6.12E+00	1.4E-02	0.12		3.70E+00	8.3E-03	2.1		6.65E+01	1.5E-01
2-Methylnaphthalene	447	0.24		1.46E+01	3.3E-02	0.17		6.94E+00	1.6E-02	0.12		3.70E+00	8.3E-03	1.5		4.75E+01	1.1E-01
C1-Anthracenes/ Phenanthrenes	670	1.3		7.93E+01	1.2E-01	1.7		6.94E+01	1.0E-01	1.3		4.01E+01	6.0E-02	5.9		1.87E+02	2.8E-01
C1-Chrysenes	929	1.6		9.76E+01	1.1E-01	0.82		3.35E+01	3.6E-02	0.72		2.22E+01	2.4E-02	1.4		4.43E+01	4.8E-02
C1-Fluoranthenes/ Pyrenes	770	1.6		9.76E+01	1.3E-01	1.8		7.35E+01	9.5E-02	1.5		4.63E+01	6.0E-02	4		1.27E+02	1.6E-01
C1-Fluorenes	611	0.29		1.77E+01	2.9E-02	0.57		2.33E+01	3.8E-02	0.39		1.20E+01	2.0E-02	1.3		4.11E+01	6.7E-02
C2-Anthracenes/ Phenanthrenes	746	2.3		1.40E+02	1.9E-01	2.4		9.80E+01	1.3E-01	1.9		5.86E+01	7.9E-02	4.9		1.55E+02	2.1E-01
C2-Chrysenes	1,008	1.2		7.32E+01	7.3E-02	0.59		2.41E+01	2.4E-02	0.47		1.45E+01	1.4E-02	0.86	J	2.72E+01	2.7E-02
C2-Fluorenes	686	0.59		3.60E+01	5.2E-02	0.92		3.76E+01	5.5E-02	0.71		2.19E+01	3.2E-02	1.7		5.38E+01	7.8E-02
C2-Napthalenes	510	0.78		4.76E+01	9.3E-02	0.75		3.06E+01	6.0E-02	0.6		1.85E+01	3.6E-02	5		1.58E+02	3.1E-01
C3-Anthracenes/ Phenanthrenes	829	2.7		1.65E+02	2.0E-01	2.2		8.98E+01	1.1E-01	1.7		5.25E+01	6.3E-02	3.8		1.20E+02	1.5E-01
C3-Chrysenes	1,112	0.5		3.05E+01	2.7E-02	0.15		6.12E+00	5.5E-03	0.13		4.01E+00	3.6E-03	0.6	U	1.90E+01	1.7E-02
C3-Fluorenes	769	0.88		5.37E+01	7.0E-02	1.2		4.90E+01	6.4E-02	0.97		2.99E+01	3.9E-02	1.7		5.38E+01	7.0E-02
C3-Napthalenes	581	1.1		6.71E+01	1.2E-01	1.5		6.12E+01	1.1E-01	1.2		3.70E+01	6.4E-02	5.9		1.87E+02	3.2E-01
C4-Anthracenes/ Phenanthrenes	913	2		1.22E+02	1.3E-01	1.1		4.49E+01	4.9E-02	0.86		2.65E+01	2.9E-02	1.3		4.11E+01	4.5E-02
C4-Chrysenes	1,214	0.24		1.46E+01	1.2E-02	0.055	U	2.24E+00	1.8E-03	0.055	U	1.70E+00	1.4E-03	0.6	U	1.90E+01	1.6E-02
C4-Napthalenes	657	0.89		5.43E+01	8.3E-02	1.5		6.12E+01	9.3E-02	1.2		3.70E+01	5.6E-02	4		1.27E+02	1.9E-01
Total Toxic Units					**2**				**2**				**1**				**5**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	054-MA1-R-C-Z1b 2.8 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	058-HB1-R-C-Z1a 2.7 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	058-HB1-R-C-Z1b 2.9 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	065-MA1-C-C-Z1a 2.0 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	16		5.80E+02	1.2E+00	2		7.55E+01	1.5E-01	4.1		1.43E+02	2.9E-01	0.06	U	3.00E+00	6.1E-03
Acenaphthylene	452	2.7	U	9.78E+01	2.2E-01	0.27	J	1.02E+01	2.3E-02	0.32	J	1.11E+01	2.5E-02	0.06	U	3.00E+00	6.6E-03
Anthracene	594	21		7.61E+02	1.3E+00	3.1		1.17E+02	2.0E-01	7.1		2.47E+02	4.2E-01	0.057	J	2.85E+00	4.8E-03
Benzo (a) anthracene	841	6.6		2.39E+02	2.8E-01	1.8		6.79E+01	8.1E-02	3.5		1.22E+02	1.5E-01	0.24		1.20E+01	1.4E-02
Benzo (a) pyrene	965	3.5	J	1.27E+02	1.3E-01	1.1		4.15E+01	4.3E-02	1.8		6.27E+01	6.5E-02	0.25		1.25E+01	1.3E-02
Benzo (b) fluoranthene	979	5.4	J	1.96E+02	2.0E-01	1.3		4.91E+01	5.0E-02	1.6		5.57E+01	5.7E-02	0.34		1.70E+01	1.7E-02
Benzo (e) pyrene	967	2	J	7.25E+01	7.5E-02	0.76		2.87E+01	3.0E-02	1.2		4.18E+01	4.3E-02	0.23		1.15E+01	1.2E-02
Benzo (g,h,i) perylene	1,095	2.7	U	9.78E+01	8.9E-02	0.29	J	1.09E+01	1.0E-02	0.42	J	1.46E+01	1.3E-02	0.07	J	3.50E+00	3.2E-03
Benzo (k) fluoranthene	981	2.7	U	9.78E+01	1.0E-01	0.96		3.62E+01	3.7E-02	1.9		6.62E+01	6.7E-02	0.38		1.90E+01	1.9E-02
Chrysene	844	6.2		2.25E+02	2.7E-01	1.8		6.79E+01	8.0E-02	3.3		1.15E+02	1.4E-01	0.37		1.85E+01	2.2E-02
Dibenz (a,h) anthracene	1,123	2.7	U	9.78E+01	8.7E-02	0.29	U	1.09E+01	9.7E-03	0.55	U	1.92E+01	1.7E-02	0.06	U	3.00E+00	2.7E-03
Fluoranthene	707	33		1.20E+03	1.7E+00	7.1		2.68E+02	3.8E-01	16		5.57E+02	7.9E-01	0.7		3.50E+01	5.0E-02
Fluorene	538	14		5.07E+02	9.4E-01	1.9		7.17E+01	1.3E-01	4.1		1.43E+02	2.7E-01	0.036	J	1.80E+00	3.3E-03
Indeno (1,2,3-cd) pyrene	1,115	1.4	J	5.07E+01	4.5E-02	0.34	J	1.28E+01	1.2E-02	0.46	J	1.60E+01	1.4E-02	0.082	J	4.10E+00	3.7E-03
Naphthalene	385	1.7	J	6.16E+01	1.6E-01	0.36	J	1.36E+01	3.5E-02	0.76	J	2.65E+01	6.9E-02	0.06	U	3.00E+00	7.8E-03
Phenanthrene	596	63		2.28E+03	3.8E+00	8.2		3.09E+02	5.2E-01	21		7.32E+02	1.2E+00	0.3		1.50E+01	2.5E-02
Pyrene	697	23		8.33E+02	1.2E+00	4.4		1.66E+02	2.4E-01	9.6		3.34E+02	4.8E-01	0.44		2.20E+01	3.2E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	7.3		2.64E+02	5.9E-01	1.1		4.15E+01	9.3E-02	2.6		9.06E+01	2.0E-01	0.06	U	3.00E+00	6.7E-03
2-Methylnaphthalene	447	14		5.07E+02	1.1E+00	0.16	J	6.04E+00	1.4E-02	0.35	J	1.22E+01	2.7E-02	0.06	U	3.00E+00	6.7E-03
C1-Anthracenes/ Phenanthrenes	670	22		7.97E+02	1.2E+00	4.9		1.85E+02	2.8E-01	12		4.18E+02	6.2E-01	0.14		7.00E+00	1.0E-02
C1-Chrysenes	929	2.7	U	9.78E+01	1.1E-01	1.4		5.28E+01	5.7E-02	2.5		8.71E+01	9.4E-02	0.24		1.20E+01	1.3E-02
C1-Fluoranthenes/ Pyrenes	770	11		3.99E+02	5.2E-01	4		1.51E+02	2.0E-01	7.3		2.54E+02	3.3E-01	0.29		1.45E+01	1.9E-02
C1-Fluorenes	611	5	J	1.81E+02	3.0E-01	1.4		5.28E+01	8.6E-02	2.9		1.01E+02	1.7E-01	0.06	U	3.00E+00	4.9E-03
C2-Anthracenes/ Phenanthrenes	746	16		5.80E+02	7.8E-01	4.2		1.58E+02	2.1E-01	9.7		3.38E+02	4.5E-01	0.06	U	3.00E+00	4.0E-03
C2-Chrysenes	1,008	2.7	U	9.78E+01	9.7E-02	0.84		3.17E+01	3.1E-02	1.3		4.53E+01	4.5E-02	0.082	J	4.10E+00	4.1E-03
C2-Fluorenes	686	2.7	U	9.78E+01	1.4E-01	1.3		4.91E+01	7.2E-02	3.3		1.15E+02	1.7E-01	0.06	U	3.00E+00	4.4E-03
C2-Napthalenes	510	19		6.88E+02	1.3E+00	3.8		1.43E+02	2.8E-01	9.2		3.21E+02	6.3E-01	0.06	U	3.00E+00	5.9E-03
C3-Anthracenes/ Phenanthrenes	829	9.4		3.41E+02	4.1E-01	3.5		1.32E+02	1.6E-01	6.1		2.13E+02	2.6E-01	0.06	U	3.00E+00	3.6E-03
C3-Chrysenes	1,112	2.7	U	9.78E+01	8.8E-02	0.53	J	2.00E+01	1.8E-02	0.87	J	3.03E+01	2.7E-02	0.076	J	3.80E+00	3.4E-03
C3-Fluorenes	769	2.7	U	9.78E+01	1.3E-01	1.7		6.42E+01	8.3E-02	3.5		1.22E+02	1.6E-01	0.06	U	3.00E+00	3.9E-03
C3-Napthalenes	581	20		7.25E+02	1.2E+00	5		1.89E+02	3.2E-01	12		4.18E+02	7.2E-01	0.06	U	3.00E+00	5.2E-03
C4-Anthracenes/ Phenanthrenes	913	2.7	U	9.78E+01	1.1E-01	1.1		4.15E+01	4.5E-02	2.3		8.01E+01	8.8E-02	0.06	U	3.00E+00	3.3E-03
C4-Chrysenes	1,214	2.7	U	9.78E+01	8.1E-02	0.24	J	9.06E+00	7.5E-03	0.85	J	2.96E+01	2.4E-02	0.06	U	3.00E+00	2.5E-03
C4-Napthalenes	657	13		4.71E+02	7.2E-01	3.7		1.40E+02	2.1E-01	8.8		3.07E+02	4.7E-01	0.06	U	3.00E+00	4.6E-03
Total Toxic Units					**21**				**4**				**9**				**0.3**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

		065-MA1-C-C-Z1b				066-MA2-R-C-Z1a				066-MA2-R-C-Z1b				075-MA1-C-C-Z1a			
		2.2		% Organic Carbon		3.6		% Organic Carbon		4.9		% Organic Carbon		2.2		% Organic Carbon	
Compound	Final Chronic Value (µg/goc)	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.049	J	2.26E+00	4.6E-03	1.2		3.35E+01	6.8E-02	23		4.67E+02	9.5E-01	0.06	U	2.75E+00	5.6E-03
Acenaphthylene	452	0.055	U	2.53E+00	5.6E-03	0.25	J	6.98E+00	1.5E-02	2.15	U	4.37E+01	9.7E-02	0.06	U	2.75E+00	6.1E-03
Anthracene	594	0.099	J	4.56E+00	7.7E-03	2.8		7.82E+01	1.3E-01	19		3.86E+02	6.5E-01	0.032	J	1.47E+00	2.5E-03
Benzo (a) anthracene	841	0.41		1.89E+01	2.2E-02	3.5		9.78E+01	1.2E-01	11		2.24E+02	2.7E-01	0.16		7.34E+00	8.7E-03
Benzo (a) pyrene	965	0.39		1.80E+01	1.9E-02	2.8		7.82E+01	8.1E-02	6.6		1.34E+02	1.4E-01	0.17		7.80E+00	8.1E-03
Benzo (b) fluoranthene	979	0.93		4.29E+01	4.4E-02	2.3		6.42E+01	6.6E-02	10	J	2.03E+02	2.1E-01	0.41	J	1.88E+01	1.9E-02
Benzo (e) pyrene	967	0.32		1.47E+01	1.5E-02	1.6		4.47E+01	4.6E-02	4	J	8.13E+01	8.4E-02	0.17		7.80E+00	8.1E-03
Benzo (g,h,i) perylene	1,095	0.074	J	3.41E+00	3.1E-03	0.48	J	1.34E+01	1.2E-02	3.9	J	7.93E+01	7.2E-02	0.067	J	3.07E+00	2.8E-03
Benzo (k) fluoranthene	981	0.055	U	2.53E+00	2.6E-03	2.2		6.15E+01	6.3E-02	2.15	U	4.37E+01	4.5E-02	0.06	U	2.75E+00	2.8E-03
Chrysene	844	0.56		2.58E+01	3.1E-02	3.1		8.66E+01	1.0E-01	11		2.24E+02	2.6E-01	0.25		1.15E+01	1.4E-02
Dibenz (a,h) anthracene	1,123	0.038	J	1.75E+00	1.6E-03	0.385	U	1.08E+01	9.6E-03	2.15	U	4.37E+01	3.9E-02	0.06	U	2.75E+00	2.5E-03
Fluoranthene	707	1.3		5.99E+01	8.5E-02	8		2.23E+02	3.2E-01	36		7.32E+02	1.0E+00	0.43		1.97E+01	2.8E-02
Fluorene	538	0.061	J	2.81E+00	5.2E-03	1.2		3.35E+01	6.2E-02	17		3.46E+02	6.4E-01	0.06	U	2.75E+00	5.1E-03
Indeno (1,2,3-cd) pyrene	1,115	0.088	J	4.06E+00	3.6E-03	0.57	J	1.59E+01	1.4E-02	3.7	J	7.52E+01	6.7E-02	0.086	J	3.94E+00	3.5E-03
Naphthalene	385	0.055	U	2.53E+00	6.6E-03	0.79		2.21E+01	5.7E-02	4.6		9.35E+01	2.4E-01	0.06	U	2.75E+00	7.1E-03
Phenanthrene	596	0.56		2.58E+01	4.3E-02	6.5		1.82E+02	3.0E-01	59		1.20E+03	2.0E+00	0.18		8.26E+00	1.4E-02
Pyrene	697	0.67		3.09E+01	4.4E-02	4.3		1.20E+02	1.7E-01	25		5.08E+02	7.3E-01	0.31		1.42E+01	2.0E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.055	U	2.53E+00	5.7E-03	1.1		3.07E+01	6.9E-02	9.8		1.99E+02	4.5E-01	0.06	U	2.75E+00	6.2E-03
2-Methylnaphthalene	447	0.055	U	2.53E+00	5.7E-03	1.2		3.35E+01	7.5E-02	20		4.07E+02	9.1E-01	0.06	U	2.75E+00	6.2E-03
C1-Anthracenes/ Phenanthrenes	670	0.26		1.20E+01	1.8E-02	5.8		1.62E+02	2.4E-01	31		6.30E+02	9.4E-01	0.06	U	2.75E+00	4.1E-03
C1-Chrysenes	929	0.23		1.06E+01	1.1E-02	2.2		6.15E+01	6.6E-02	7.7		1.57E+02	1.7E-01	0.15		6.88E+00	7.4E-03
C1-Fluoranthenes/ Pyrenes	770	0.49		2.26E+01	2.9E-02	4.7		1.31E+02	1.7E-01	17		3.46E+02	4.5E-01	0.15		6.88E+00	8.9E-03
C1-Fluorenes	611	0.055	U	2.53E+00	4.1E-03	1.1		3.07E+01	5.0E-02	10		2.03E+02	3.3E-01	0.06	U	2.75E+00	4.5E-03
C2-Anthracenes/ Phenanthrenes	746	0.19		8.76E+00	1.2E-02	6.6		1.84E+02	2.5E-01	27		5.49E+02	7.4E-01	0.06	U	2.75E+00	3.7E-03
C2-Chrysenes	1,008	0.1	J	4.61E+00	4.6E-03	1.7		4.75E+01	4.7E-02	3.8	J	7.72E+01	7.7E-02	0.06	U	2.75E+00	2.7E-03
C2-Fluorenes	686	0.055	U	2.53E+00	3.7E-03	2		5.59E+01	8.1E-02	6.6		1.34E+02	2.0E-01	0.06	U	2.75E+00	4.0E-03
C2-Napthalenes	510	0.055	U	2.53E+00	5.0E-03	4.4		1.23E+02	2.4E-01	36		7.32E+02	1.4E+00	0.06	U	2.75E+00	5.4E-03
C3-Anthracenes/ Phenanthrenes	829	0.14		6.45E+00	7.8E-03	4.8		1.34E+02	1.6E-01	18		3.66E+02	4.4E-01	0.06	U	2.75E+00	3.3E-03
C3-Chrysenes	1,112	0.19		8.76E+00	7.9E-03	1.3		3.63E+01	3.3E-02	2.15	U	4.37E+01	3.9E-02	0.06	U	2.75E+00	2.5E-03
C3-Fluorenes	769	0.055	U	2.53E+00	3.3E-03	2.2		6.15E+01	8.0E-02	12		2.44E+02	3.2E-01	0.06	U	2.75E+00	3.6E-03
C3-Napthalenes	581	0.055	U	2.53E+00	4.4E-03	6.7		1.87E+02	3.2E-01	43		8.74E+02	1.5E+00	0.06	U	2.75E+00	4.7E-03
C4-Anthracenes/ Phenanthrenes	913	0.055	U	2.53E+00	2.8E-03	2.2		6.15E+01	6.7E-02	7.1		1.44E+02	1.6E-01	0.06	U	2.75E+00	3.0E-03
C4-Chrysenes	1,214	0.073	J	3.36E+00	2.8E-03	1		2.79E+01	2.3E-02	2.15	U	4.37E+01	3.6E-02	0.06	U	2.75E+00	2.3E-03
C4-Napthalenes	657	0.055	U	2.53E+00	3.9E-03	3.9		1.09E+02	1.7E-01	26		5.28E+02	8.0E-01	0.06	U	2.75E+00	4.2E-03
Total Toxic Units					**0.5**				**4**				**17**				**0.2**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

		075-MA1-C-C-Z1b				080-MC1-C-C-Z1a				080-MC1-C-C-Z1b				083-EA1-R-C-Z1a			
		2.3		% Organic Carbon		2.5		% Organic Carbon		2.7		% Organic Carbon		2.0		% Organic Carbon	
Compound	Final Chronic Value (µg/goc)	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.06	U	2.67E+00	5.4E-03	0.06	U	2.40E+00	4.9E-03	0.06	U	2.21E+00	4.5E-03	0.034	J	1.67E+00	3.4E-03
Acenaphthylene	452	0.06	U	2.67E+00	5.9E-03	0.06	U	2.40E+00	5.3E-03	0.06	U	2.21E+00	4.9E-03	0.055	U	2.71E+00	6.0E-03
Anthracene	594	0.06	U	2.67E+00	4.5E-03	0.036	J	1.44E+00	2.4E-03	0.06	U	2.21E+00	3.7E-03	0.068	J	3.35E+00	5.6E-03
Benzo (a) anthracene	841	0.13		5.78E+00	6.9E-03	0.19		7.60E+00	9.0E-03	0.15		5.54E+00	6.6E-03	0.26		1.28E+01	1.5E-02
Benzo (a) pyrene	965	0.13		5.78E+00	6.0E-03	0.2		8.00E+00	8.3E-03	0.15		5.54E+00	5.7E-03	0.26		1.28E+01	1.3E-02
Benzo (b) fluoranthene	979	0.16		7.11E+00	7.3E-03	0.22		8.80E+00	9.0E-03	0.23		8.49E+00	8.7E-03	0.32		1.58E+01	1.6E-02
Benzo (e) pyrene	967	0.12	J	5.33E+00	5.5E-03	0.17		6.80E+00	7.0E-03	0.14		5.17E+00	5.3E-03	0.22		1.08E+01	1.1E-02
Benzo (g,h,i) perylene	1,095	0.055	J	2.44E+00	2.2E-03	0.097	J	3.88E+00	3.5E-03	0.072	J	2.66E+00	2.4E-03	0.095	J	4.68E+00	4.3E-03
Benzo (k) fluoranthene	981	0.19		8.44E+00	8.6E-03	0.25		1.00E+01	1.0E-02	0.15		5.54E+00	5.6E-03	0.31		1.53E+01	1.6E-02
Chrysene	844	0.18		8.00E+00	9.5E-03	0.3		1.20E+01	1.4E-02	0.22		8.12E+00	9.6E-03	0.38		1.87E+01	2.2E-02
Dibenz (a,h) anthracene	1,123	0.06	U	2.67E+00	2.4E-03	0.06	U	2.40E+00	2.1E-03	0.031	J	1.14E+00	1.0E-03	0.04	J	1.97E+00	1.8E-03
Fluoranthene	707	0.34		1.51E+01	2.1E-02	0.49		1.96E+01	2.8E-02	0.39		1.44E+01	2.0E-02	0.7		3.45E+01	4.9E-02
Fluorene	538	0.06	U	2.67E+00	5.0E-03	0.06	U	2.40E+00	4.5E-03	0.06	U	2.21E+00	4.1E-03	0.042	J	2.07E+00	3.8E-03
Indeno (1,2,3-cd) pyrene	1,115	0.066	J	2.93E+00	2.6E-03	0.11	J	4.40E+00	3.9E-03	0.08	J	2.95E+00	2.6E-03	0.093	J	4.58E+00	4.1E-03
Naphthalene	385	0.06	U	2.67E+00	6.9E-03	0.06	U	2.40E+00	6.2E-03	0.06	U	2.21E+00	5.8E-03	0.041	J	2.02E+00	5.2E-03
Phenanthrene	596	0.16		7.11E+00	1.2E-02	0.22		8.80E+00	1.5E-02	0.2		7.38E+00	1.2E-02	0.31		1.53E+01	2.6E-02
Pyrene	697	0.25		1.11E+01	1.6E-02	0.4		1.60E+01	2.3E-02	0.33		1.22E+01	1.7E-02	0.51		2.51E+01	3.6E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.06	U	2.67E+00	6.0E-03	0.06	U	2.40E+00	5.4E-03	0.06	U	2.21E+00	5.0E-03	0.055	U	2.71E+00	6.1E-03
2-Methylnaphthalene	447	0.06	U	2.67E+00	6.0E-03	0.06	U	2.40E+00	5.4E-03	0.06	U	2.21E+00	5.0E-03	0.055	U	2.71E+00	6.1E-03
C1-Anthracenes/ Phenanthrenes	670	0.06	U	2.67E+00	4.0E-03	0.06	U	2.40E+00	3.6E-03	0.06	U	2.21E+00	3.3E-03	0.15		7.39E+00	1.1E-02
C1-Chrysenes	929	0.06	U	2.67E+00	2.9E-03	0.13		5.20E+00	5.6E-03	0.06	U	2.21E+00	2.4E-03	0.25		1.23E+01	1.3E-02
C1-Fluoranthenes/ Pyrenes	770	0.06	U	2.67E+00	3.5E-03	0.15		6.00E+00	7.8E-03	0.13		4.80E+00	6.2E-03	0.26		1.28E+01	1.7E-02
C1-Fluorenes	611	0.06	U	2.67E+00	4.4E-03	0.06	U	2.40E+00	3.9E-03	0.06	U	2.21E+00	3.6E-03	0.055	U	2.71E+00	4.4E-03
C2-Anthracenes/ Phenanthrenes	746	0.06	U	2.67E+00	3.6E-03	0.06	U	2.40E+00	3.2E-03	0.06	U	2.21E+00	3.0E-03	0.16		7.88E+00	1.1E-02
C2-Chrysenes	1,008	0.06	U	2.67E+00	2.6E-03	0.06	U	2.40E+00	2.4E-03	0.06	U	2.21E+00	2.2E-03	0.11	J	5.42E+00	5.4E-03
C2-Fluorenes	686	0.06	U	2.67E+00	3.9E-03	0.06	U	2.40E+00	3.5E-03	0.06	U	2.21E+00	3.2E-03	0.055	U	2.71E+00	3.9E-03
C2-Napthalenes	510	0.06	U	2.67E+00	5.2E-03	0.06	U	2.40E+00	4.7E-03	0.06	U	2.21E+00	4.3E-03	0.055	U	2.71E+00	5.3E-03
C3-Anthracenes/ Phenanthrenes	829	0.06	U	2.67E+00	3.2E-03	0.06	U	2.40E+00	2.9E-03	0.06	U	2.21E+00	2.7E-03	0.16		7.88E+00	9.5E-03
C3-Chrysenes	1,112	0.06	U	2.67E+00	2.4E-03	0.06	U	2.40E+00	2.2E-03	0.06	U	2.21E+00	2.0E-03	0.055	U	2.71E+00	2.4E-03
C3-Fluorenes	769	0.06	U	2.67E+00	3.5E-03	0.06	U	2.40E+00	3.1E-03	0.06	U	2.21E+00	2.9E-03	0.055	U	2.71E+00	3.5E-03
C3-Napthalenes	581	0.06	U	2.67E+00	4.6E-03	0.06	U	2.40E+00	4.1E-03	0.06	U	2.21E+00	3.8E-03	0.055	U	2.71E+00	4.7E-03
C4-Anthracenes/ Phenanthrenes	913	0.06	U	2.67E+00	2.9E-03	0.06	U	2.40E+00	2.6E-03	0.06	U	2.21E+00	2.4E-03	0.055	U	2.71E+00	3.0E-03
C4-Chrysenes	1,214	0.06	U	2.67E+00	2.2E-03	0.06	U	2.40E+00	2.0E-03	0.06	U	2.21E+00	1.8E-03	0.055	U	2.71E+00	2.2E-03
C4-Napthalenes	657	0.06	U	2.67E+00	4.1E-03	0.09	J	3.60E+00	5.5E-03	0.06	U	2.21E+00	3.4E-03	0.055	U	2.71E+00	4.1E-03
Total Toxic Units					**0.2**				**0.2**				**0.2**				**0.4**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

		083-EA1-R-C-Z1b				085-HB1-L-C-Z1a				085-HB1-L-C-Z1b				095-HB1-R-C-Z1a			
		2.1		% Organic Carbon		2.6		% Organic Carbon		3.1		% Organic Carbon		2.2		% Organic Carbon	
Compound	Final Chronic Value (µg/goc)	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.055	U	2.67E+00	5.4E-03	0.07	U	2.70E+00	5.5E-03	0.065	U	2.11E+00	4.3E-03	0.047	J	2.11E+00	4.3E-03
Acenaphthylene	452	0.055	U	2.67E+00	5.9E-03	0.07	U	2.70E+00	6.0E-03	0.065	U	2.11E+00	4.7E-03	0.06	U	2.69E+00	6.0E-03
Anthracene	594	0.04	J	1.94E+00	3.3E-03	0.04	J	1.54E+00	2.6E-03	0.047	J	1.53E+00	2.6E-03	0.12		5.38E+00	9.1E-03
Benzo (a) anthracene	841	0.18		8.74E+00	1.0E-02	0.22		8.49E+00	1.0E-02	0.2		6.49E+00	7.7E-03	0.37		1.66E+01	2.0E-02
Benzo (a) pyrene	965	0.18		8.74E+00	9.1E-03	0.29		1.12E+01	1.2E-02	0.2		6.49E+00	6.7E-03	0.34		1.52E+01	1.6E-02
Benzo (b) fluoranthene	979	0.25		1.21E+01	1.2E-02	0.38		1.47E+01	1.5E-02	0.22		7.14E+00	7.3E-03	0.38		1.70E+01	1.7E-02
Benzo (e) pyrene	967	0.16		7.77E+00	8.0E-03	0.28		1.08E+01	1.1E-02	0.17		5.52E+00	5.7E-03	0.29		1.30E+01	1.3E-02
Benzo (g,h,i) perylene	1,095	0.072	J	3.50E+00	3.2E-03	0.12	J	4.63E+00	4.2E-03	0.072	J	2.34E+00	2.1E-03	0.091	J	4.08E+00	3.7E-03
Benzo (k) fluoranthene	981	0.2		9.71E+00	9.9E-03	0.36		1.39E+01	1.4E-02	0.27		8.77E+00	8.9E-03	0.5		2.24E+01	2.3E-02
Chrysene	844	0.27		1.31E+01	1.6E-02	0.4		1.54E+01	1.8E-02	0.28		9.09E+00	1.1E-02	0.5		2.24E+01	2.7E-02
Dibenz (a,h) anthracene	1,123	0.03	J	1.46E+00	1.3E-03	0.07	U	2.70E+00	2.4E-03	0.065	U	2.11E+00	1.9E-03	0.033	J	1.48E+00	1.3E-03
Fluoranthene	707	0.48		2.33E+01	3.3E-02	0.68		2.63E+01	3.7E-02	0.56		1.82E+01	2.6E-02	1		4.48E+01	6.3E-02
Fluorene	538	0.03	J	1.46E+00	2.7E-03	0.07	U	2.70E+00	5.0E-03	0.042	J	1.36E+00	2.5E-03	0.057	J	2.56E+00	4.8E-03
Indeno (1,2,3-cd) pyrene	1,115	0.085	J	4.13E+00	3.7E-03	0.13	J	5.02E+00	4.5E-03	0.089	J	2.89E+00	2.6E-03	0.094	J	4.22E+00	3.8E-03
Naphthalene	385	0.055	U	2.67E+00	6.9E-03	0.07	U	2.70E+00	7.0E-03	0.065	U	2.11E+00	5.5E-03	0.06	U	2.69E+00	7.0E-03
Phenanthrene	596	0.24		1.17E+01	2.0E-02	0.32		1.24E+01	2.1E-02	0.3		9.74E+00	1.6E-02	0.47		2.11E+01	3.5E-02
Pyrene	697	0.36		1.75E+01	2.5E-02	0.51		1.97E+01	2.8E-02	0.4		1.30E+01	1.9E-02	0.65		2.91E+01	4.2E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.055	U	2.67E+00	6.0E-03	0.07	U	2.70E+00	6.1E-03	0.065	U	2.11E+00	4.7E-03	0.06	U	2.69E+00	6.0E-03
2-Methylnaphthalene	447	0.034	J	1.65E+00	3.7E-03	0.07	U	2.70E+00	6.0E-03	0.065	U	2.11E+00	4.7E-03	0.06	U	2.69E+00	6.0E-03
C1-Anthracenes/ Phenanthrenes	670	0.11	J	5.34E+00	8.0E-03	0.07	U	2.70E+00	4.0E-03	0.065	U	2.11E+00	3.1E-03	0.19		8.52E+00	1.3E-02
C1-Chrysenes	929	0.14		6.80E+00	7.3E-03	0.21		8.11E+00	8.7E-03	0.16		5.19E+00	5.6E-03	0.37		1.66E+01	1.8E-02
C1-Fluoranthenes/ Pyrenes	770	0.18		8.74E+00	1.1E-02	0.042	J	1.62E+00	2.1E-03	0.18		5.84E+00	7.6E-03	0.4		1.79E+01	2.3E-02
C1-Fluorenes	611	0.055	U	2.67E+00	4.4E-03	0.07	U	2.70E+00	4.4E-03	0.065	U	2.11E+00	3.5E-03	0.06	U	2.69E+00	4.4E-03
C2-Anthracenes/ Phenanthrenes	746	0.13		6.31E+00	8.5E-03	0.07	U	2.70E+00	3.6E-03	0.065	U	2.11E+00	2.8E-03	0.23		1.03E+01	1.4E-02
C2-Chrysenes	1,008	0.055	U	2.67E+00	2.6E-03	0.07	U	2.70E+00	2.7E-03	0.14		4.55E+00	4.5E-03	0.14		6.28E+00	6.2E-03
C2-Fluorenes	686	0.055	U	2.67E+00	3.9E-03	0.07	U	2.70E+00	3.9E-03	0.065	U	2.11E+00	3.1E-03	0.06	U	2.69E+00	3.9E-03
C2-Napthalenes	510	0.055	U	2.67E+00	5.2E-03	0.07	U	2.70E+00	5.3E-03	0.065	U	2.11E+00	4.1E-03	0.044	J	1.97E+00	3.9E-03
C3-Anthracenes/ Phenanthrenes	829	0.055	U	2.67E+00	3.2E-03	0.07	U	2.70E+00	3.3E-03	0.065	U	2.11E+00	2.5E-03	0.21		9.42E+00	1.1E-02
C3-Chrysenes	1,112	0.055	U	2.67E+00	2.4E-03	0.07	U	2.70E+00	2.4E-03	0.065	U	2.11E+00	1.9E-03	0.06	U	2.69E+00	2.4E-03
C3-Fluorenes	769	0.055	U	2.67E+00	3.5E-03	0.07	U	2.70E+00	3.5E-03	0.065	U	2.11E+00	2.7E-03	0.06	U	2.69E+00	3.5E-03
C3-Napthalenes	581	0.055	U	2.67E+00	4.6E-03	0.07	U	2.70E+00	4.7E-03	0.065	U	2.11E+00	3.6E-03	0.11	J	4.93E+00	8.5E-03
C4-Anthracenes/ Phenanthrenes	913	0.055	U	2.67E+00	2.9E-03	0.07	U	2.70E+00	3.0E-03	0.065	U	2.11E+00	2.3E-03	0.06	U	2.69E+00	2.9E-03
C4-Chrysenes	1,214	0.055	U	2.67E+00	2.2E-03	0.07	U	2.70E+00	2.2E-03	0.065	U	2.11E+00	1.7E-03	0.06	U	2.69E+00	2.2E-03
C4-Napthalenes	657	0.055	U	2.67E+00	4.1E-03	0.07	U	2.70E+00	4.1E-03	0.065	U	2.11E+00	3.2E-03	0.088	J	3.95E+00	6.0E-03
Total Toxic Units					**0.3**				**0.3**				**0.2**				**0.4**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	095-HB1-R-C-Z1b 2.2 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	095-HB1-R-C-Z3 6.2 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	098-HB2-R-C-Z1a 2.8 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	098-HB2-R-C-Z1b 2.9 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.057	J	2.58E+00	5.3E-03	0.83		1.35E+01	2.7E-02	0.06	U	2.14E+00	4.3E-03	0.065	U	2.24E+00	4.6E-03
Acenaphthylene	452	0.055	U	2.49E+00	5.5E-03	0.22	U	3.57E+00	7.9E-03	0.06	U	2.14E+00	4.7E-03	0.065	U	2.24E+00	5.0E-03
Anthracene	594	0.1	J	4.52E+00	7.6E-03	5.2		8.44E+01	1.4E-01	0.06	U	2.14E+00	3.6E-03	0.039	J	1.34E+00	2.3E-03
Benzo (a) anthracene	841	0.31		1.40E+01	1.7E-02	0.55		8.93E+00	1.1E-02	0.14		4.98E+00	5.9E-03	0.17		5.86E+00	7.0E-03
Benzo (a) pyrene	965	0.3		1.36E+01	1.4E-02	0.43	J	6.98E+00	7.2E-03	0.14		4.98E+00	5.2E-03	0.2		6.90E+00	7.1E-03
Benzo (b) fluoranthene	979	0.33		1.49E+01	1.5E-02	0.55		8.93E+00	9.1E-03	0.16		5.69E+00	5.8E-03	0.24		8.28E+00	8.5E-03
Benzo (e) pyrene	967	0.23		1.04E+01	1.1E-02	0.38	J	6.17E+00	6.4E-03	0.13		4.63E+00	4.8E-03	0.18		6.21E+00	6.4E-03
Benzo (g,h,i) perylene	1,095	0.078	J	3.53E+00	3.2E-03	0.22	U	3.57E+00	3.3E-03	0.052	J	1.85E+00	1.7E-03	0.062	J	2.14E+00	2.0E-03
Benzo (k) fluoranthene	981	0.4		1.81E+01	1.8E-02	0.41	J	6.66E+00	6.8E-03	0.2		7.12E+00	7.3E-03	0.29		1.00E+01	1.0E-02
Chrysene	844	0.43		1.95E+01	2.3E-02	0.75		1.22E+01	1.4E-02	0.21		7.47E+00	8.9E-03	0.28		9.66E+00	1.1E-02
Dibenz (a,h) anthracene	1,123	0.034	J	1.54E+00	1.4E-03	0.22	U	3.57E+00	3.2E-03	0.06	U	2.14E+00	1.9E-03	0.065	U	2.24E+00	2.0E-03
Fluoranthene	707	0.99		4.48E+01	6.3E-02	1.2		1.95E+01	2.8E-02	0.38		1.35E+01	1.9E-02	0.53		1.83E+01	2.6E-02
Fluorene	538	0.059	J	2.67E+00	5.0E-03	0.91		1.48E+01	2.7E-02	0.06	U	2.14E+00	4.0E-03	0.065	U	2.24E+00	4.2E-03
Indeno (1,2,3-cd) pyrene	1,115	0.082	J	3.71E+00	3.3E-03	0.22	U	3.57E+00	3.2E-03	0.07	J	2.49E+00	2.2E-03	0.079	J	2.72E+00	2.4E-03
Naphthalene	385	0.055	U	2.49E+00	6.5E-03	2.5		4.06E+01	1.1E-01	0.06	U	2.14E+00	5.5E-03	0.065	U	2.24E+00	5.8E-03
Phenanthrene	596	0.55		2.49E+01	4.2E-02	3.9		6.33E+01	1.1E-01	0.16		5.69E+00	9.6E-03	0.2		6.90E+00	1.2E-02
Pyrene	697	0.63		2.85E+01	4.1E-02	1		1.62E+01	2.3E-02	0.28		9.96E+00	1.4E-02	0.33		1.14E+01	1.6E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.055	U	2.49E+00	5.6E-03	2.1		3.41E+01	7.6E-02	0.06	U	2.14E+00	4.8E-03	0.065	U	2.24E+00	5.0E-03
2-Methylnaphthalene	447	0.055	U	2.49E+00	5.6E-03	2.9		4.71E+01	1.1E-01	0.06	U	2.14E+00	4.8E-03	0.065	U	2.24E+00	5.0E-03
C1-Anthracenes/ Phenanthrenes	670	0.19		8.60E+00	1.3E-02	9.9		1.61E+02	2.4E-01	0.066	J	2.35E+00	3.5E-03	0.097	J	3.34E+00	5.0E-03
C1-Chrysenes	929	0.31		1.40E+01	1.5E-02	1.5		2.44E+01	2.6E-02	0.1	J	3.56E+00	3.8E-03	0.15		5.17E+00	5.6E-03
C1-Fluoranthenes/ Pyrenes	770	0.31		1.40E+01	1.8E-02	2.2		3.57E+01	4.6E-02	0.11	J	3.91E+00	5.1E-03	0.16		5.52E+00	7.2E-03
C1-Fluorenes	611	0.055	U	2.49E+00	4.1E-03	2.5		4.06E+01	6.6E-02	0.06	U	2.14E+00	3.5E-03	0.065	U	2.24E+00	3.7E-03
C2-Anthracenes/ Phenanthrenes	746	0.21		9.50E+00	1.3E-02	14		2.27E+02	3.0E-01	0.079	J	2.81E+00	3.8E-03	0.096	J	3.31E+00	4.4E-03
C2-Chrysenes	1,008	0.094	J	4.25E+00	4.2E-03	1.2		1.95E+01	1.9E-02	0.06	U	2.14E+00	2.1E-03	0.065	U	2.24E+00	2.2E-03
C2-Fluorenes	686	0.055	U	2.49E+00	3.6E-03	4.3		6.98E+01	1.0E-01	0.06	U	2.14E+00	3.1E-03	0.065	U	2.24E+00	3.3E-03
C2-Napthalenes	510	0.07	J	3.17E+00	6.2E-03	10		1.62E+02	3.2E-01	0.06	U	2.14E+00	4.2E-03	0.065	U	2.24E+00	4.4E-03
C3-Anthracenes/ Phenanthrenes	829	0.18		8.14E+00	9.8E-03	5.4		8.77E+01	1.1E-01	0.06	U	2.14E+00	2.6E-03	0.065	U	2.24E+00	2.7E-03
C3-Chrysenes	1,112	0.055	U	2.49E+00	2.2E-03	0.94		1.53E+01	1.4E-02	0.06	U	2.14E+00	1.9E-03	0.065	U	2.24E+00	2.0E-03
C3-Fluorenes	769	0.055	U	2.49E+00	3.2E-03	4.6		7.47E+01	9.7E-02	0.06	U	2.14E+00	2.8E-03	0.065	U	2.24E+00	2.9E-03
C3-Napthalenes	581	0.13		5.88E+00	1.0E-02	14		2.27E+02	3.9E-01	0.06	U	2.14E+00	3.7E-03	0.065	U	2.24E+00	3.9E-03
C4-Anthracenes/ Phenanthrenes	913	0.055	U	2.49E+00	2.7E-03	2		3.25E+01	3.6E-02	0.06	U	2.14E+00	2.3E-03	0.065	U	2.24E+00	2.5E-03
C4-Chrysenes	1,214	0.055	U	2.49E+00	2.0E-03	0.22	U	3.57E+00	2.9E-03	0.06	U	2.14E+00	1.8E-03	0.065	U	2.24E+00	1.8E-03
C4-Napthalenes	657	0.084	J	3.80E+00	5.8E-03	8.5		1.38E+02	2.1E-01	0.06	U	2.14E+00	3.2E-03	0.065	U	2.24E+00	3.4E-03
Total Toxic Units					**0.4**				**3**				**0.2**				**0.2**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	100-HB1-L-C-Z1a				100-HB1-L-C-Z1b				102-HB1-R-C-Z1a				102-HB1-R-C-Z1b			
		1.5 % Organic Carbon				2.5 % Organic Carbon				1.9 % Organic Carbon				2.1 % Organic Carbon			
		PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.055	U	3.64E+00	7.4E-03	0.055	U	2.24E+00	4.6E-03	0.06	U	3.09E+00	6.3E-03	0.06	U	2.88E+00	5.9E-03
Acenaphthylene	452	0.055	U	3.64E+00	8.1E-03	0.055	U	2.24E+00	5.0E-03	0.06	U	3.09E+00	6.8E-03	0.06	U	2.88E+00	6.4E-03
Anthracene	594	0.055	U	3.64E+00	6.1E-03	0.055	U	2.24E+00	3.8E-03	0.06	U	3.09E+00	5.2E-03	0.06	U	2.88E+00	4.9E-03
Benzo (a) anthracene	841	0.061	J	4.04E+00	4.8E-03	0.13		5.31E+00	6.3E-03	0.14		7.22E+00	8.6E-03	0.13		6.25E+00	7.4E-03
Benzo (a) pyrene	965	0.059	J	3.91E+00	4.0E-03	0.14		5.71E+00	5.9E-03	0.15		7.73E+00	8.0E-03	0.15		7.21E+00	7.5E-03
Benzo (b) fluoranthene	979	0.075	J	4.97E+00	5.1E-03	0.31		1.27E+01	1.3E-02	0.24		1.24E+01	1.3E-02	0.19		9.13E+00	9.3E-03
Benzo (e) pyrene	967	0.062	J	4.11E+00	4.2E-03	0.14		5.71E+00	5.9E-03	0.15		7.73E+00	8.0E-03	0.13		6.25E+00	6.5E-03
Benzo (g,h,i) perylene	1,095	0.037	J	2.45E+00	2.2E-03	0.037	J	1.51E+00	1.4E-03	0.076	J	3.92E+00	3.6E-03	0.06	J	2.88E+00	2.6E-03
Benzo (k) fluoranthene	981	0.083	J	5.50E+00	5.6E-03	0.055	U	2.24E+00	2.3E-03	0.17		8.76E+00	8.9E-03	0.19		9.13E+00	9.3E-03
Chrysene	844	0.09	J	5.96E+00	7.1E-03	0.23		9.39E+00	1.1E-02	0.24		1.24E+01	1.5E-02	0.21		1.01E+01	1.2E-02
Dibenz (a,h) anthracene	1,123	0.055	U	3.64E+00	3.2E-03	0.055	U	2.24E+00	2.0E-03	0.06	U	3.09E+00	2.8E-03	0.06	U	2.88E+00	2.6E-03
Fluoranthene	707	0.16		1.06E+01	1.5E-02	0.36		1.47E+01	2.1E-02	0.39		2.01E+01	2.8E-02	0.36		1.73E+01	2.4E-02
Fluorene	538	0.055	U	3.64E+00	6.8E-03	0.055	U	2.24E+00	4.2E-03	0.06	U	3.09E+00	5.7E-03	0.06	U	2.88E+00	5.4E-03
Indeno (1,2,3-cd) pyrene	1,115	0.031	J	2.05E+00	1.8E-03	0.048	J	1.96E+00	1.8E-03	0.084	J	4.33E+00	3.9E-03	0.072	J	3.46E+00	3.1E-03
Naphthalene	385	0.055	U	3.64E+00	9.5E-03	0.055	U	2.24E+00	5.8E-03	0.06	U	3.09E+00	8.0E-03	0.06	U	2.88E+00	7.5E-03
Phenanthrene	596	0.076	J	5.03E+00	8.4E-03	0.16		6.53E+00	1.1E-02	0.17		8.76E+00	1.5E-02	0.14		6.73E+00	1.1E-02
Pyrene	697	0.13		8.61E+00	1.2E-02	0.28		1.14E+01	1.6E-02	0.3		1.55E+01	2.2E-02	0.26		1.25E+01	1.8E-02
Alkylated PAHs																	
1-Methylnaphthalene	446	0.055	U	3.64E+00	8.2E-03	0.055	U	2.24E+00	5.0E-03	0.06	U	3.09E+00	6.9E-03	0.06	U	2.88E+00	6.5E-03
2-Methylnaphthalene	447	0.055	U	3.64E+00	8.1E-03	0.055	U	2.24E+00	5.0E-03	0.06	U	3.09E+00	6.9E-03	0.06	U	2.88E+00	6.5E-03
C1-Anthracenes/ Phenanthrenes	670	0.055	U	3.64E+00	5.4E-03	0.055	U	2.24E+00	3.4E-03	0.06	U	3.09E+00	4.6E-03	0.06	U	2.88E+00	4.3E-03
C1-Chrysenes	929	0.055	U	3.64E+00	3.9E-03	0.055	U	2.24E+00	2.4E-03	0.06	U	3.09E+00	3.3E-03	0.06	U	2.88E+00	3.1E-03
C1-Fluoranthenes/ Pyrenes	770	0.055	U	3.64E+00	4.7E-03	0.11	J	4.49E+00	5.8E-03	0.038	J	1.96E+00	2.5E-03	0.06	U	2.88E+00	3.7E-03
C1-Fluorenes	611	0.055	U	3.64E+00	6.0E-03	0.055	U	2.24E+00	3.7E-03	0.06	U	3.09E+00	5.1E-03	0.06	U	2.88E+00	4.7E-03
C2-Anthracenes/ Phenanthrenes	746	0.055	U	3.64E+00	4.9E-03	0.055	U	2.24E+00	3.0E-03	0.06	U	3.09E+00	4.1E-03	0.06	U	2.88E+00	3.9E-03
C2-Chrysenes	1,008	0.055	U	3.64E+00	3.6E-03	0.055	U	2.24E+00	2.2E-03	0.06	U	3.09E+00	3.1E-03	0.06	U	2.88E+00	2.9E-03
C2-Fluorenes	686	0.055	U	3.64E+00	5.3E-03	0.055	U	2.24E+00	3.3E-03	0.06	U	3.09E+00	4.5E-03	0.06	U	2.88E+00	4.2E-03
C2-Napthalenes	510	0.055	U	3.64E+00	7.1E-03	0.055	U	2.24E+00	4.4E-03	0.06	U	3.09E+00	6.1E-03	0.06	U	2.88E+00	5.7E-03
C3-Anthracenes/ Phenanthrenes	829	0.055	U	3.64E+00	4.4E-03	0.055	U	2.24E+00	2.7E-03	0.06	U	3.09E+00	3.7E-03	0.06	U	2.88E+00	3.5E-03
C3-Chrysenes	1,112	0.055	U	3.64E+00	3.3E-03	0.055	U	2.24E+00	2.0E-03	0.06	U	3.09E+00	2.8E-03	0.06	U	2.88E+00	2.6E-03
C3-Fluorenes	769	0.055	U	3.64E+00	4.7E-03	0.055	U	2.24E+00	2.9E-03	0.06	U	3.09E+00	4.0E-03	0.06	U	2.88E+00	3.8E-03
C3-Napthalenes	581	0.055	U	3.64E+00	6.3E-03	0.055	U	2.24E+00	3.9E-03	0.06	U	3.09E+00	5.3E-03	0.06	U	2.88E+00	5.0E-03
C4-Anthracenes/ Phenanthrenes	913	0.055	U	3.64E+00	4.0E-03	0.055	U	2.24E+00	2.5E-03	0.06	U	3.09E+00	3.4E-03	0.06	U	2.88E+00	3.2E-03
C4-Chrysenes	1,214	0.055	U	3.64E+00	3.0E-03	0.055	U	2.24E+00	1.8E-03	0.06	U	3.09E+00	2.5E-03	0.06	U	2.88E+00	2.4E-03
C4-Napthalenes	657	0.055	U	3.64E+00	5.5E-03	0.055	U	2.24E+00	3.4E-03	0.1	J	5.15E+00	7.8E-03	0.06	U	2.88E+00	4.4E-03
Total Toxic Units					**0.2**				**0.2**				**0.2**				**0.2**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	111-HBO-L-CP 1.0 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	115-HBO-U-CP 0.7 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	117-EA-CP 1.0 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	119-EA-CP 0.4 % Organic Carbon PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																	
Acenaphthene	491	0.047	J	4.93E+00	1.0E-02	0.0495	U	7.17E+00	1.5E-02	0.055	U	5.29E+00	1.1E-02	0.043	U	1.17E+01	2.4E-02
Acenaphthylene	452	0.055	U	5.77E+00	1.3E-02	0.0495	U	7.17E+00	1.6E-02	0.055	U	5.29E+00	1.2E-02	0.027	J	7.36E+00	1.6E-02
Anthracene	594	0.067	J	7.03E+00	1.2E-02	0.0495	U	7.17E+00	1.2E-02	0.031	J	2.98E+00	5.0E-03	0.14		3.81E+01	6.4E-02
Benzo (a) anthracene	841	0.24		2.52E+01	3.0E-02	0.13		1.88E+01	2.2E-02	0.11		1.06E+01	1.3E-02	0.21		5.72E+01	6.8E-02
Benzo (a) pyrene	965	0.23		2.41E+01	2.5E-02	0.13		1.88E+01	2.0E-02	0.11		1.06E+01	1.1E-02	0.15		4.09E+01	4.2E-02
Benzo (b) fluoranthene	979	0.3		3.15E+01	3.2E-02	0.18		2.61E+01	2.7E-02	0.12		1.15E+01	1.2E-02	0.22	J	5.99E+01	6.1E-02
Benzo (e) pyrene	967	0.19		1.99E+01	2.1E-02	0.1		1.45E+01	1.5E-02	0.098	J	9.42E+00	9.7E-03	0.084	J	2.29E+01	2.4E-02
Benzo (g,h,i) perylene	1,095	0.095	J	9.97E+00	9.1E-03	0.058	J	8.41E+00	7.7E-03	0.1	J	9.62E+00	8.8E-03	0.075	J	2.04E+01	1.9E-02
Benzo (k) fluoranthene	981	0.2		2.10E+01	2.1E-02	0.12		1.74E+01	1.8E-02	0.12		1.15E+01	1.2E-02	0.043	U	1.17E+01	1.2E-02
Chrysene	844	0.35		3.67E+01	4.4E-02	0.2		2.90E+01	3.4E-02	0.16		1.54E+01	1.8E-02	0.26		7.08E+01	8.4E-02
Dibenz (a,h) anthracene	1,123	0.039	J	4.09E+00	3.6E-03	0.0495	U	7.17E+00	6.4E-03	0.055	U	5.29E+00	4.7E-03	0.035	J	9.54E+00	8.5E-03
Fluoranthene	707	0.7		7.35E+01	1.0E-01	0.41		5.94E+01	8.4E-02	0.28		2.69E+01	3.8E-02	0.37		1.01E+02	1.4E-01
Fluorene	538	0.053	J	5.56E+00	1.0E-02	0.0495	U	7.17E+00	1.3E-02	0.055	U	5.29E+00	9.8E-03	0.043	U	1.17E+01	2.2E-02
Indeno (1,2,3-cd) pyrene	1,115	0.098	J	1.03E+01	9.2E-03	0.066	J	9.57E+00	8.6E-03	0.1	J	9.62E+00	8.6E-03	0.081	J	2.21E+01	2.0E-02
Naphthalene	385	0.055	U	5.77E+00	1.5E-02	0.0495	U	7.17E+00	1.9E-02	0.055	U	5.29E+00	1.4E-02	0.043	U	1.17E+01	3.0E-02
Phenanthrene	596	0.37		3.88E+01	6.5E-02	0.19		2.75E+01	4.6E-02	0.13		1.25E+01	2.1E-02	0.16		4.36E+01	7.3E-02
Pyrene	697	0.52		5.46E+01	7.8E-02	0.31		4.49E+01	6.4E-02	0.25		2.40E+01	3.4E-02	0.31		8.45E+01	1.2E-01
Alkylated PAHs																	
1-Methylnaphthalene	446	0.055	U	5.77E+00	1.3E-02	0.0495	U	7.17E+00	1.6E-02	0.055	U	5.29E+00	1.2E-02	0.043	U	1.17E+01	2.6E-02
2-Methylnaphthalene	447	0.055	U	5.77E+00	1.3E-02	0.0495	U	7.17E+00	1.6E-02	0.055	U	5.29E+00	1.2E-02	0.043	U	1.17E+01	2.6E-02
C1-Anthracenes/ Phenanthrenes	670	0.12		1.26E+01	1.9E-02	0.0495	U	7.17E+00	1.1E-02	0.055	U	5.29E+00	7.9E-03	0.14		3.81E+01	5.7E-02
C1-Chrysenes	929	0.18		1.89E+01	2.0E-02	0.0495	U	7.17E+00	7.7E-03	0.055	U	5.29E+00	5.7E-03	0.043	U	1.17E+01	1.3E-02
C1-Fluoranthenes/ Pyrenes	770	0.16		1.68E+01	2.2E-02	0.0495	U	7.17E+00	9.3E-03	0.055	U	5.29E+00	6.9E-03	0.23		6.27E+01	8.1E-02
C1-Fluorenes	611	0.055	U	5.77E+00	9.4E-03	0.0495	U	7.17E+00	1.2E-02	0.055	U	5.29E+00	8.7E-03	0.043	U	1.17E+01	1.9E-02
C2-Anthracenes/ Phenanthrenes	746	0.14		1.47E+01	2.0E-02	0.0495	U	7.17E+00	9.6E-03	0.055	U	5.29E+00	7.1E-03	0.043	U	1.17E+01	1.6E-02
C2-Chrysenes	1,008	0.12		1.26E+01	1.2E-02	0.0495	U	7.17E+00	7.1E-03	0.055	U	5.29E+00	5.2E-03	0.043	U	1.17E+01	1.2E-02
C2-Fluorenes	686	0.055	U	5.77E+00	8.4E-03	0.0495	U	7.17E+00	1.0E-02	0.055	U	5.29E+00	7.7E-03	0.043	U	1.17E+01	1.7E-02
C2-Napthalenes	510	0.028	J	2.94E+00	5.8E-03	0.0495	U	7.17E+00	1.4E-02	0.055	U	5.29E+00	1.0E-02	0.043	U	1.17E+01	2.3E-02
C3-Anthracenes/ Phenanthrenes	829	0.092	J	9.65E+00	1.2E-02	0.0495	U	7.17E+00	8.7E-03	0.055	U	5.29E+00	6.4E-03	0.043	U	1.17E+01	1.4E-02
C3-Chrysenes	1,112	0.055	U	5.77E+00	5.2E-03	0.0495	U	7.17E+00	6.5E-03	0.055	U	5.29E+00	4.8E-03	0.043	U	1.17E+01	1.1E-02
C3-Fluorenes	769	0.055	U	5.77E+00	7.5E-03	0.0495	U	7.17E+00	9.3E-03	0.055	U	5.29E+00	6.9E-03	0.043	U	1.17E+01	1.5E-02
C3-Napthalenes	581	0.043	J	4.51E+00	7.8E-03	0.0495	U	7.17E+00	1.2E-02	0.055	U	5.29E+00	9.1E-03	0.043	U	1.17E+01	2.0E-02
C4-Anthracenes/ Phenanthrenes	913	0.055	U	5.77E+00	6.3E-03	0.0495	U	7.17E+00	7.9E-03	0.055	U	5.29E+00	5.8E-03	0.043	U	1.17E+01	1.3E-02
C4-Chrysenes	1,214	0.055	U	5.77E+00	4.8E-03	0.0495	U	7.17E+00	5.9E-03	0.055	U	5.29E+00	4.4E-03	0.043	U	1.17E+01	9.7E-03
C4-Napthalenes	657	0.055	U	5.77E+00	8.8E-03	0.0495	U	7.17E+00	1.1E-02	0.055	U	5.29E+00	8.0E-03	0.043	U	1.17E+01	1.8E-02
Total Toxic Units					**0.7**				**0.6**				**0.4**				**1**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2a.
Evaluation of Sediment PAHs for Benthic Invertebrates, Buffalo River

Compound	Final Chronic Value (µg/goc)	121-EA-CP 1.8 % Organic Carbon				123-EA-CP 1.0 % Organic Carbon				E1-B-U-BULK 3.9 % Organic Carbon			
		PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs													
Acenaphthene	491	0.06	U	3.41E+00	6.9E-03	2.5		2.58E+02	5.2E-01	0.11	J	2.86E+00	5.8E-03
Acenaphthylene	452	0.06	U	3.41E+00	7.5E-03	0.59	J	6.08E+01	1.3E-01	0.15	J	3.90E+00	8.6E-03
Anthracene	594	0.032	J	1.82E+00	3.1E-03	2.5		2.58E+02	4.3E-01	0.25		6.49E+00	1.1E-02
Benzo (a) anthracene	841	0.15		8.52E+00	1.0E-02	3.6		3.71E+02	4.4E-01	1		2.60E+01	3.1E-02
Benzo (a) pyrene	965	0.15		8.52E+00	8.8E-03	2.4		2.47E+02	2.6E-01	0.95		2.47E+01	2.6E-02
Benzo (b) fluoranthene	979	0.2		1.14E+01	1.2E-02	1.6		1.65E+02	1.7E-01	1.2		3.12E+01	3.2E-02
Benzo (e) pyrene	967	0.14		7.95E+00	8.2E-03	1.2		1.24E+02	1.3E-01	0.74		1.92E+01	2.0E-02
Benzo (g,h,i) perylene	1,095	0.087	J	4.94E+00	4.5E-03	0.74		7.63E+01	7.0E-02	0.1	J	2.60E+00	2.4E-03
Benzo (k) fluoranthene	981	0.16		9.09E+00	9.3E-03	2.5		2.58E+02	2.6E-01	1.1		2.86E+01	2.9E-02
Chrysene	844	0.2		1.14E+01	1.3E-02	3.1		3.20E+02	3.8E-01	1.1		2.86E+01	3.4E-02
Dibenz (a,h) anthracene	1,123	0.037	J	2.10E+00	1.9E-03	0.43	J	4.43E+01	3.9E-02	0.095	U	2.47E+00	2.2E-03
Fluoranthene	707	0.37		2.10E+01	3.0E-02	7.6		7.84E+02	1.1E+00	2.2		5.71E+01	8.1E-02
Fluorene	538	0.06	U	3.41E+00	6.3E-03	2.9		2.99E+02	5.6E-01	0.18	J	4.68E+00	8.7E-03
Indeno (1,2,3-cd) pyrene	1,115	0.1	J	5.68E+00	5.1E-03	0.88		9.07E+01	8.1E-02	0.14	J	3.64E+00	3.3E-03
Naphthalene	385	0.06	U	3.41E+00	8.9E-03	0.22	J	2.27E+01	5.9E-02	0.67		1.74E+01	4.5E-02
Phenanthrene	596	0.15		8.52E+00	1.4E-02	5.2		5.36E+02	9.0E-01	0.95		2.47E+01	4.1E-02
Pyrene	697	0.32		1.82E+01	2.6E-02	5.2		5.36E+02	7.7E-01	1.7		4.42E+01	6.3E-02
Alkylated PAHs													
1-Methylnaphthalene	446	0.06	U	3.41E+00	7.6E-03	0.305	U	3.14E+01	7.1E-02	0.094	J	2.44E+00	5.5E-03
2-Methylnaphthalene	447	0.06	U	3.41E+00	7.6E-03	0.305	U	3.14E+01	7.0E-02	0.1	J	2.60E+00	5.8E-03
C1-Anthracenes/ Phenanthrenes	670	0.06	U	3.41E+00	5.1E-03	2.6		2.68E+02	4.0E-01	0.095	U	2.47E+00	3.7E-03
C1-Chrysenes	929	0.06	U	3.41E+00	3.7E-03	1.9		1.96E+02	2.1E-01	0.67		1.74E+01	1.9E-02
C1-Fluoranthenes/ Pyrenes	770	0.06	U	3.41E+00	4.4E-03	4.2		4.33E+02	5.6E-01	0.83		2.16E+01	2.8E-02
C1-Fluorenes	611	0.06	U	3.41E+00	5.6E-03	0.7		7.22E+01	1.2E-01	0.095	U	2.47E+00	4.0E-03
C2-Anthracenes/ Phenanthrenes	746	0.06	U	3.41E+00	4.6E-03	1.3		1.34E+02	1.8E-01	0.095	U	2.47E+00	3.3E-03
C2-Chrysenes	1,008	0.06	U	3.41E+00	3.4E-03	0.305	U	3.14E+01	3.1E-02	0.095	U	2.47E+00	2.4E-03
C2-Fluorenes	686	0.06	U	3.41E+00	5.0E-03	0.305	U	3.14E+01	4.6E-02	0.095	U	2.47E+00	3.6E-03
C2-Napthalenes	510	0.06	U	3.41E+00	6.7E-03	0.305	U	3.14E+01	6.2E-02	0.095	U	2.47E+00	4.8E-03
C3-Anthracenes/ Phenanthrenes	829	0.06	U	3.41E+00	4.1E-03	0.83		8.56E+01	1.0E-01	0.095	U	2.47E+00	3.0E-03
C3-Chrysenes	1,112	0.06	U	3.41E+00	3.1E-03	0.305	U	3.14E+01	2.8E-02	0.095	U	2.47E+00	2.2E-03
C3-Fluorenes	769	0.06	U	3.41E+00	4.4E-03	0.305	U	3.14E+01	4.1E-02	0.095	U	2.47E+00	3.2E-03
C3-Napthalenes	581	0.06	U	3.41E+00	5.9E-03	0.305	U	3.14E+01	5.4E-02	0.095	U	2.47E+00	4.2E-03
C4-Anthracenes/ Phenanthrenes	913	0.06	U	3.41E+00	3.7E-03	0.305	U	3.14E+01	3.4E-02	0.095	U	2.47E+00	2.7E-03
C4-Chrysenes	1,214	0.06	U	3.41E+00	2.8E-03	0.305	U	3.14E+01	2.6E-02	0.095	U	2.47E+00	2.0E-03
C4-Napthalenes	657	0.06	U	3.41E+00	5.2E-03	0.305	U	3.14E+01	4.8E-02	0.17	J	4.42E+00	6.7E-03
Total Toxic Units					**0.3**				**8**				**0.5**

Notes:

% Percent
mg/kg Milligrams per kilogram
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
A toxic unit value exceeding 1 indicates the potential for toxicity t

Table 5-2b.
Evaluation of Sediment PAHs for Benthic Invertebrates, Cattaraugus Creek and Tonawanda Creek

	RS-C-01-PP01 1.5 % Organic Carbon				RS-C-02-PP01 1.0 % Organic Carbon				RS-C-03-PP01 0.1 % Organic Carbon				RS-T-01-PP01 5.2 % Organic Carbon			
Compound	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs																
Acenaphthene	0.065	U	4.42E+00	9.0E-03	0.055	U	5.34E+00	1.1E-02	0.042	U	3.04E+01	6.2E-02	0.31	J	5.95E+00	1.2E-02
Acenaphthylene	0.065	U	4.42E+00	9.8E-03	0.055	U	5.34E+00	1.2E-02	0.042	U	3.04E+01	6.7E-02	0.26	J	4.99E+00	1.1E-02
Anthracene	0.065	U	4.42E+00	7.4E-03	0.055	U	5.34E+00	9.0E-03	0.042	U	3.04E+01	5.1E-02	0.53		1.02E+01	1.7E-02
Benzo (a) anthracene	0.065	U	4.42E+00	5.3E-03	0.055	U	5.34E+00	6.3E-03	0.042	U	3.04E+01	3.6E-02	2.5		4.80E+01	5.7E-02
Benzo (a) pyrene	0.035	J	2.38E+00	2.5E-03	0.033	J	3.20E+00	3.3E-03	0.042	U	3.04E+01	3.2E-02	2.3		4.41E+01	4.6E-02
Benzo (b) fluoranthene	0.037	J	2.52E+00	2.6E-03	0.037	J	3.59E+00	3.7E-03	0.042	U	3.04E+01	3.1E-02	4	J	7.68E+01	7.8E-02
Benzo (e) pyrene	0.036	J	2.45E+00	2.5E-03	0.033	J	3.20E+00	3.3E-03	0.042	U	3.04E+01	3.1E-02	1.6		3.07E+01	3.2E-02
Benzo (g,h,i) perylene	0.065	U	4.42E+00	4.0E-03	0.055	U	5.34E+00	4.9E-03	0.042	U	3.04E+01	2.8E-02	0.24	J	4.61E+00	4.2E-03
Benzo (k) fluoranthene	0.038	J	2.59E+00	2.6E-03	0.031	J	3.01E+00	3.1E-03	0.042	U	3.04E+01	3.1E-02	0.185	UJ	3.55E+00	3.6E-03
Chrysene	0.062	J	4.22E+00	5.0E-03	0.056	J	5.44E+00	6.4E-03	0.042	U	3.04E+01	3.6E-02	2.5		4.80E+01	5.7E-02
Dibenz (a,h) anthracene	0.065	U	4.42E+00	3.9E-03	0.055	U	5.34E+00	4.8E-03	0.042	U	3.04E+01	2.7E-02	0.185	U	3.55E+00	3.2E-03
Fluoranthene	0.073	J	4.97E+00	7.0E-03	0.067	J	6.50E+00	9.2E-03	0.042	U	3.04E+01	4.3E-02	5.9		1.13E+02	1.6E-01
Fluorene	0.065	U	4.42E+00	8.2E-03	0.055	U	5.34E+00	9.9E-03	0.042	U	3.04E+01	5.7E-02	0.36	J	6.91E+00	1.3E-02
Indeno (1,2,3-cd) pyrene	0.065	UJ	4.42E+00	4.0E-03	0.055	UJ	5.34E+00	4.8E-03	0.042	UJ	3.04E+01	2.7E-02	0.32	J	6.14E+00	5.5E-03
Naphthalene	0.065	U	4.42E+00	1.1E-02	0.055	U	5.34E+00	1.4E-02	0.042	U	3.04E+01	7.9E-02	0.24	J	4.61E+00	1.2E-02
Phenanthrene	0.065	U	4.42E+00	7.4E-03	0.035	J	3.40E+00	5.7E-03	0.042	U	3.04E+01	5.1E-02	1.8		3.45E+01	5.8E-02
Pyrene	0.067	J	4.56E+00	6.5E-03	0.055	J	5.34E+00	7.7E-03	0.042	U	3.04E+01	4.4E-02	3.2		6.14E+01	8.8E-02
Alkylated PAHs																
1-Methylnaphthalene	0.065	U	4.42E+00	9.9E-03	0.055	U	5.34E+00	1.2E-02	0.042	U	3.04E+01	6.8E-02	0.3	J	5.76E+00	1.3E-02
2-Methylnaphthalene	0.065	U	4.42E+00	9.9E-03	0.055	U	5.34E+00	1.2E-02	0.042	U	3.04E+01	6.8E-02	0.26	J	4.99E+00	1.1E-02
C1-Anthracenes/ Phenanthrenes	0.065	U	4.42E+00	6.6E-03	0.055	U	5.34E+00	8.0E-03	0.042	U	3.04E+01	4.5E-02	3		5.76E+01	8.6E-02
C1-Chrysenes	0.065	U	4.42E+00	4.8E-03	0.055	U	5.34E+00	5.7E-03	0.042	U	3.04E+01	3.3E-02	2		3.84E+01	4.1E-02
C1-Fluoranthenes/ Pyrenes	0.065	U	4.42E+00	5.7E-03	0.055	U	5.34E+00	6.9E-03	0.042	U	3.04E+01	4.0E-02	4.9		9.40E+01	1.2E-01
C1-Fluorenes	0.065	U	4.42E+00	7.2E-03	0.055	U	5.34E+00	8.7E-03	0.042	U	3.04E+01	5.0E-02	0.56		1.07E+01	1.8E-02
C2-Anthracenes/ Phenanthrenes	0.065	U	4.42E+00	5.9E-03	0.055	U	5.34E+00	7.2E-03	0.042	U	3.04E+01	4.1E-02	5.7		1.09E+02	1.5E-01
C2-Chrysenes	0.065	U	4.42E+00	4.4E-03	0.055	U	5.34E+00	5.3E-03	0.042	U	3.04E+01	3.0E-02	1.3		2.50E+01	2.5E-02
C2-Fluorenes	0.065	U	4.42E+00	6.4E-03	0.055	U	5.34E+00	7.8E-03	0.042	U	3.04E+01	4.4E-02	1.3		2.50E+01	3.6E-02
C2-Napthalenes	0.065	U	4.42E+00	8.7E-03	0.055	U	5.34E+00	1.0E-02	0.042	U	3.04E+01	6.0E-02	3.3		6.33E+01	1.2E-01
C3-Anthracenes/ Phenanthrenes	0.065	U	4.42E+00	5.3E-03	0.055	U	5.34E+00	6.4E-03	0.042	U	3.04E+01	3.7E-02	5.7		1.09E+02	1.3E-01
C3-Chrysenes	0.065	U	4.42E+00	4.0E-03	0.055	U	5.34E+00	4.8E-03	0.042	U	3.04E+01	2.7E-02	1.4		2.69E+01	2.4E-02
C3-Fluorenes	0.065	U	4.42E+00	5.8E-03	0.055	U	5.34E+00	6.9E-03	0.042	U	3.04E+01	4.0E-02	2.2		4.22E+01	5.5E-02
C3-Napthalenes	0.065	U	4.42E+00	7.6E-03	0.055	U	5.34E+00	9.2E-03	0.042	U	3.04E+01	5.2E-02	6.8		1.31E+02	2.2E-01
C4-Anthracenes/ Phenanthrenes	0.065	U	4.42E+00	4.8E-03	0.055	U	5.34E+00	5.8E-03	0.042	U	3.04E+01	3.3E-02	3.4		6.53E+01	7.1E-02
C4-Chrysenes	0.065	U	4.42E+00	3.6E-03	0.055	U	5.34E+00	4.4E-03	0.042	U	3.04E+01	2.5E-02	0.52		9.98E+00	8.2E-03
C4-Napthalenes	0.065	U	4.42E+00	6.7E-03	0.055	U	5.34E+00	8.1E-03	0.042	U	3.04E+01	4.6E-02	5.2		9.98E+01	1.5E-01
Total Toxic Units				**0.2**				**0.2**				**1**				**2**

Table 5-2b.
Evaluation of Sediment PAHs for Benthic Invertebrates, Cattaraugus Creek and Tonawanda Creek

Compound	RS-T-02-PP01 2.5 % Organic Carbon				RS-T-03-PP01 3.3 % Organic Carbon			
	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units	PAH Concentration (mg/kg)		PAH Concentration (µg/goc)	Toxic Units
Unsubstituted PAHs								
Acenaphthene	0.34	J	1.34E+01	2.7E-02	0.077	J	2.36E+00	4.8E-03
Acenaphthylene	0.215	U	8.46E+00	1.9E-02	0.073	J	2.24E+00	5.0E-03
Anthracene	0.58		2.28E+01	3.8E-02	0.14		4.29E+00	7.2E-03
Benzo (a) anthracene	1.7		6.69E+01	8.0E-02	0.99		3.04E+01	3.6E-02
Benzo (a) pyrene	1.5		5.91E+01	6.1E-02	1.3		3.99E+01	4.1E-02
Benzo (b) fluoranthene	1.5		5.91E+01	6.0E-02	2.8	J	8.59E+01	8.8E-02
Benzo (e) pyrene	0.9		3.54E+01	3.7E-02	1		3.07E+01	3.2E-02
Benzo (g,h,i) perylene	0.54		2.13E+01	1.9E-02	0.16		4.91E+00	4.5E-03
Benzo (k) fluoranthene	1.2		4.72E+01	4.8E-02	0.07	UJ	2.15E+00	2.2E-03
Chrysene	1.8		7.09E+01	8.4E-02	1.1		3.37E+01	4.0E-02
Dibenz (a,h) anthracene	0.215	U	8.46E+00	7.5E-03	0.079	J	2.42E+00	2.2E-03
Fluoranthene	4.4		1.73E+02	2.5E-01	2.3		7.06E+01	1.0E-01
Fluorene	0.34	J	1.34E+01	2.5E-02	0.065	J	1.99E+00	3.7E-03
Indeno (1,2,3-cd) pyrene	0.62	J	2.44E+01	2.2E-02	0.2	J	6.13E+00	5.5E-03
Naphthalene	0.47		1.85E+01	4.8E-02	0.12	J	3.68E+00	9.6E-03
Phenanthrene	2.8		1.10E+02	1.8E-01	0.46		1.41E+01	2.4E-02
Pyrene	4		1.57E+02	2.3E-01	1.2		3.68E+01	5.3E-02
Alkylated PAHs								
1-Methylnaphthalene	0.215	U	8.46E+00	1.9E-02	0.07	U	2.15E+00	4.8E-03
2-Methylnaphthalene	0.14	J	5.51E+00	1.2E-02	0.036	J	1.10E+00	2.5E-03
C1-Anthracenes/ Phenanthrenes	0.73		2.87E+01	4.3E-02	0.07	U	2.15E+00	3.2E-03
C1-Chrysenes	0.9		3.54E+01	3.8E-02	0.66		2.02E+01	2.2E-02
C1-Fluoranthenes/ Pyrenes	1.3		5.12E+01	6.6E-02	0.93		2.85E+01	3.7E-02
C1-Fluorenes	0.215	U	8.46E+00	1.4E-02	0.07	U	2.15E+00	3.5E-03
C2-Anthracenes/ Phenanthrenes	0.215	U	8.46E+00	1.1E-02	0.26		7.98E+00	1.1E-02
C2-Chrysenes	0.215	U	8.46E+00	8.4E-03	0.66		2.02E+01	2.0E-02
C2-Fluorenes	0.215	U	8.46E+00	1.2E-02	0.07	U	2.15E+00	3.1E-03
C2-Napthalenes	0.215	U	8.46E+00	1.7E-02	0.07	U	2.15E+00	4.2E-03
C3-Anthracenes/ Phenanthrenes	0.215	U	8.46E+00	1.0E-02	0.35		1.07E+01	1.3E-02
C3-Chrysenes	0.215	U	8.46E+00	7.6E-03	0.31		9.51E+00	8.6E-03
C3-Fluorenes	0.215	U	8.46E+00	1.1E-02	0.07	U	2.15E+00	2.8E-03
C3-Napthalenes	0.215	U	8.46E+00	1.5E-02	0.07	U	2.15E+00	3.7E-03
C4-Anthracenes/ Phenanthrenes	0.215	U	8.46E+00	9.3E-03	0.07	U	2.15E+00	2.4E-03
C4-Chrysenes	0.215	U	8.46E+00	7.0E-03	0.13	J	3.99E+00	3.3E-03
C4-Napthalenes	0.215	U	8.46E+00	1.3E-02	0.07	U	2.15E+00	3.3E-03
Total Toxic Units				**2**				**0.6**

Notes: A toxic unit value exceeding 1 indicates the potential for toxicity to benthic organisms.

% Percent
µg/goc Micrograms per gram organic carbon
J Estimated value
PAH Polycyclic aromatic hydrocarbon
U Not-detected, value shown is one-half the non-detect value
RS-C Reference Site Cattaraugus Creek
RS-T Reference Site Tonawanda Creek

Table 5-3
Mercury No Effect Sediment Concentrations for Benthic Invertebrates
Buffalo, NY

Location	Species	Hg (mg/kg)	Reference
Calcasieu, LA	*Hyalella azteca*	4.1	Sferra et al. 1999
Brunswick, GA	*Hyalella azteca*	17.8 to 24.7	Winger et al. 1993
Peninsular Harbor, ONT	*Hyalella azteca*	19.5 to 22.6	Milani et al. 2002

Notes:
GA Georgia
Hg Mercury
LA Louisiana
ONT Ontario

Table 5-4a
PCB No Effect Body Residues in Fish
Buffalo, NY

Species	Exposure Media	PCB Type	No-Effect Concentration[a] (mg/kg wet weight)	Effect Endpoint	Reference
Eurasian minnow (*Phoxinus phoxinus*)	Food	Clophen A50	1.6	Larval survival	Bengtsson 1980
Sheepshead minnow (*Cyprinodon variegatus*)	Water	Aroclor 1254	1.9	Larval survival	Hansen et al. 1974
Mummichog (*Fundulus heteroclitus*)	Food	Aroclor 1268	14 to 15	Fecundity, fertilization success, hatch success, larval survival, juvenile weight,[b] sex ratios; 2 generation study	Matta et al. 2001
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1248	2.8 to 30.6[d]	Larval growth; 2 generation study	DeFoe et al. 1978
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1254	105	Fecundity[e]	Nebeker et al. 1974
Three-spined stickleback (*Gasterosteus aculeatus*)	Food	Clophen A50	289	Fecundity	Holm et al. 1993
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1260	350 to 567[d]	Larval survival and growth; 2 generation study	DeFoe et al. 1978

Notes:

a. PCB concentration in parental fish; concentration in females used if different than males.

b. Increased weight (growth) observed with PCB exposure; not an adverse effect.

c. Concentration converted from dry weight.

d. Concentrations presented graphically by DeFoe et al. (1978) and reported numerically by Jarvinen and Ankley (1999).

e. Control fish contained 1.1 mg/kg to 2.7 mg/kg Aroclor 1254.

mg/kg: Milligram per kilogram
PCB: Polychlorinated biphenyl

Table 5-4b
Methylmercury No Effect Body Residues in Fish
Buffalo, NY

Location	Species	Hg (mg/kg wet weight)	Reference
Ontario Lake Fish Residues	Walleye	0.75	Weiner and Spry 1996
	Northern pike	0.58	
	Large mouth bass	0.45	
	Small mouth bass	0.53	
	Small mouth bass	0.63	
Bioassay Control Residues	Fathead minnow	0.068	Sanderheinrich and Miller 2006
	Fathead minnow	0.079	Drevnick and Sanderheinrich 2003
Bioassay No Effect Residues	Brook trout	2.7[a]	McKim et al 1976
	Rainbow trout	30[b]	Wobeser 1975
	Killifish	0.2[b]	Matta et al. 2001
	Fathead minnow	12.6[b]	Olson et al. 1975

Notes:
(a) 3-generation reproduction
(b) Survival

mg/kg: Milligram per kilogram

Table 5-5a
Chronological Reduction in Hepatic Neoplasia in Brown Bullhead
from the Buffalo River, 1983 to 2008
Buffalo, NY

	Black and Baumann 1991 collected (1983-1986)	Baumann et al. 1996 collected (1988)	ENVIRON 2008
n	36	100	37
Foci of Cellular Alteration (%)	38.8	NA	29.8
Hepatocellular Carcinomas (%)	NA	NA	5.4
Cholangiocarcinomas (%)	NA	NA	0
Hepatocellular Tumors (%)	5.5	5*	2.7
Bile Ductular Tumors (%)	11.1		0
Total Liver Tumors (%)	16.6	24	8.1

Notes:
* Malignancies
n Number of samples
NA Not available

Table 5-5b
Natural Attenuation and Post-Remedial Attenuation of Liver Tumors in Brown Bullhead, Black River, Ohio [a]
Buffalo, NY

	1982	1987	1989-1990	1992	1993	1994	1998
n	48	42	Dredging	37	56	27	na
Foci of Cellular Alteration	21	34	NA	4	9	15	25
Cancer	38	10	NA	48	46	0	7
Non-Cancer Neoplasm							
	22	23	NA	11	18	15	25
Total Liver Tumors	60	33	NA	59	64	0	7

Notes:

(a) Baumann and Harshbarger (1998) and USEPA (2000)
n Number of samples
NA Not available

Table 5-6
Incidence of DELTs in Brown Bullhead from the Buffalo River, 1988 to 2008
Buffalo, NY

	Baumann et al. 1996[a]	Yang 2004[b]	Irvine et al. 2005[c]	ENVIRON 2008
n	100	43	NR	37
Total DELTs (%)	NR	NR	87	35
Raised Tumors (%)	23	20.9	NR	2.7§

Notes:

(a) 1988 data
(b) 1998 data
(c) 2003-2004 data
NR = not reported
§ Only one raised lesion was encountered. This was not confirmed histologically to be a tumor.

Table 5-7

Summary of Ecological Indicators for the Buffalo River, 2003 to 2008

Buffalo River, NY

Reach	River Mile	Surface Sediment Chemistry						Invertebrate Metrics			
		PAH TUs	Pore water PAH	SEM-AVS	SEM> AVS/gOC	Hg	Pb[a]	Sediment Grab NYSDEC	Sediment Grab USEPA	Hester-Dendy NYSDEC	Hester-Dendy USEPA
Cazenovia Creek	---	NA	NA	NA	NA	NA	NA	severe	moderate	slight	slight
0	>6.3	NA	NA	NA	NA	NA	NA	moderate - severe	slight to moderate	moderate	slight to moderate
1	5.5-6.3	<1	<1	<1	<1	AVS	0 free Pb	moderate - severe	slight	slight	slight to moderate
2	4.7-5.5	<1	<1	<1	<1	AVS	0 free Pb	severe	moderate	moderate	moderate
3	3.4-4.7	4-5	18	<1	<1	AVS	0 free Pb	NA	NA	NA	NA
4	2-3.4	2	<1	<1	<1	AVS	0 free Pb	severe	moderate	slight	slight
5	1.2-2.0	<1	<1	<1	<1	AVS	0 free Pb	NA	NA	NA	NA
6	0-1.2	8	<1	<1	<1	AVS	0 free Pb	severe	slight	slight	slight
Ship Canal	---	<1	<1	<1	<1	AVS	0 free Pb	NA	NA	NA	NA

Notes:

(a) Based on AVS-SEM; It is acknowledged that NYSDEC does not concur with the USEPA (2005b) method of estimating free metal concentrations of divalent cations.

(b) TLT= total liver tumors

AVS	Acid volatile sulfide
CPUE	Catch per unit effort
gOC	Gram organic carbon
Hg	Mercury
IBI	Index of Biotic Integrity
NA	Not applicable/not available
PAH	Polycyclic aromatic hydrocarbons
Pb	Lead
PCB	Polychlorinated biphenyls
SEM	Simultaneously extracted metals
TLM	Target lipid model
TU	Toxic unit

No Impairment

Potential Slight Impairment Using Metrics that Consider Bioavailability

Perceived Impairment based on Approach

Table 5-7

Summary of Ecological Indicators for the Buffalo River, 2003 to 2008

Buffalo River, NY

Fish Metrics						Sediment Toxicity		
CPUE	Taxa	NYSDEC	IBI 2008	Histopathology[b]	Bioaccumulation	2005 Surface	2007 Surface	2003 TLM
188	12	severe	poor	NA	NA	NA	Below test acceptance criteria	NA
86-103	8-15	severe/ moderate	fair/poor	NA	NA	NA	Toxicity observed	NA
124	10	severe	fair	2.7% TLT	PCBs and Hg < Effect Body Residues	No Substantial Toxicity	NA	<1
108	10	severe	poor	NA			NA	NA
325	15	moderate	fair	2.7% TLT			NA	1.5-3.0
NA	NA	NA	NA	NA			NA	<1
NA	NA	NA	NA	2.7% TLT		NA	NA	NA
NA	NA	NA	NA	NA		NA	NA	2.7
NA	NA	NA	NA	NA		NA	Toxicity observed	1.1

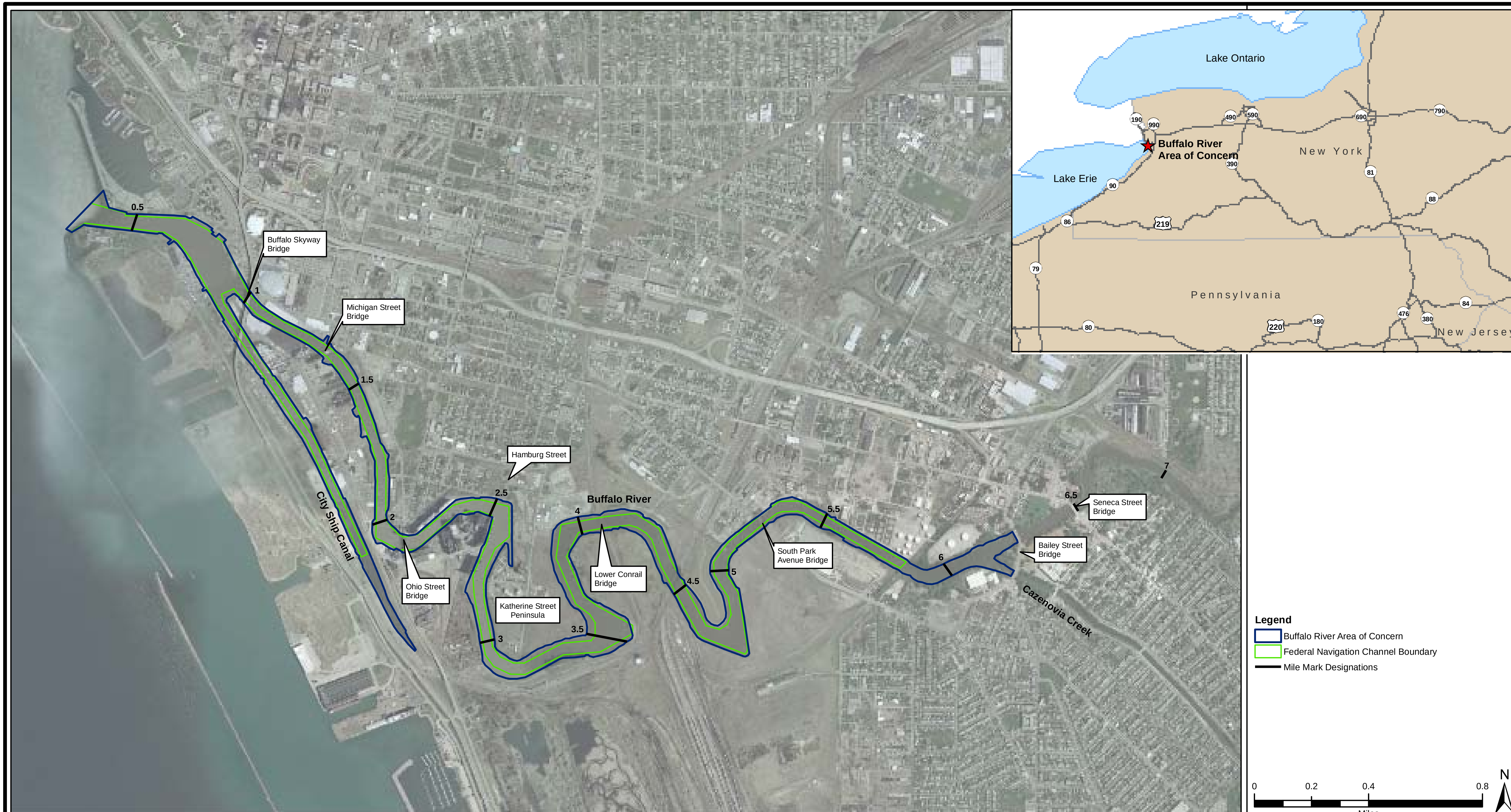
Table 5-8
Summary of PCB Concentrations in Carp from the Buffalo River
Buffalo, NY

Data Date	Data Source	PCB Fillet Fish Concentration (mg/kg)	PCB Whole Fish Concentration (mg/kg)
1977	Buffalo River Remedial Action Plan 1989		4.26**
1980	Buffalo River Remedial Action Plan 1989		0.69 - 0.82**
1983	Buffalo River Remedial Action Plan 1989		3.63 - 14.5**
1984	NYSDEC Toxic Substances in Fish and Wildlife Analyses: 1987 [a]		6.67
1987	1993 USEPA HHRA[b]		2 - 4.1
1991	Loganathan et al. 1995[b]	2.4 - 5	
2004	NYSDEC memo 2006		0.272 - 2.242**
April 2004	2008 Draft Fish Tissue Data Report (NYSDEC data)	0.296 - 2.127	
Oct 2007	2008 Draft Fish Tissue Data Report (NYSDEC split results)	0.64 - 2.03	1.06 - 1.99*

Notes:
Concentrations are presented as the range of values from the indicated source except where only a single result was reported.
Data sources do not indicate that results were adjusted for lipid content.
The high and low ends of ranges of Aroclors were summed to conservatively estimate the range of total PCB concentrations when individual samples were not provided in the cited source.
(a) Results are a composite of three whole carp
(b) Ranges are based on results from young of year, middle aged, and old fish.
* Reported results are for the remaining fish carcass after removal of the edible portion.
** Sample type (fillet vs whole body) was not specified in the indicated reference.

PCB Polychlorinated biphenyl

Figures

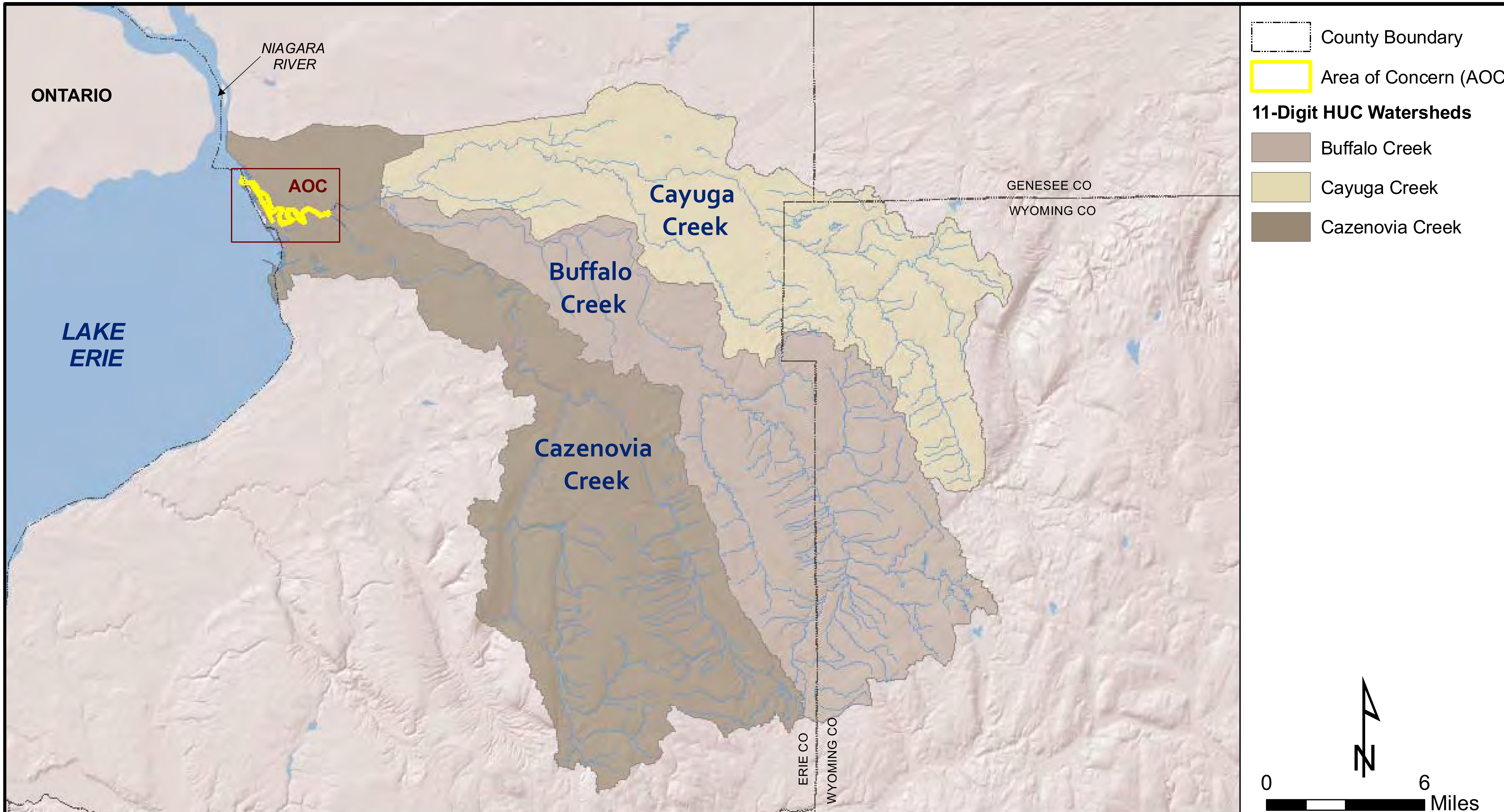


ENVIRON
MACTEC

SITE LOCATION MAP
BUFFALO RIVER, NY

Figure 1-1

Drafter: B. Radakovich
Date: 01/19/2009
File Name: 20090119_SiteLocation_Map.mxd



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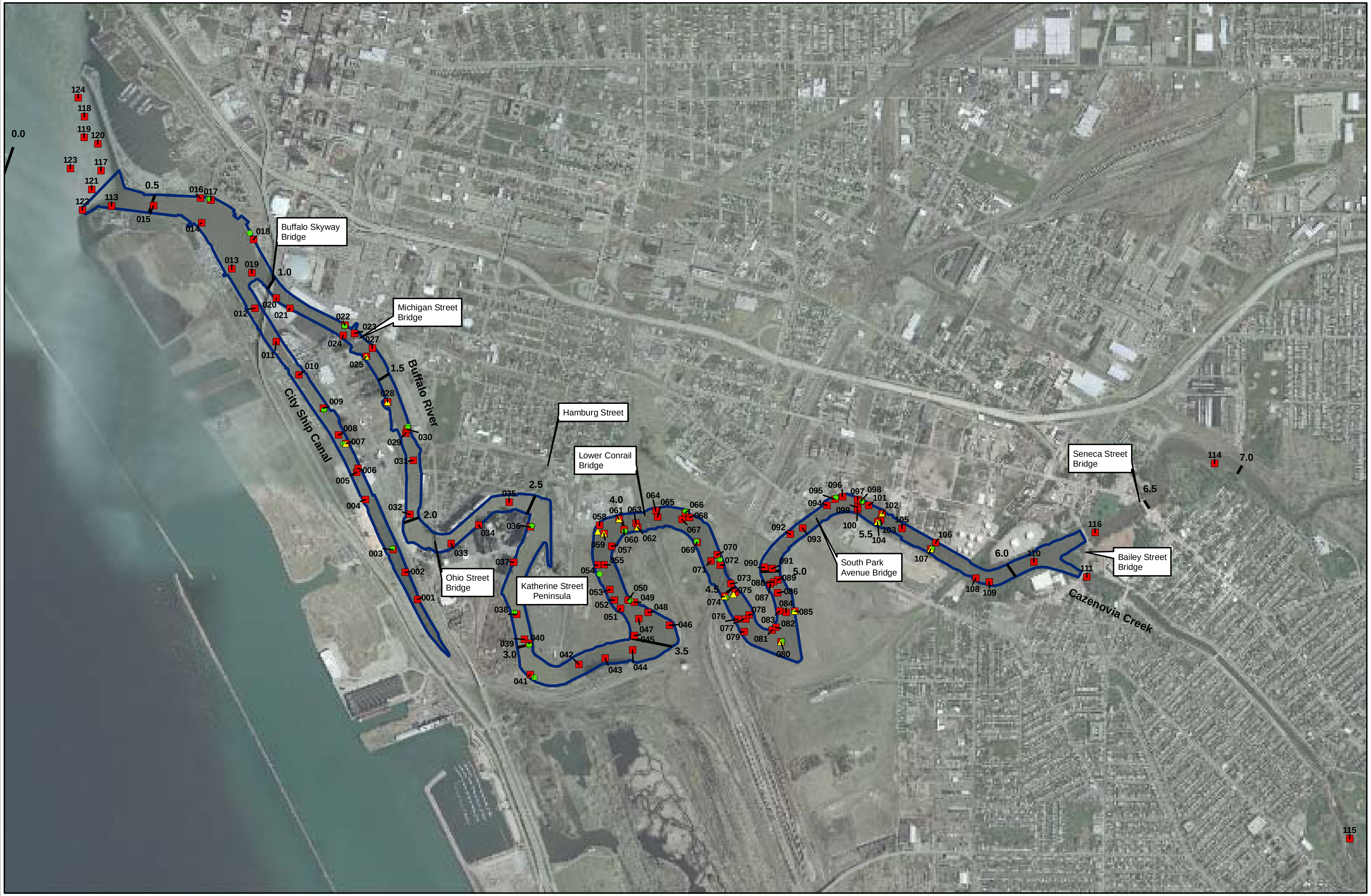
BUFFALO RIVER AOC AND ASSOCIATED WATERSHEDS

Figure 1-2

Friday, October 3, 2008 3:27:14 PM
\\mesrv02\Client_Files\Honeywell Buffalo River\GIS\Projects\MXD\Fig1-2_Watershed.mxd



Legend

- Buffalo River Area of Concern
- Mile Mark Designations

2008 Sample Locations
Sample Type

- Chemical Analysis
- Pore Water Anaylisis
- Geotechnical Analysis

001-127: 2008 Core Location Number

0 0.2 0.4 0.8
Miles

N

ENVIRON
MACTEC

2008 SEDIMENT SAMPLE LOCATIONS
BUFFALO RIVER

Figure
2-1

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20081210_SampleLocations.mxd

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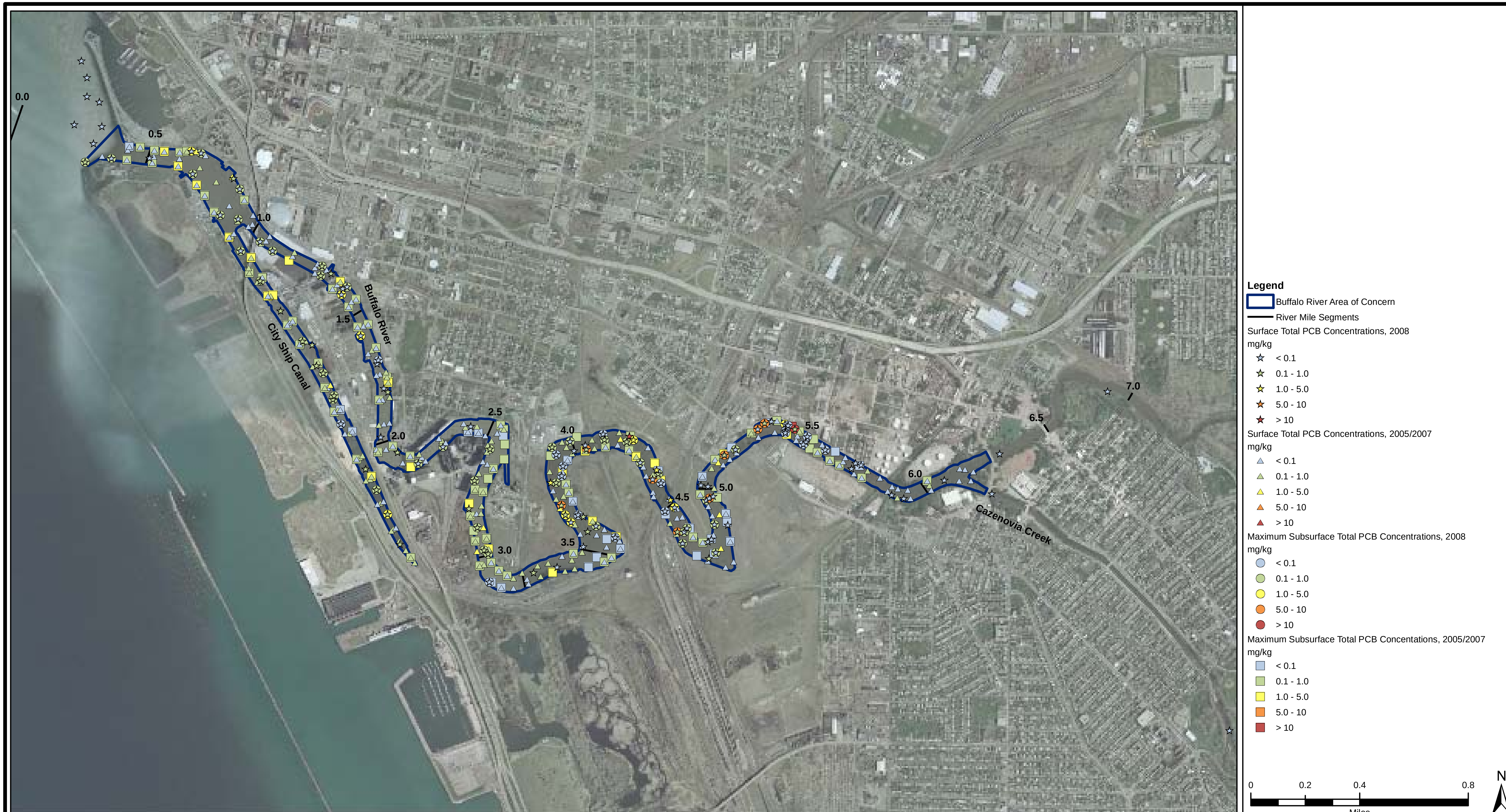
TOTAL PAH SURFACE AND MAXIMUM SUBSURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS BUFFALO RIVER, NY

Figure 2-2

Drafter: B. Radakovich
Contract Number:
File Name: 20081211_Surface_PAH.mxd



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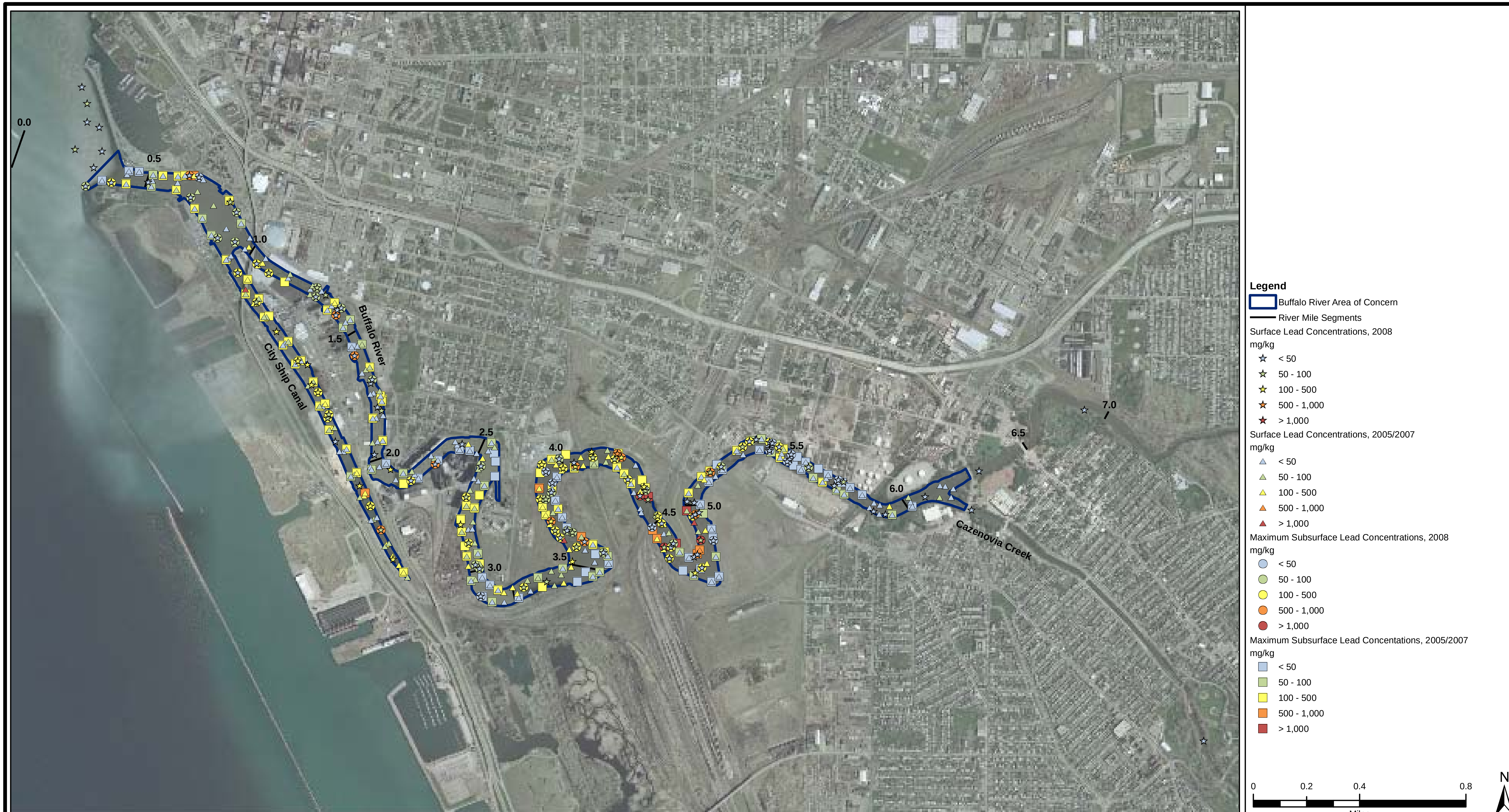
TOTAL PCB SURFACE AND MAXIMUM SUBSURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS BUFFALO RIVER, NY

Figure 2-3

Drafter: B. Radakovich
Contract Number:
File Name: 20081211_SurfacePCB.mxd



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LEAD SURFACE AND MAXIMUM SUBSURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS BUFFALO RIVER, NY

Figure 2-4

Drafter: B. Radakovich
Date 01/12/2009
File Name: 20081211_Lead_Point.mxd

Legend

Buffalo River Area of Concern

River Mile Segments

Surface Mercury Concentrations, 2008
mg/kg
- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

Surface Mercury Concentrations, 2005/2007
mg/kg
- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

Maximum Subsurface Mercury Concentrations, 2008
mg/kg
- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

Maximum Subsurface Mercury Concentations, 2005/2007
mg/kg
- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

0 0.2 0.4 0.8
Miles

N

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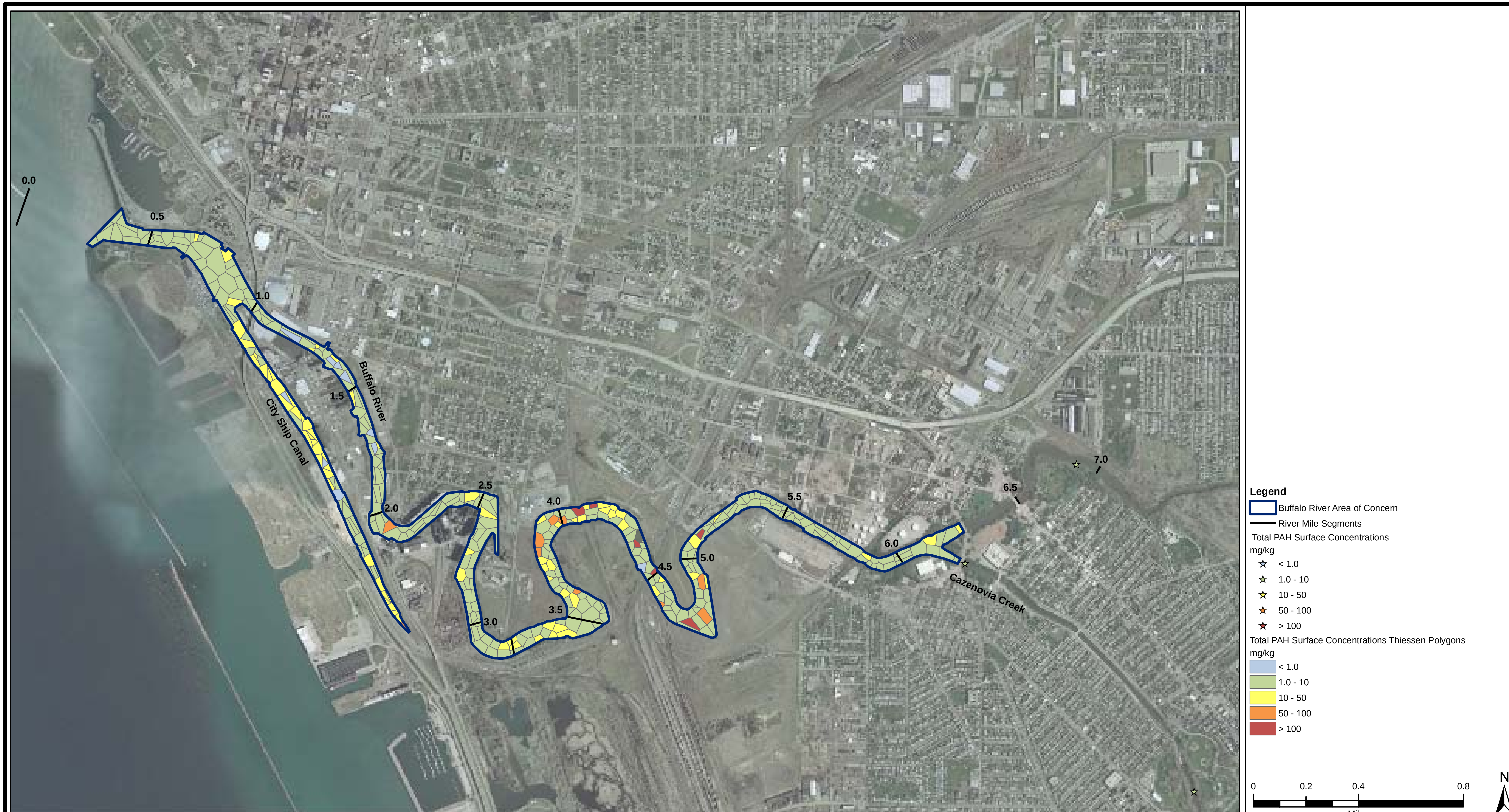
MERCURY SURFACE AND MAXIMUM SUBSURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS BUFFALO RIVER, NY

Figure 2-5

Drafter: B. Radakovich
Contract Number:
File Name: 20081211_Mercury_Point.mxd



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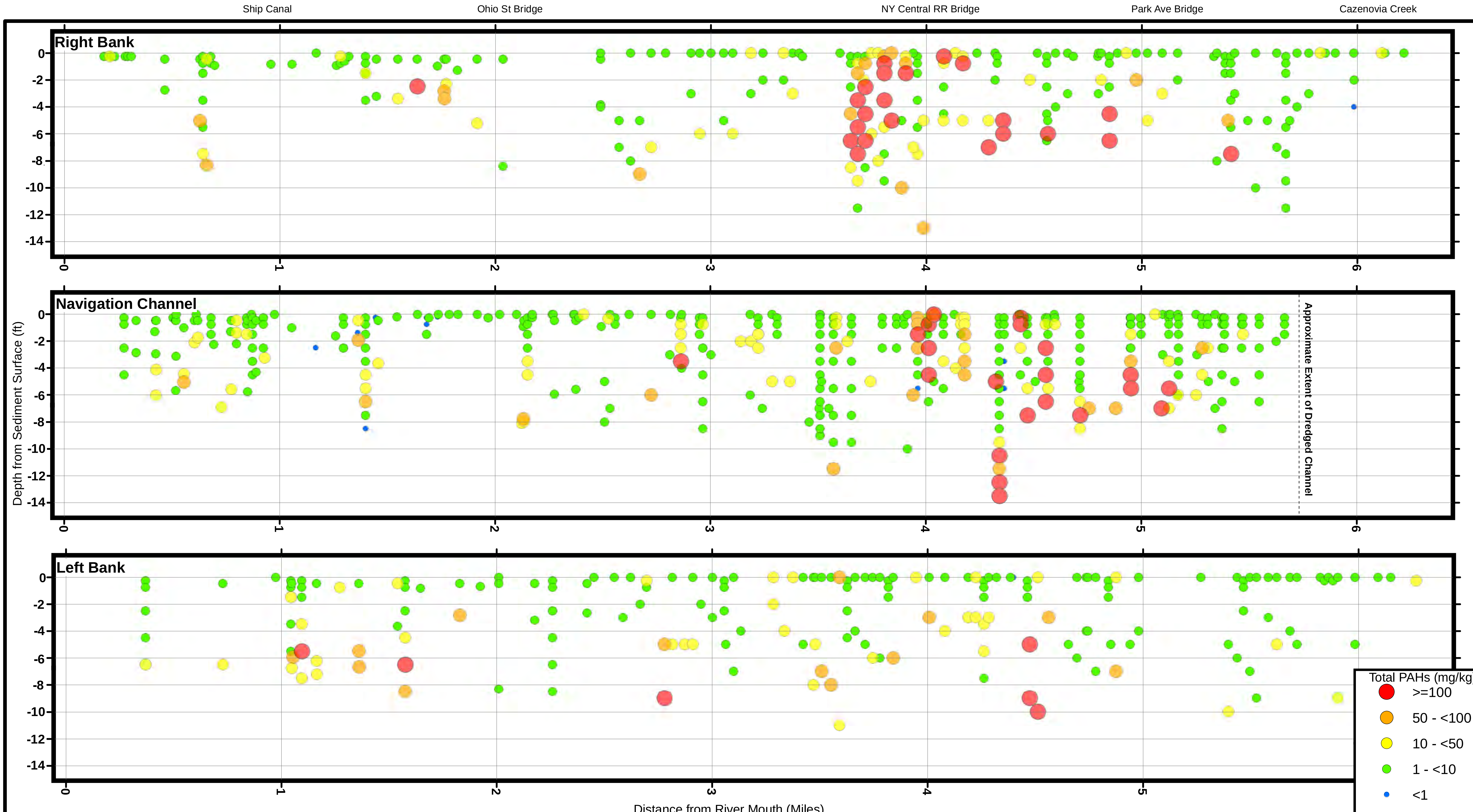
TOTAL PAH SURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS THIESSEN POLYGON ANALYSIS BUFFALO RIVER, NY

Figure 2-6

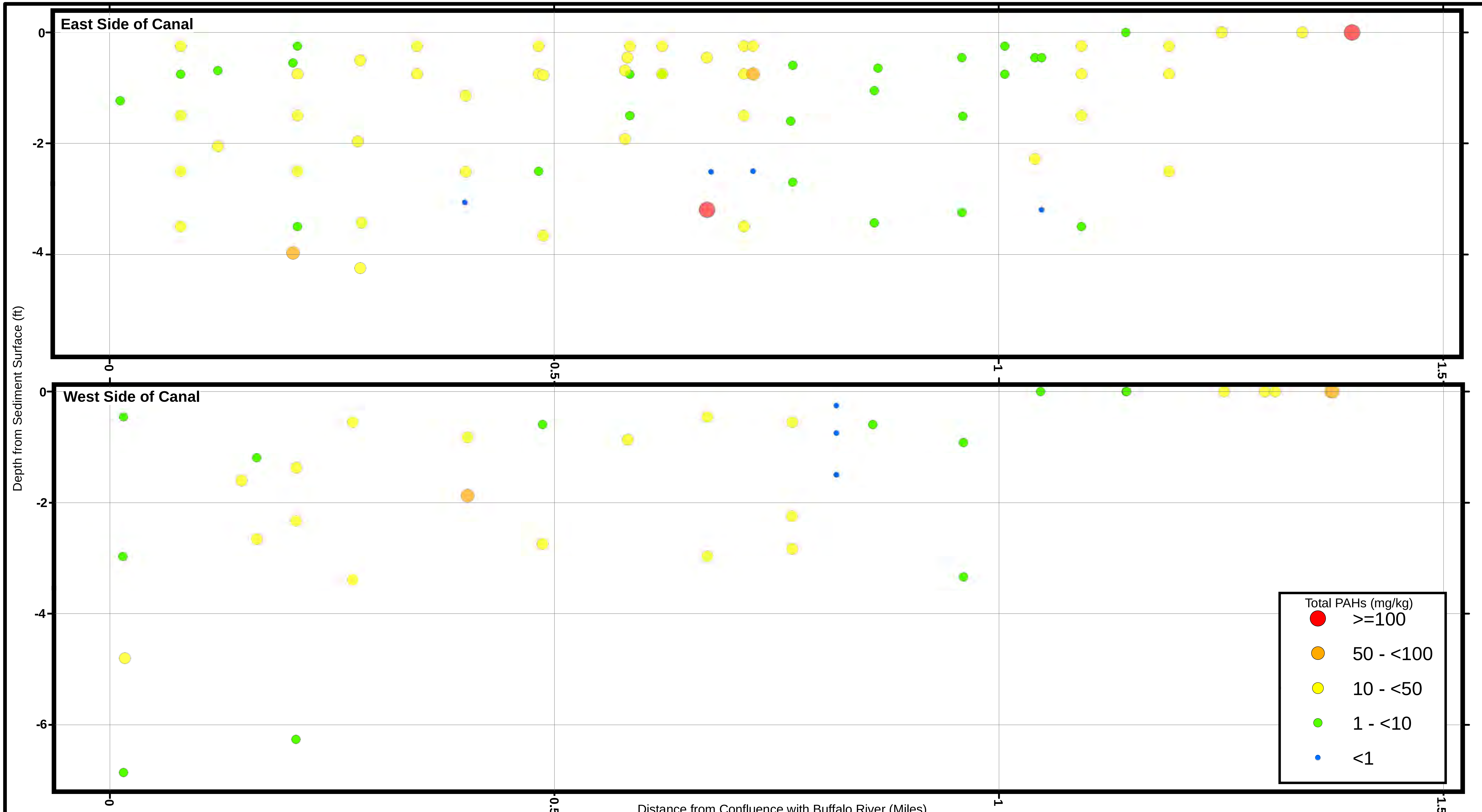
Drafter: B. Radakovich
Contract Number:
File Name: 20090123_Surface_PAH_Thiessen.mxd



ENVIRON MACTEC

VERTICAL PROFILES OF TOTAL PAH CONCENTRATIONS FOR THE BUFFALO RIVER FROM 2005/2007 AND 2008 SAMPLING EVENTS

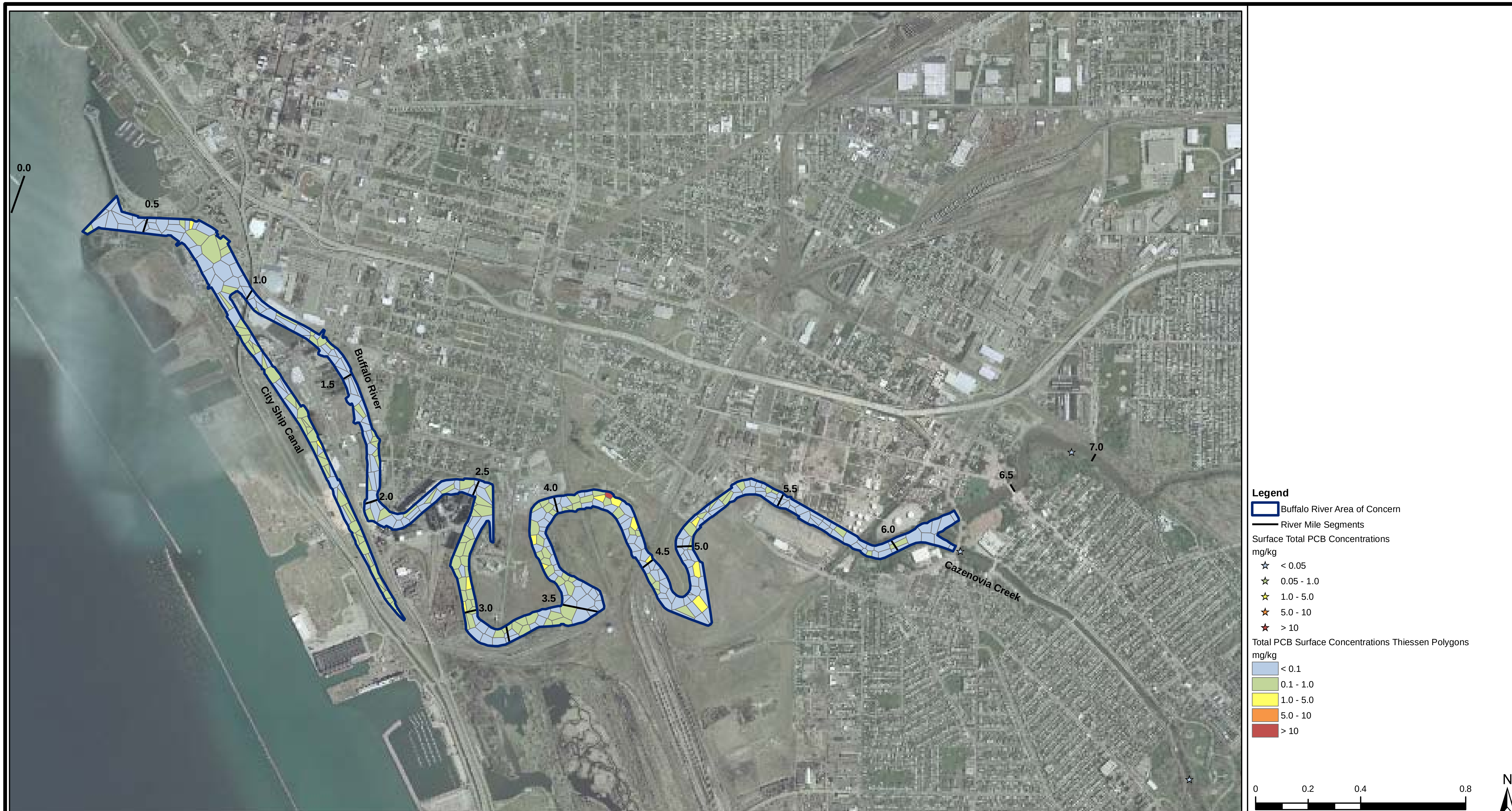
Figure 2-7



ENVIRON MACTEC

VERTICAL PROFILES OF TOTAL PAH CONCENTRATIONS FOR THE CITY SHIP CANAL FROM 2005/2007 AND 2008 SAMPLING EVENTS

Figure 2-8



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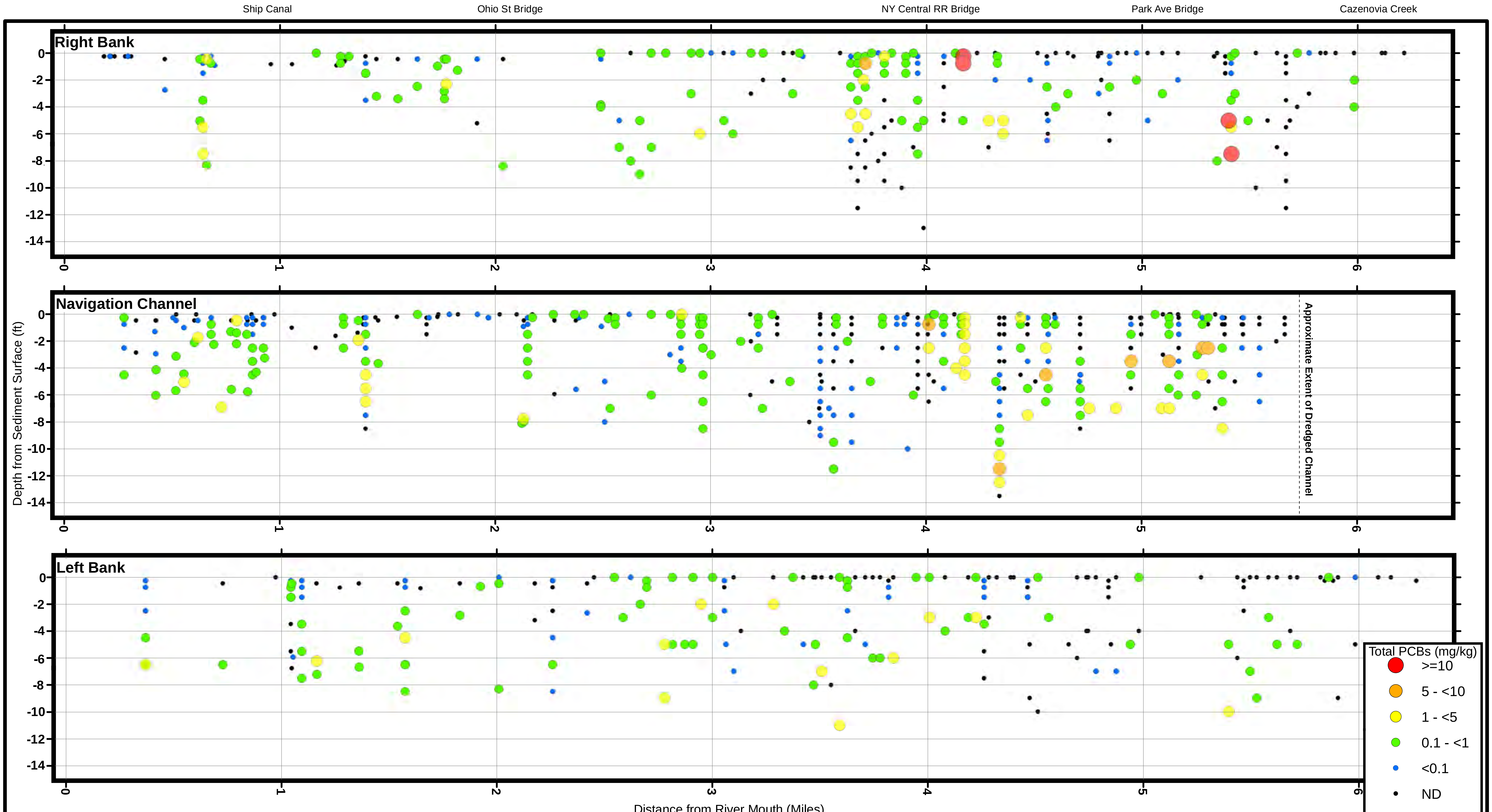
TOTAL PCB SURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS THIESSEN POLYGON ANALYSIS BUFFALO RIVER, NY

Figure 2-9

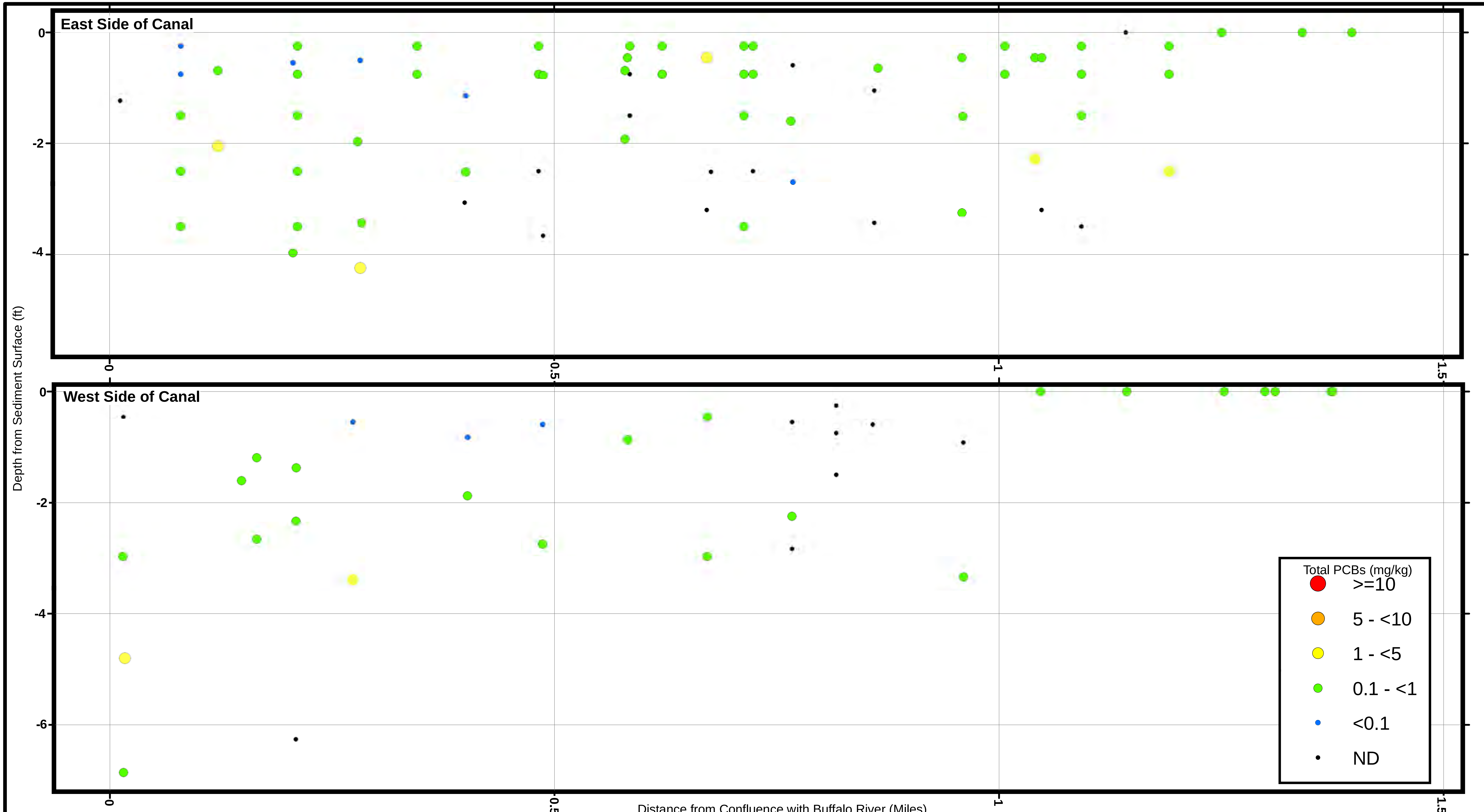
Drafter: B. Radakovich
Contract Number:
File Name: 20090123_Surface_PCB_Thiessen.mxd



ENVIRON MACTEC

VERTICAL PROFILES OF TOTAL PCB CONCENTRATIONS FOR THE BUFFALO RIVER FROM 2005/2007 AND 2008 SAMPLING EVENTS

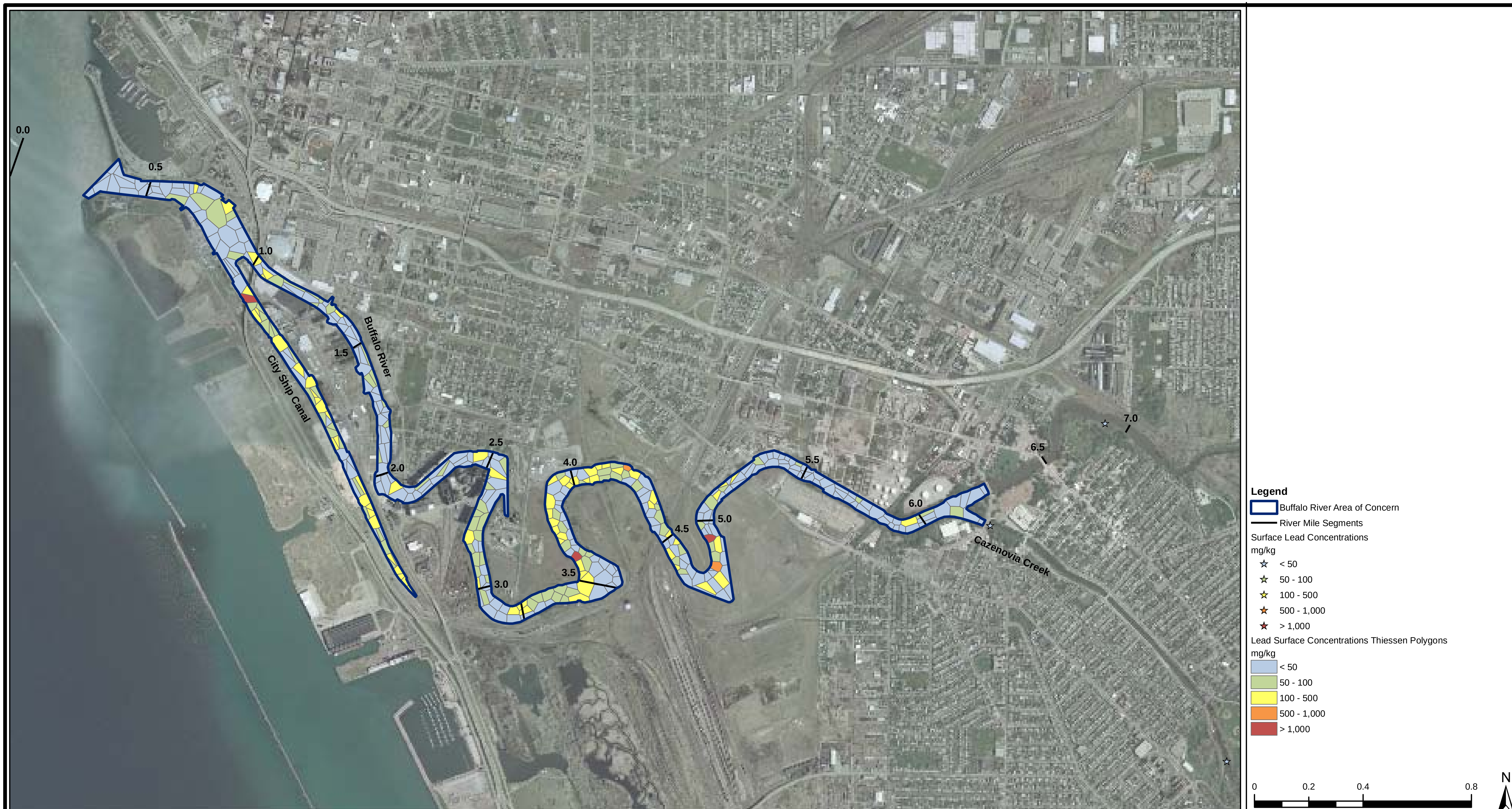
Figure 2-10



ENVIRON MACTEC

VERTICAL PROFILES OF TOTAL PCB CONCENTRATIONS FOR THE CITY SHIP CANAL FROM 2005/2007 AND 2008 SAMPLING EVENTS

Figure 2-11



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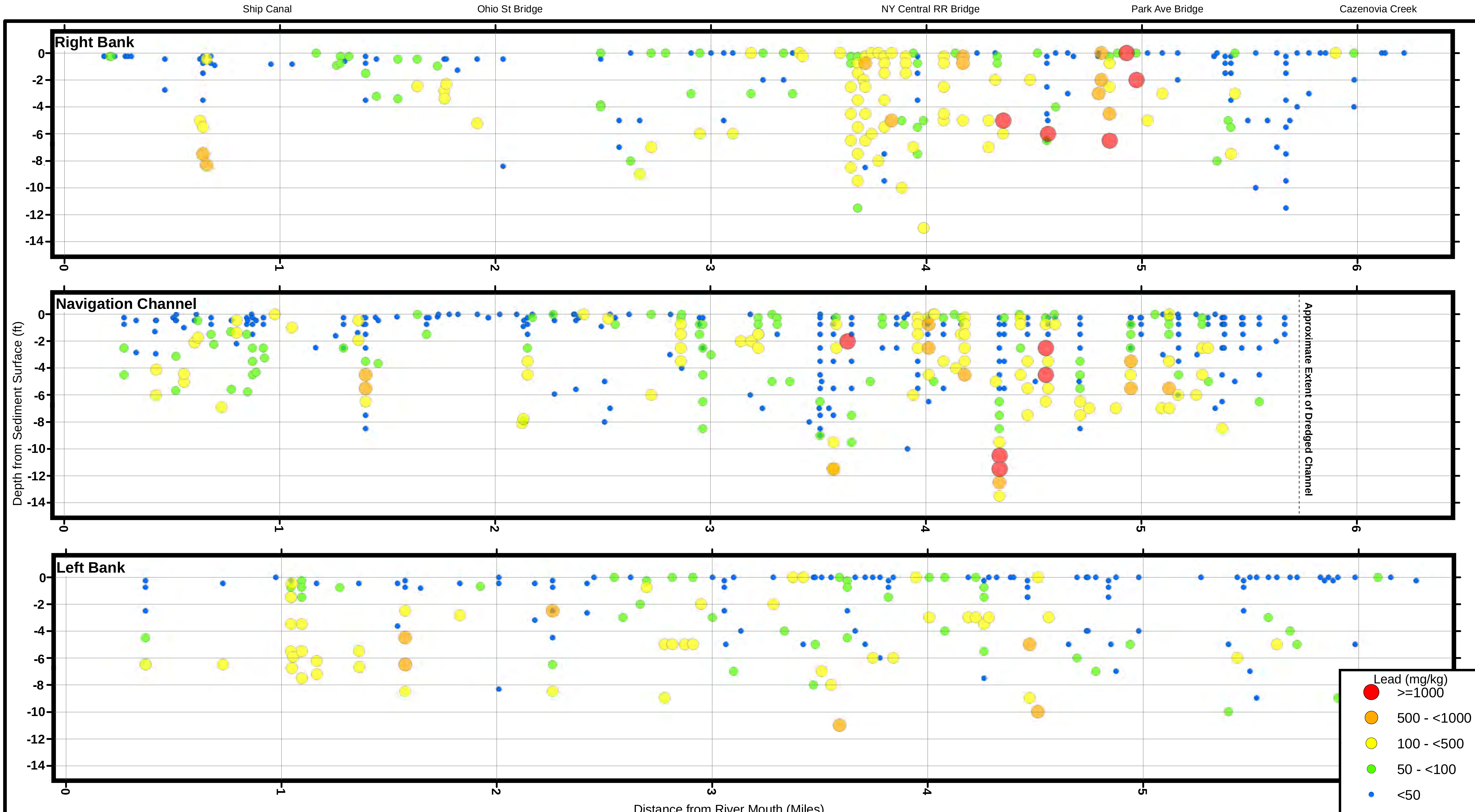
LEAD SURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS THIESSEN POLYGON ANALYSIS BUFFALO RIVER, NY

Figure 2-12

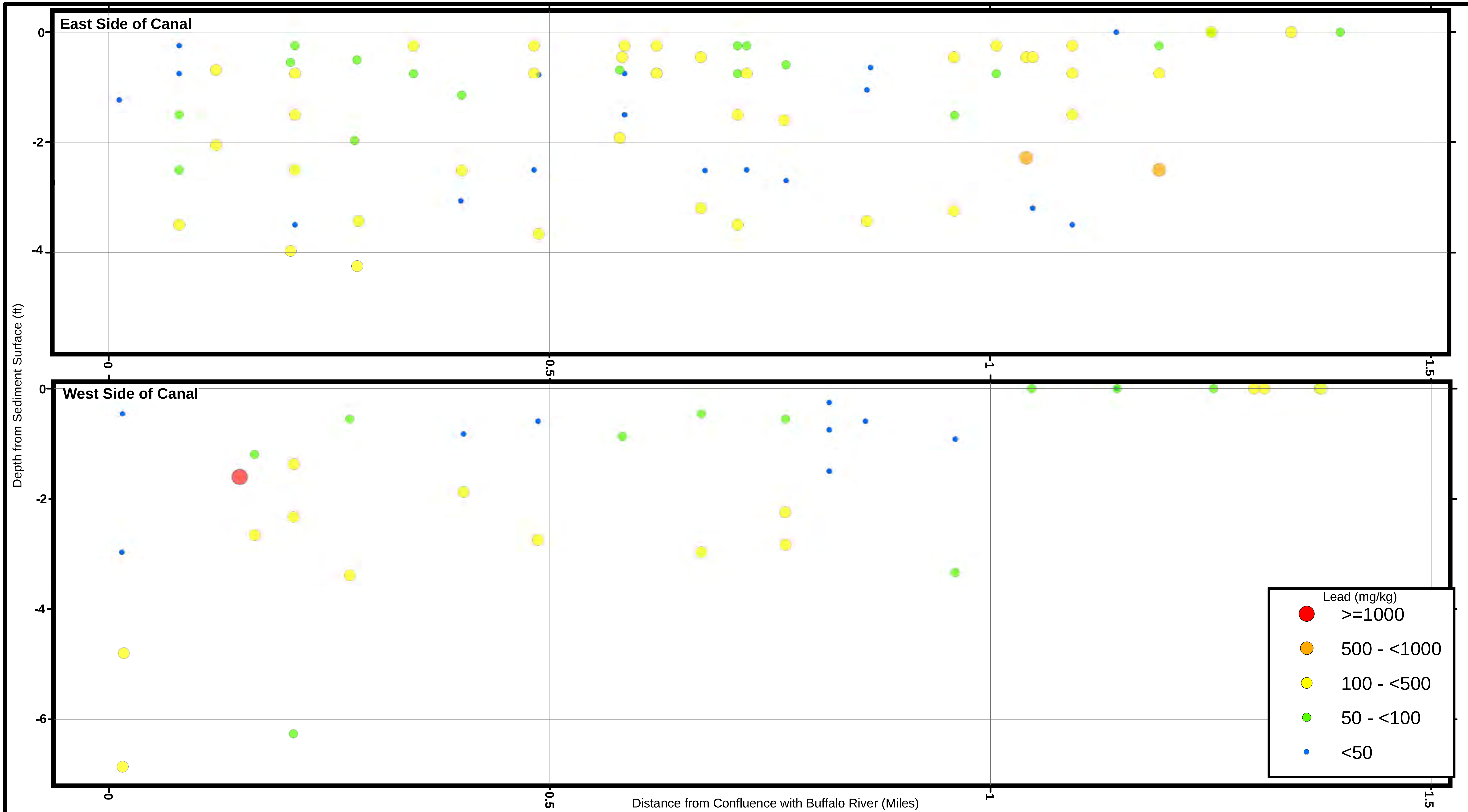
Drafter: B. Radakovich
Date: 01/12/2009
File Name: 20090123_Surface_Lead_Thiessen.mxd



ENVIRON MACTEC

VERTICAL PROFILES OF LEAD CONCENTRATIONS FOR THE BUFFALO RIVER FROM 2005/2007 AND 2008 SAMPLING EVENTS

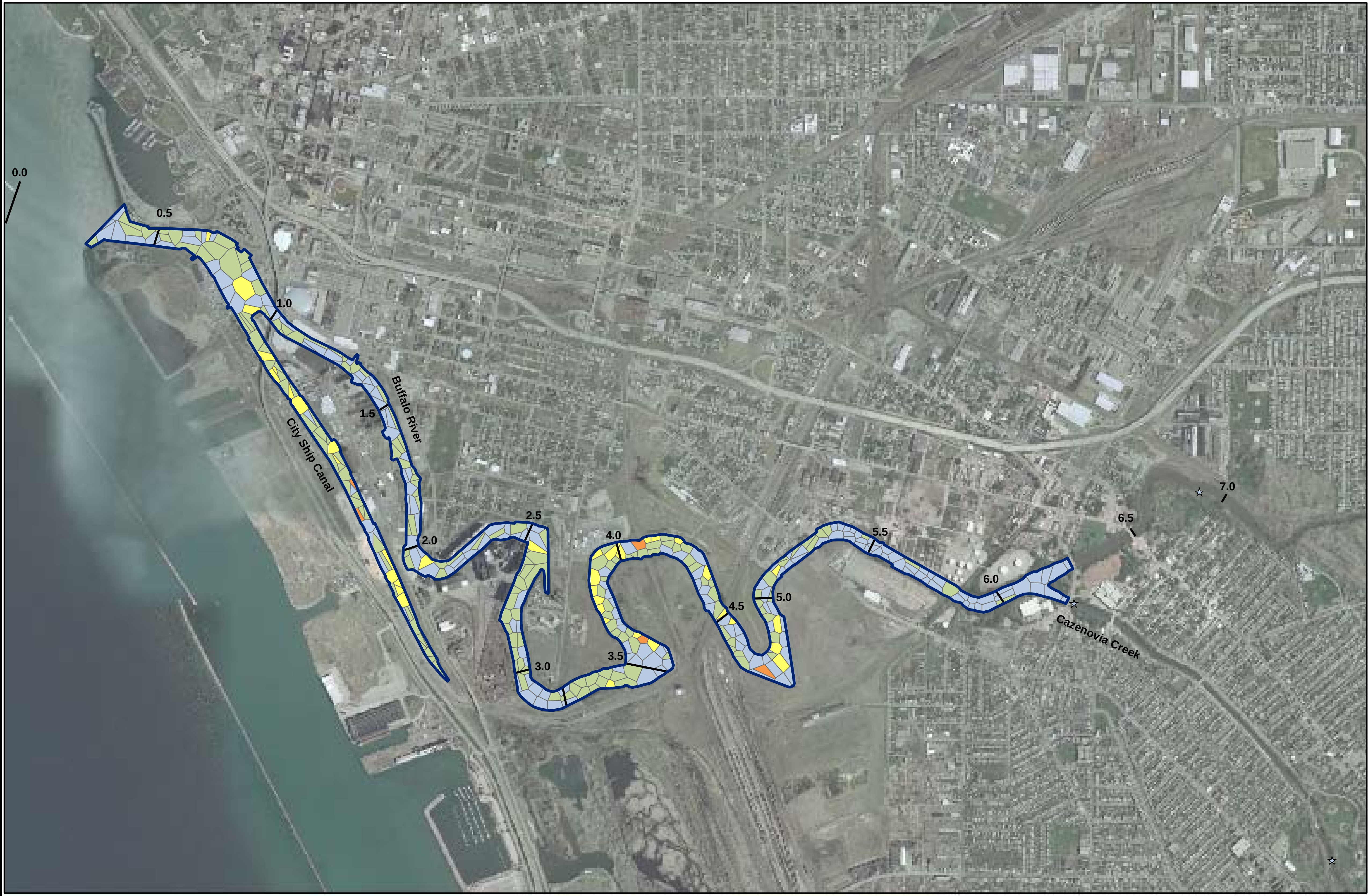
Figure 2-13



ENVIRON MACTEC

VERTICLE PROFILES OF LEAD CONCENTRATIONS FOR THE CITY SHIP CANAL FROM 2005/2007 AND 2008 SAMPLING EVENTS

Figure 2-14



Legend

- Buffalo River Area of Concern
- River Mile Segments

Mercury Surface Concentrations
mg/kg

- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

Mercury Surface Concentrations Thiessen Polygon
mg/kg

- < 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 10
- > 10

0 0.2 0.4 0.8
Miles

N

ENVIRON
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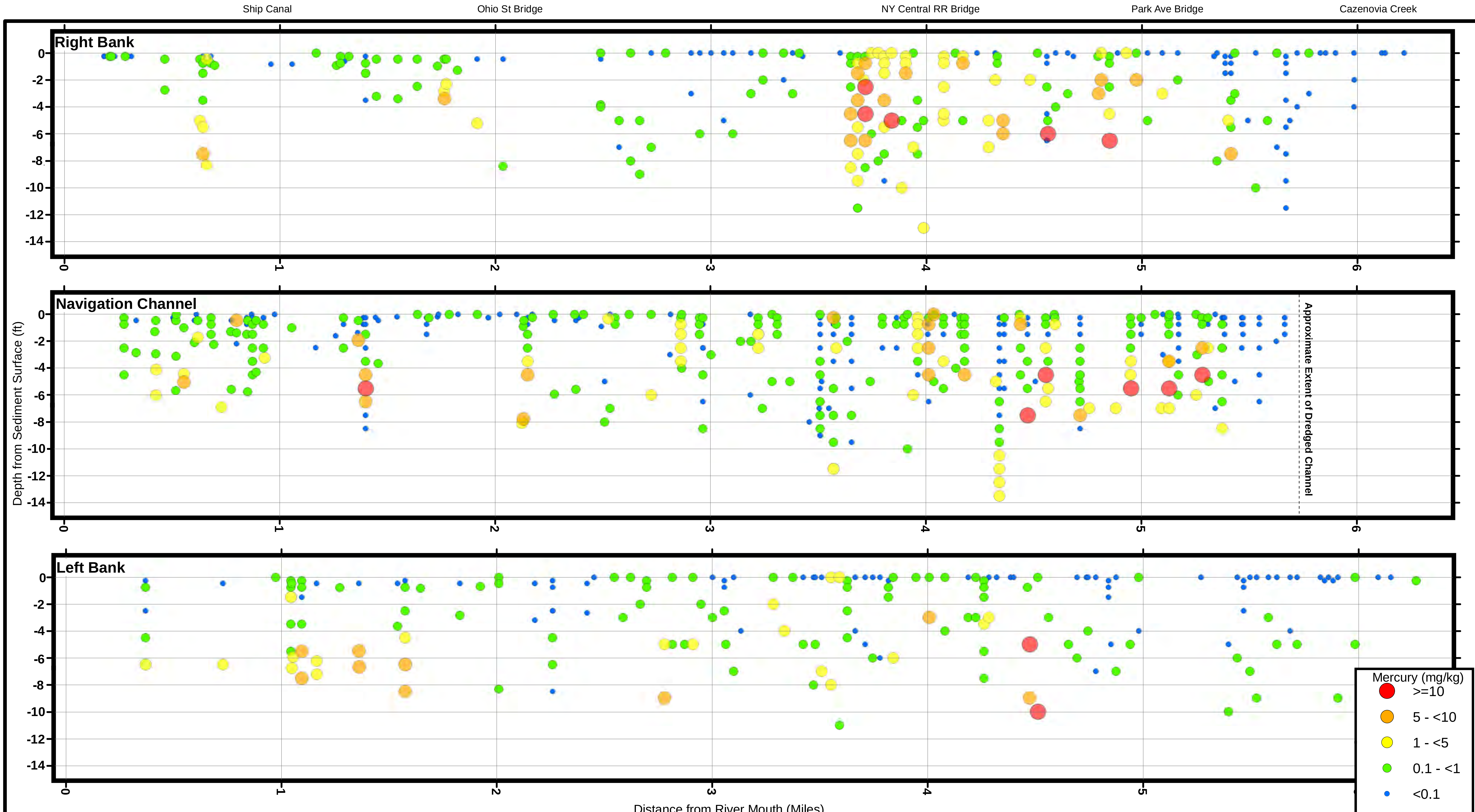
MERCURY SURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS THIESSEN POLYGON ANALYSIS BUFFALO RIVER, NY

Figure 2-15

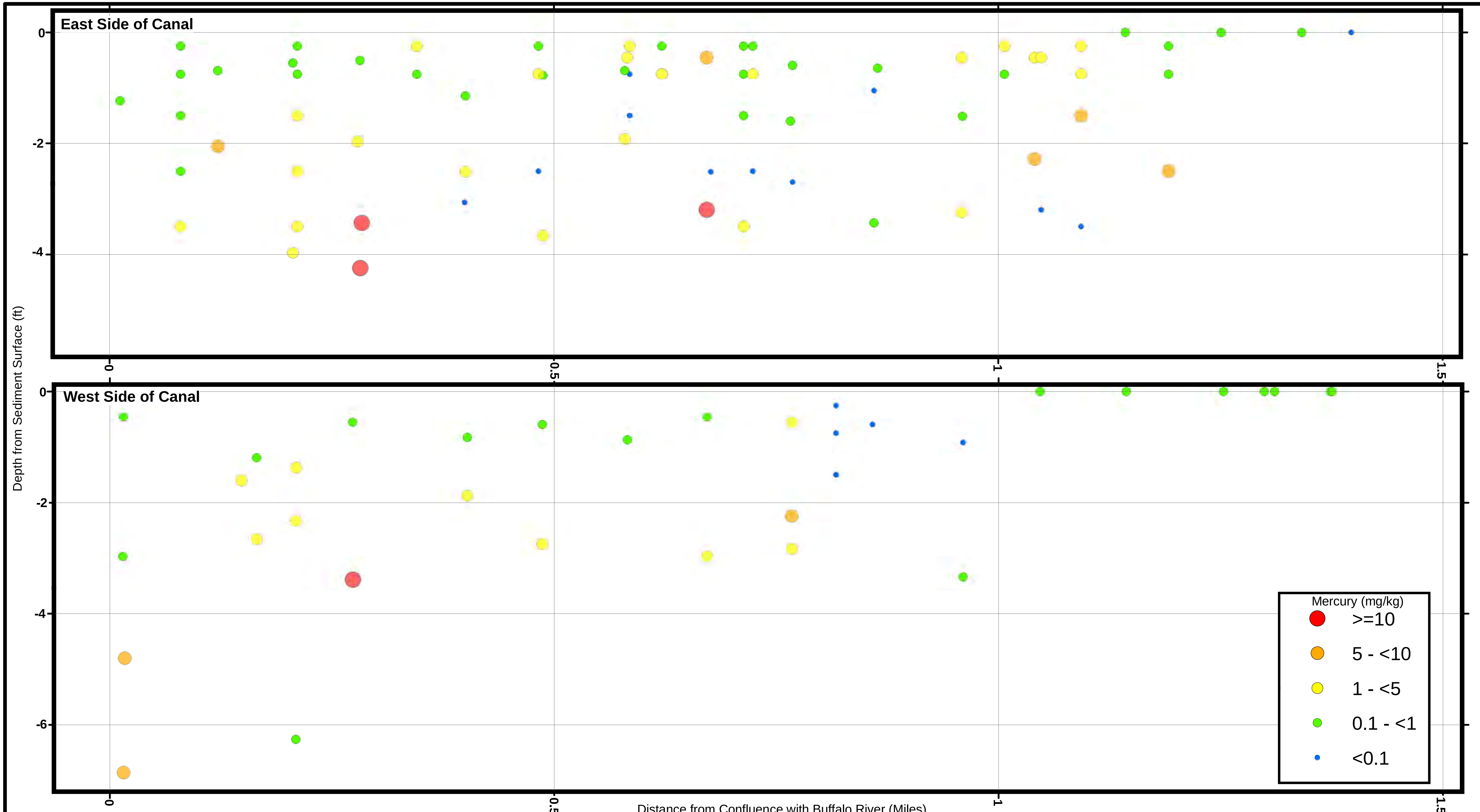
Drafter: B. Radakovich
Contract Number:
File Name: 20090123_Surface_Mercury_Thiessen.mxd



ENVIRON MACTEC

VERTICLE PROFILES OF MERCURY CONCENTRATIONS FOR THE BUFFALO RIVER FROM 2005/2006 AND 2008 SAMPLING EVENTS

Figure 2-16



ENVIRON

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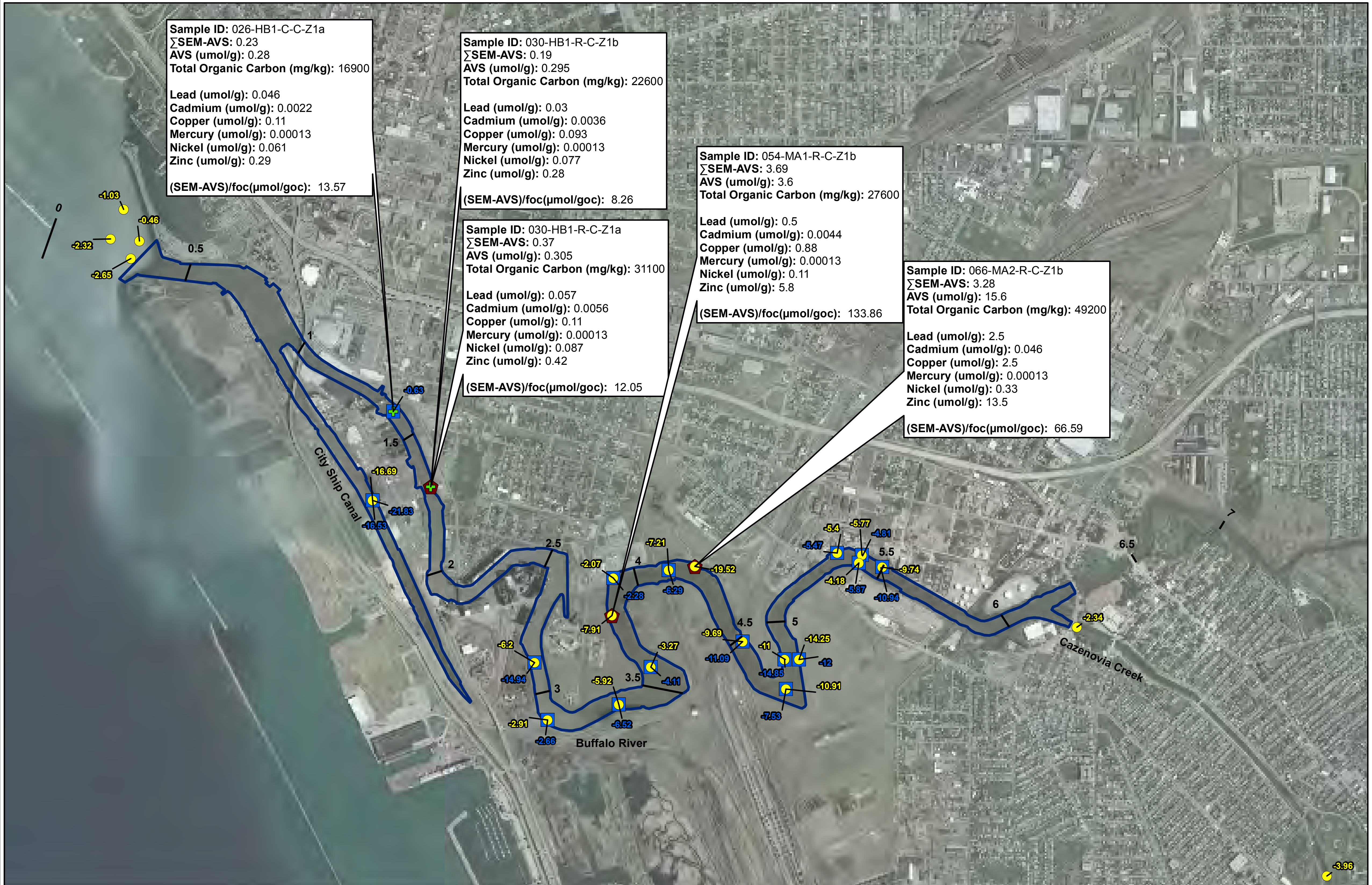
VERTICAL PROFILES OF MERCURY CONCENTRATIONS FOR THE CITY SHIP CANAL FROM 2005/2007 AND 2008 SAMPLING EVENTS

Figure 2-17



Legend

- Buffalo River Area of Concern
- River Mile Segments
- SEM > AVS Surface Sample Locations (0 - 6")
- AVS > SEM Surface Sample Locations (0 - 6")
- SEM > AVS Subsurface Sample Locations (6 - 12")
- AVS > SEM Subsurface Sample Locations (6 - 12")

AVS - Acid Volatile Sulfides

SEM - Simultaneously Extracted Metals

∑SEM = Sum of Metals (cadmium, copper, lead, mercury, nickel, and zinc)

Sum of Metals = Divalent metals cadmium, copper, lead, mercury, nickel, and zinc.

µmol/g - micromoles per gram dry sediment

foc - Fraction of organic carbon

In 89% of sediment samples (40 of 45 samples) AVS exceeds SEM indicating that toxicity due to divalent metals is very unlikely.

For sediment samples in which SEM minus AVS results in a negative number than AVS is in excess of SEM and toxicity due to divalent metals is very unlikely.

At locations where SEM minus AVS is positive (SEM > AVS) samples were further analyzed using an evaluation of OC-normalized excess metals (USEPA 2005):

Where [∑SEM-AVS]/foc < 130 µmol per gram – Toxicity unlikely
Where [∑SEM-AVS]/foc > 3,000 µmol per gram - Toxicity likely

0 0.2 0.4 0.8
Miles
N

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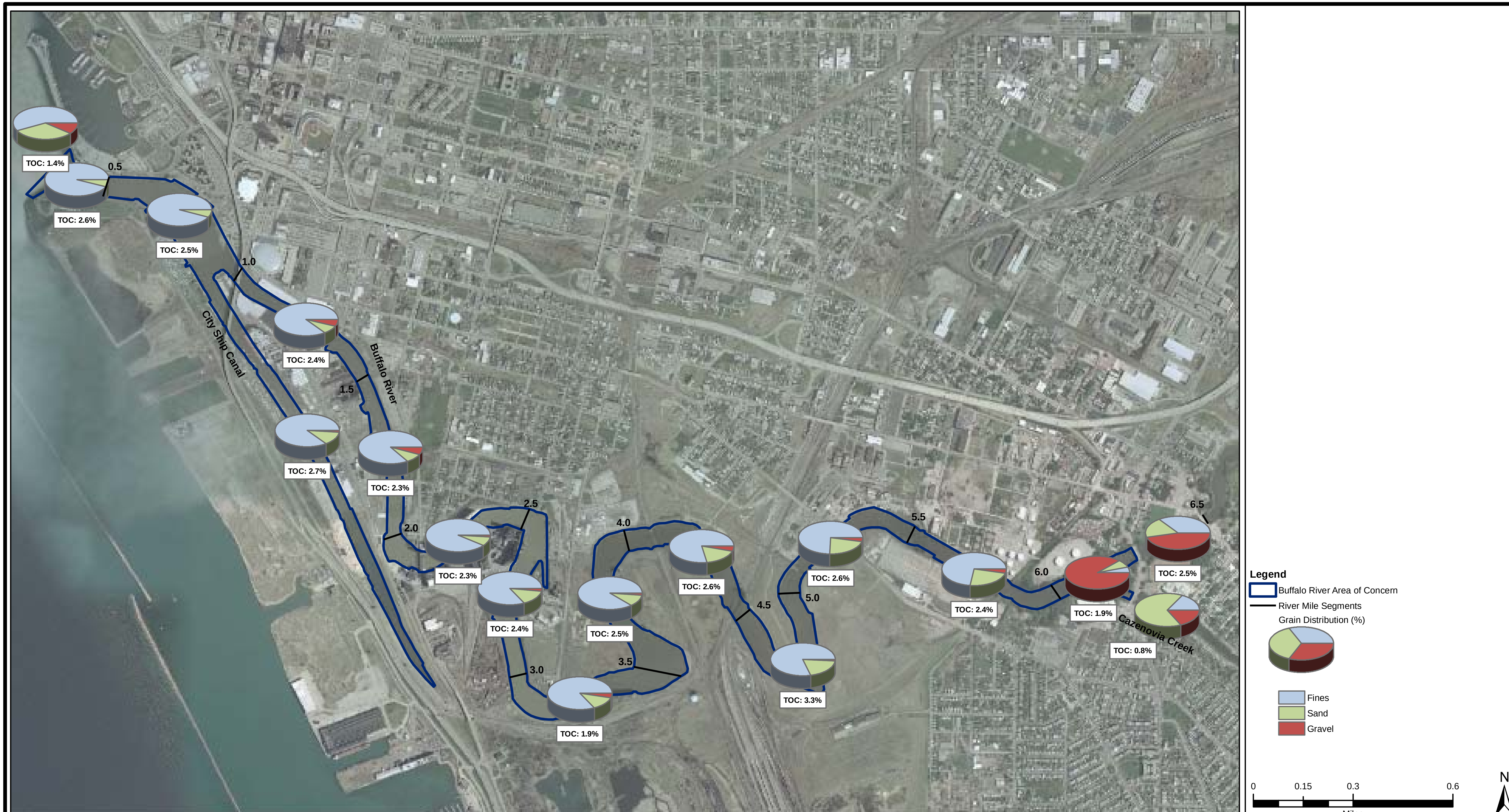
EVALUATION OF ACID VOLATILE SULFIDES AND SIMULTANEOUSLY EXTRACTED METALS IN BUFFALO RIVER SEDIMENTS FROM 2008 SAMPLING EVENT BUFFALO RIVER, NY

Figure 2-18

Drafter: B. Radakovich
Contract Number:
File Name: 20081218_AVS_Gtr_SEM.mxd



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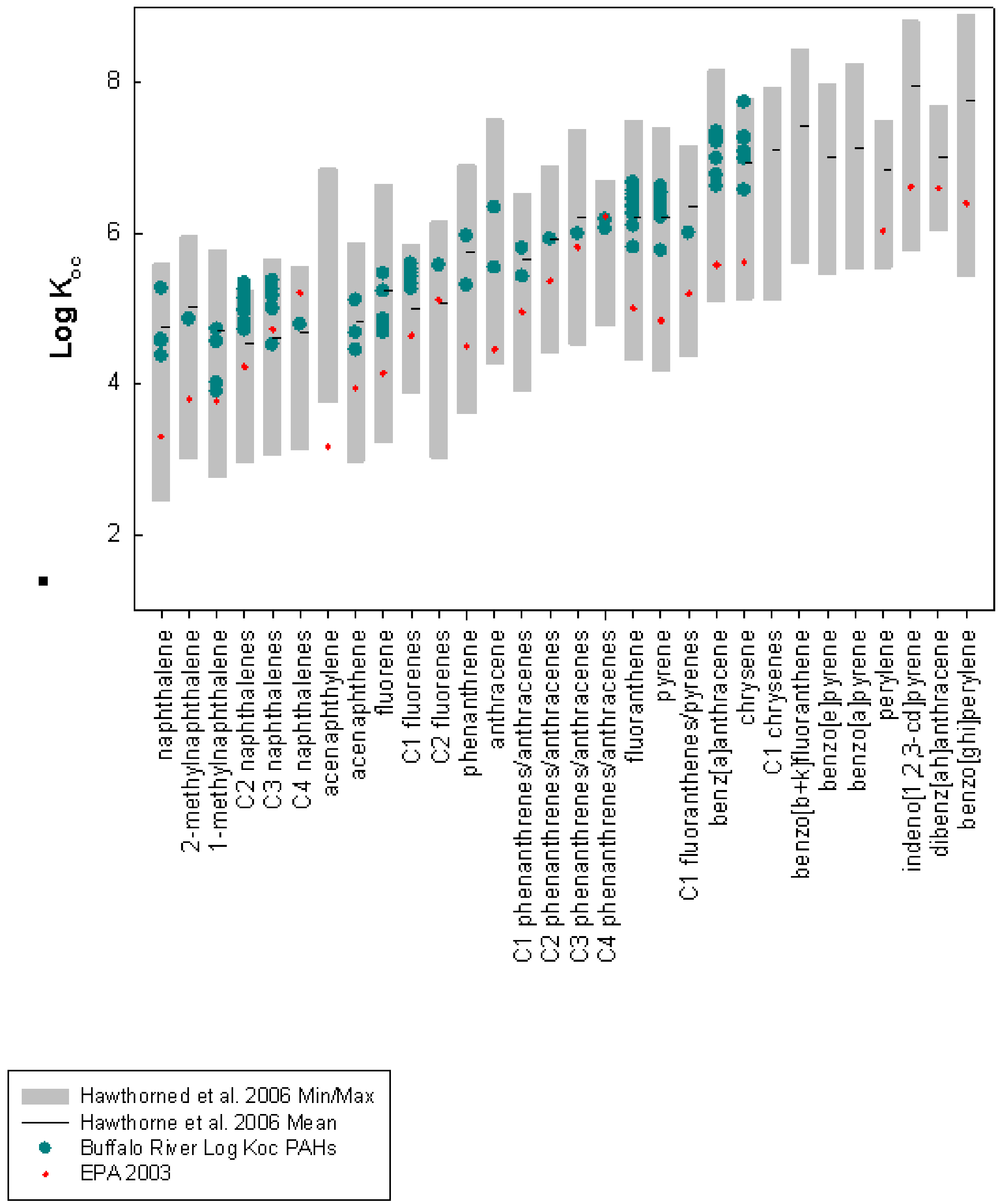
GRAIN SIZE DISTRIBUTIONS AND TOTAL ORGANIC CARBON CONCENTRATIONS
BUFFALO RIVER, NY

Figure 2-19

Drafter: B. Radakovich
Contract Number: 0220873B5
File Name: 20081230_GrainDistribution.mxd



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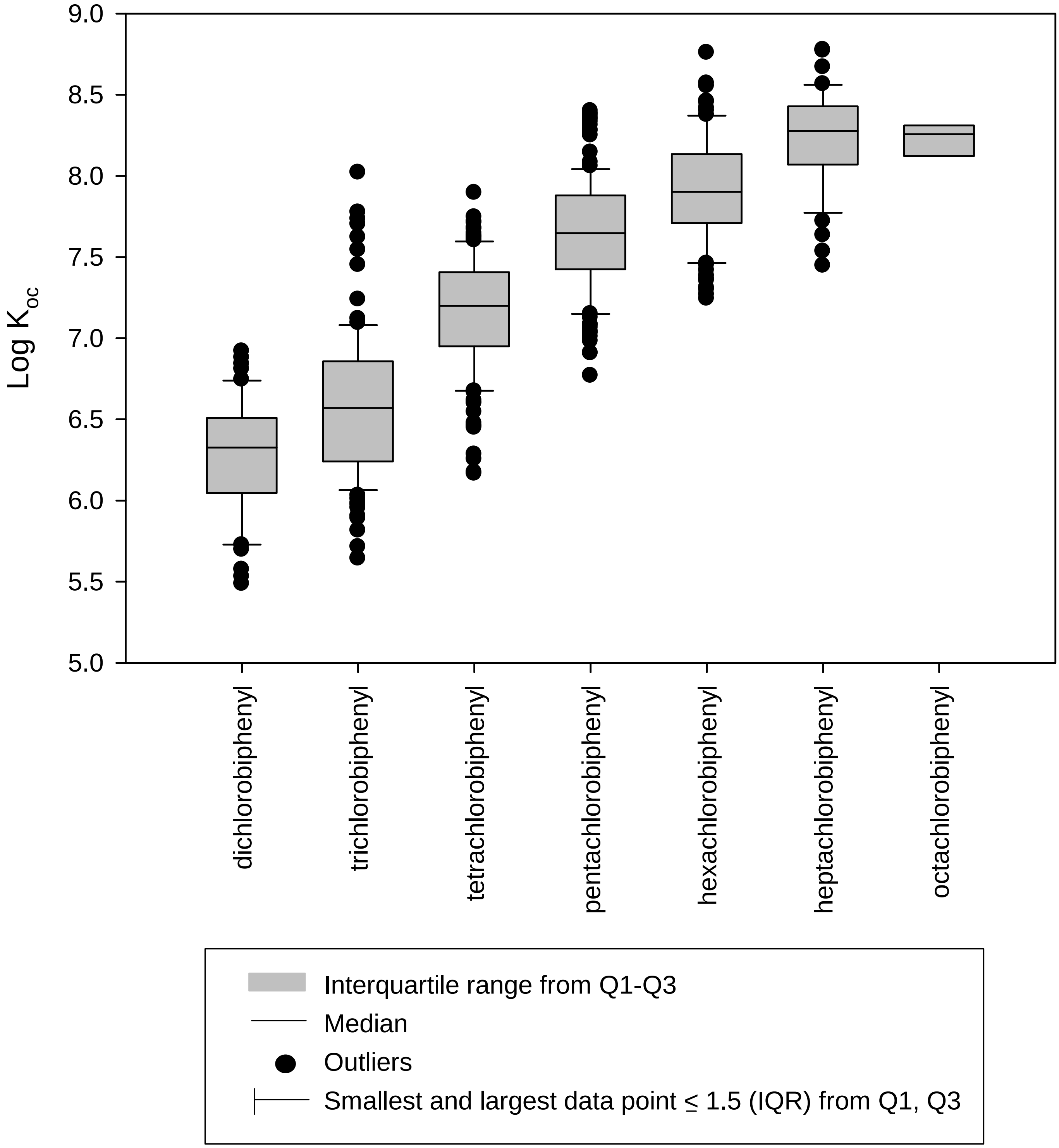
LOG Koc VALUES FOR PAHS IN SEDIMENTS

Figure 2-20



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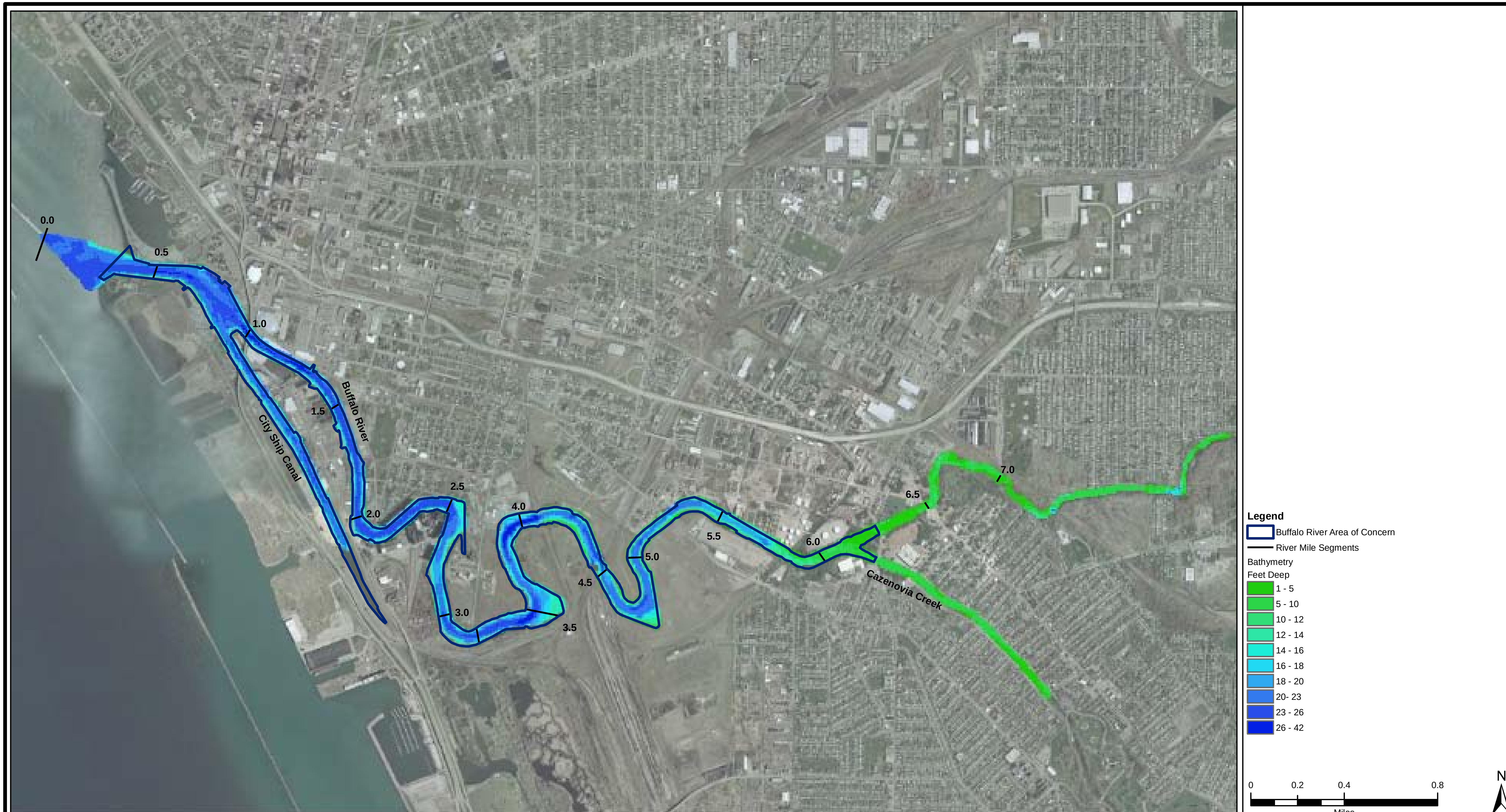
LOG Koc VALUES FOR PCB HOMOLOGS IN BUFFALO RIVER SEDIMENTS

Figure 2-21



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BUFFALO RIVER BATHYMETRY
FROM 2007 AND 2008 SURVEYS
BUFFALO RIVER, NY

Figure
3-1

Drafter: B. Radakovich
Contract Number:
File Name: 20090226_Bathymetry.mxd

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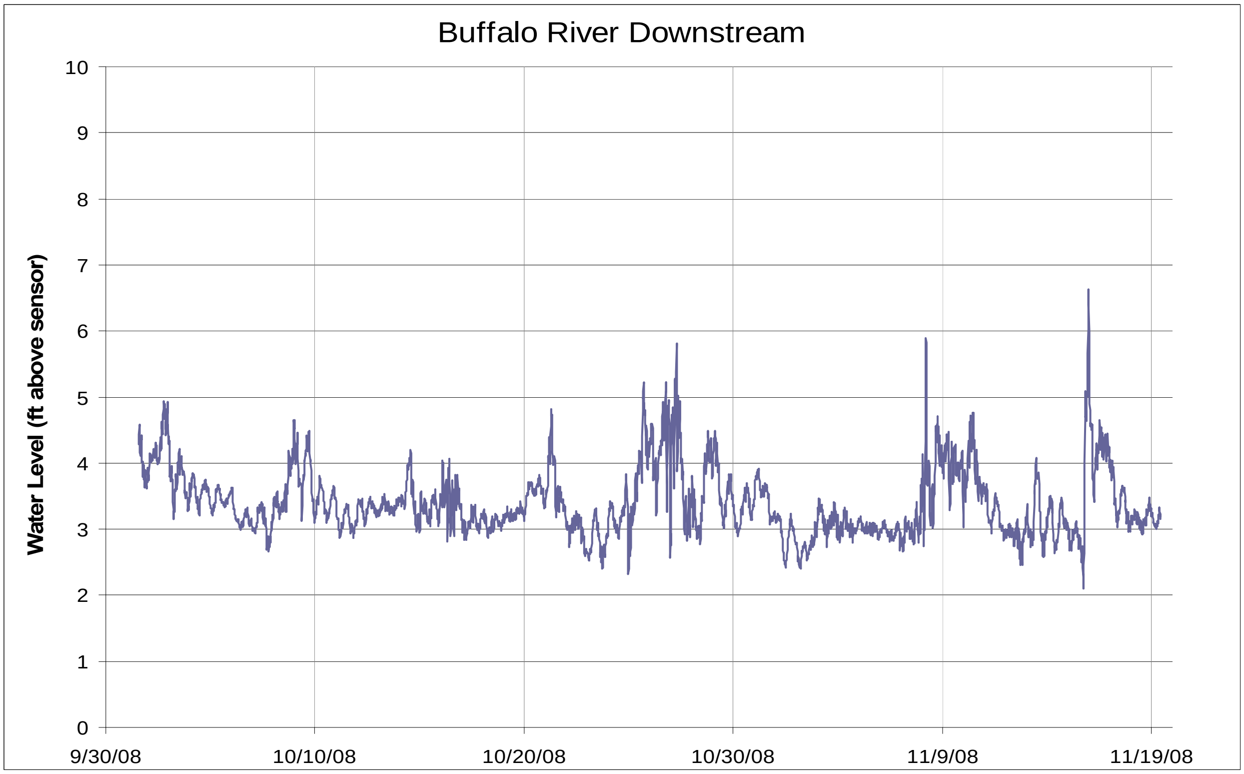
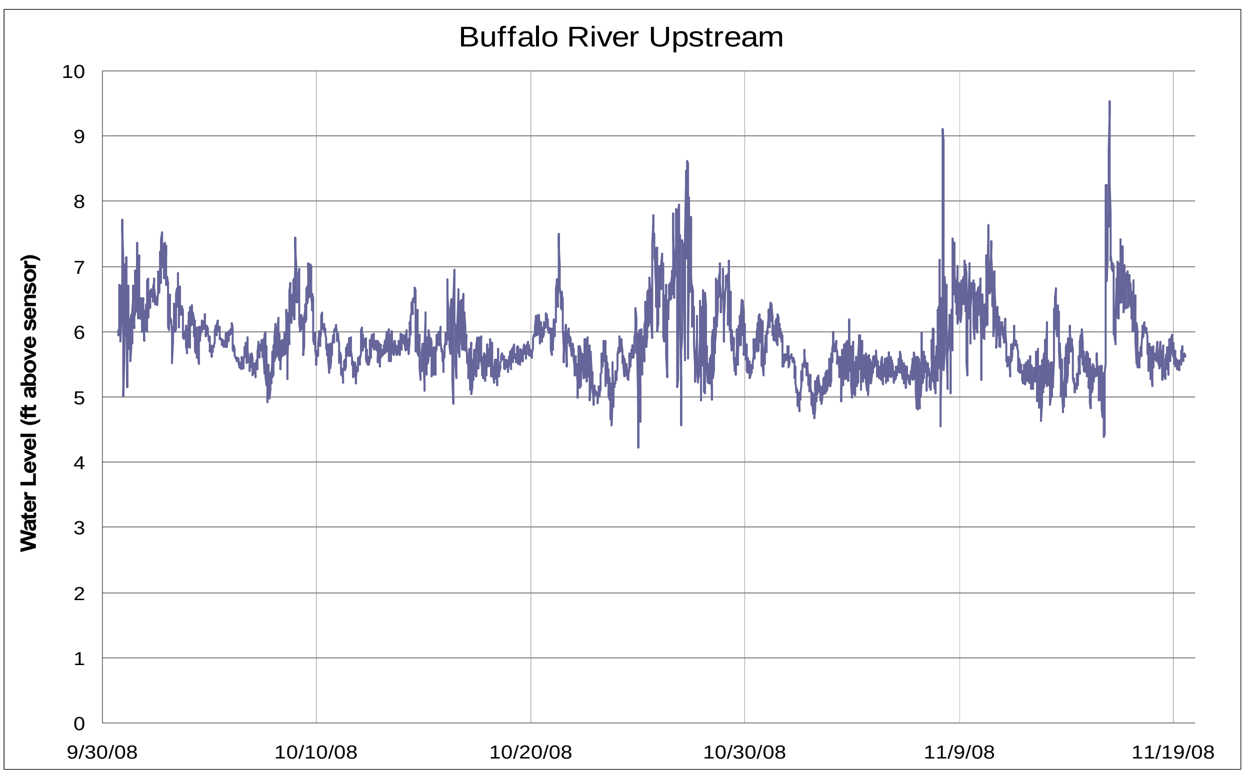
MACTEC

HYDRODYNAMIC MONITORING LOCATIONS
BUFFALO RIVER, NY

Figure
3-2

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20081216_2009 Monitoring_Location.mxd





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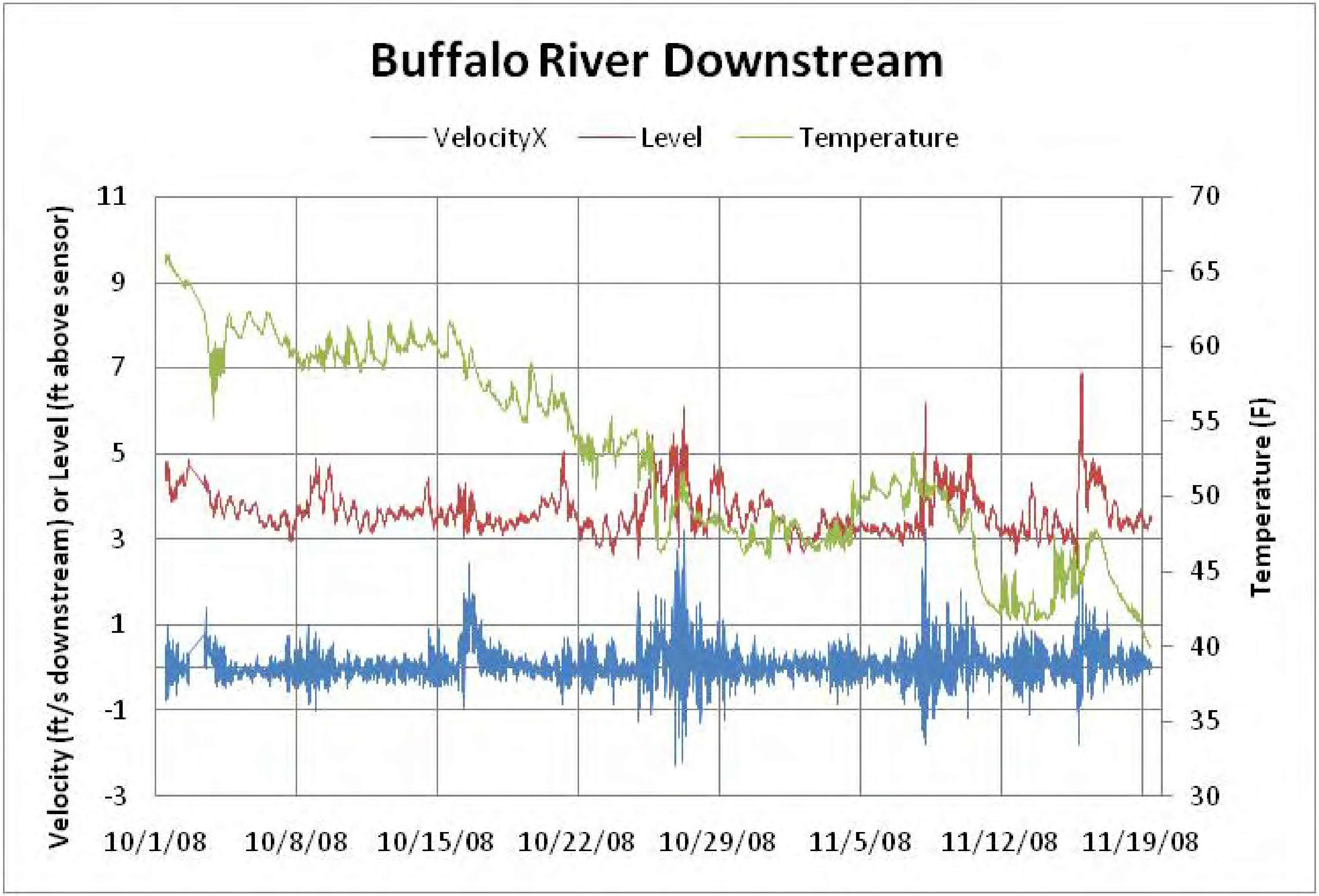
DOWNSTREAM & UPSTREAM WATER SURFACE LEVEL BUFFALO RIVER, NY

Figure 3-3



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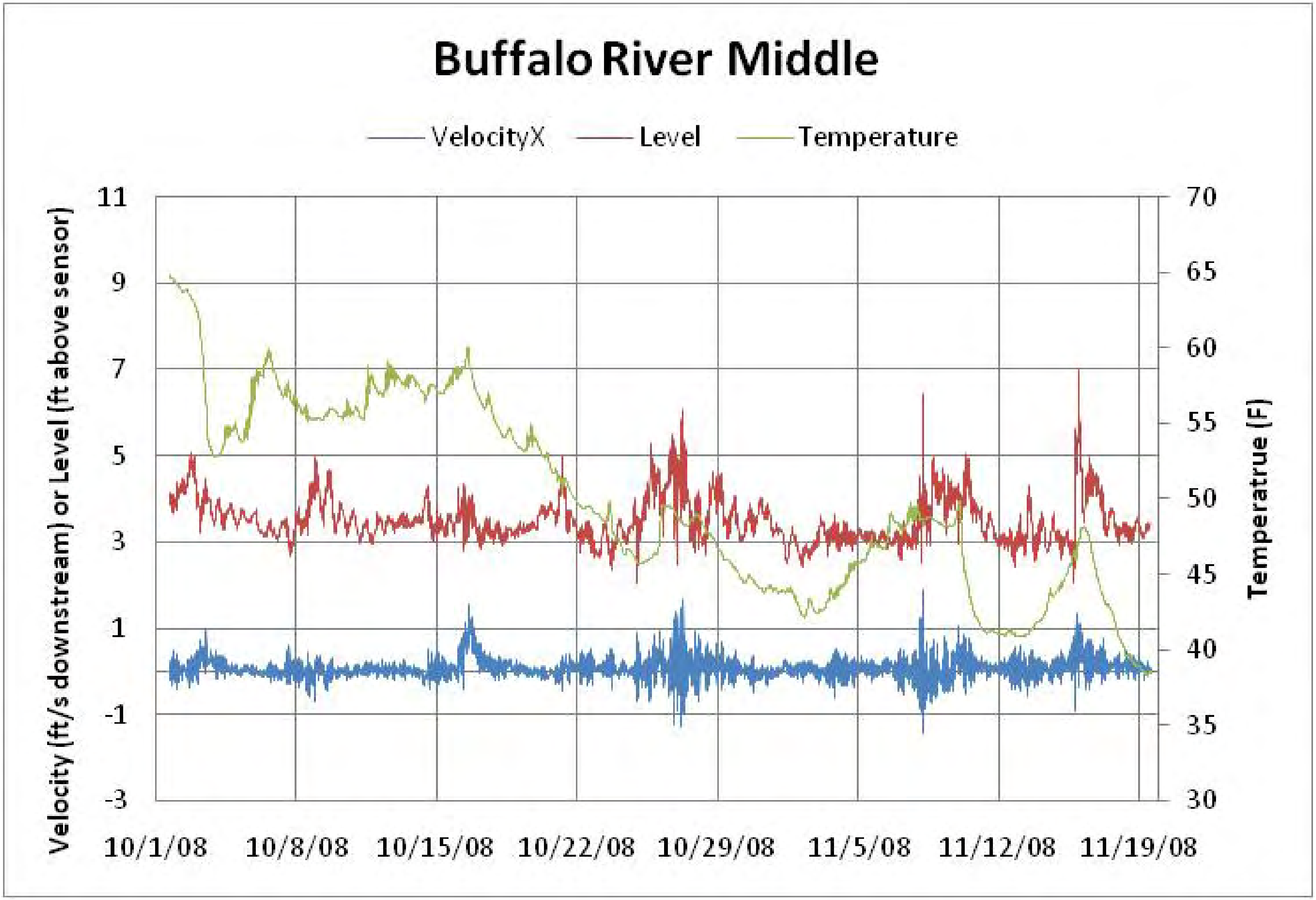
LimnoTech

DOWNSTREAM ADCP DATA (SIDELOOKER)
BUFFALO RIVER, NY

Figure 3-4



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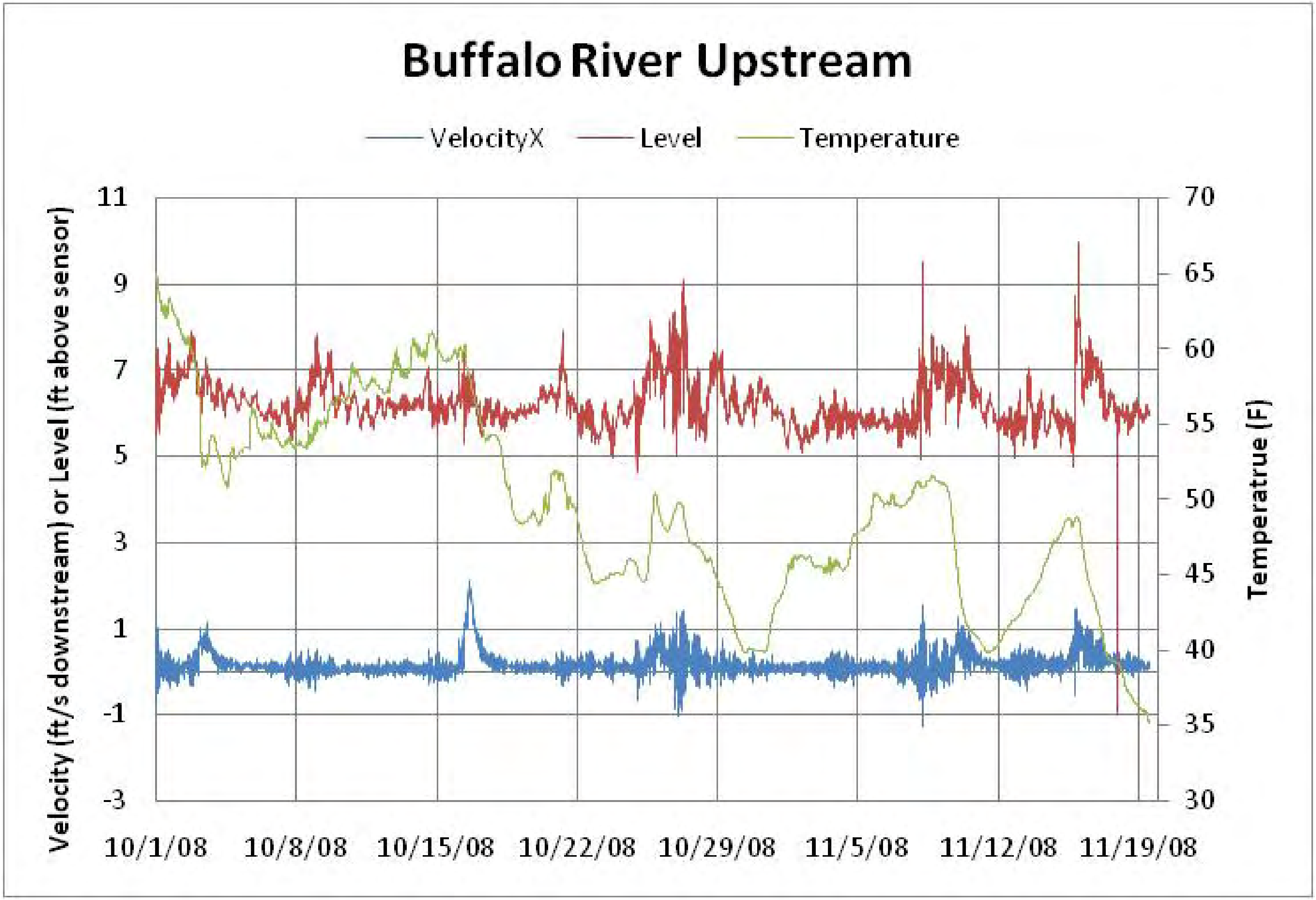
MIDSTREAM ADCP DATA (SIDELOOKER)
BUFFALO RIVER, NY

Figure 3-5



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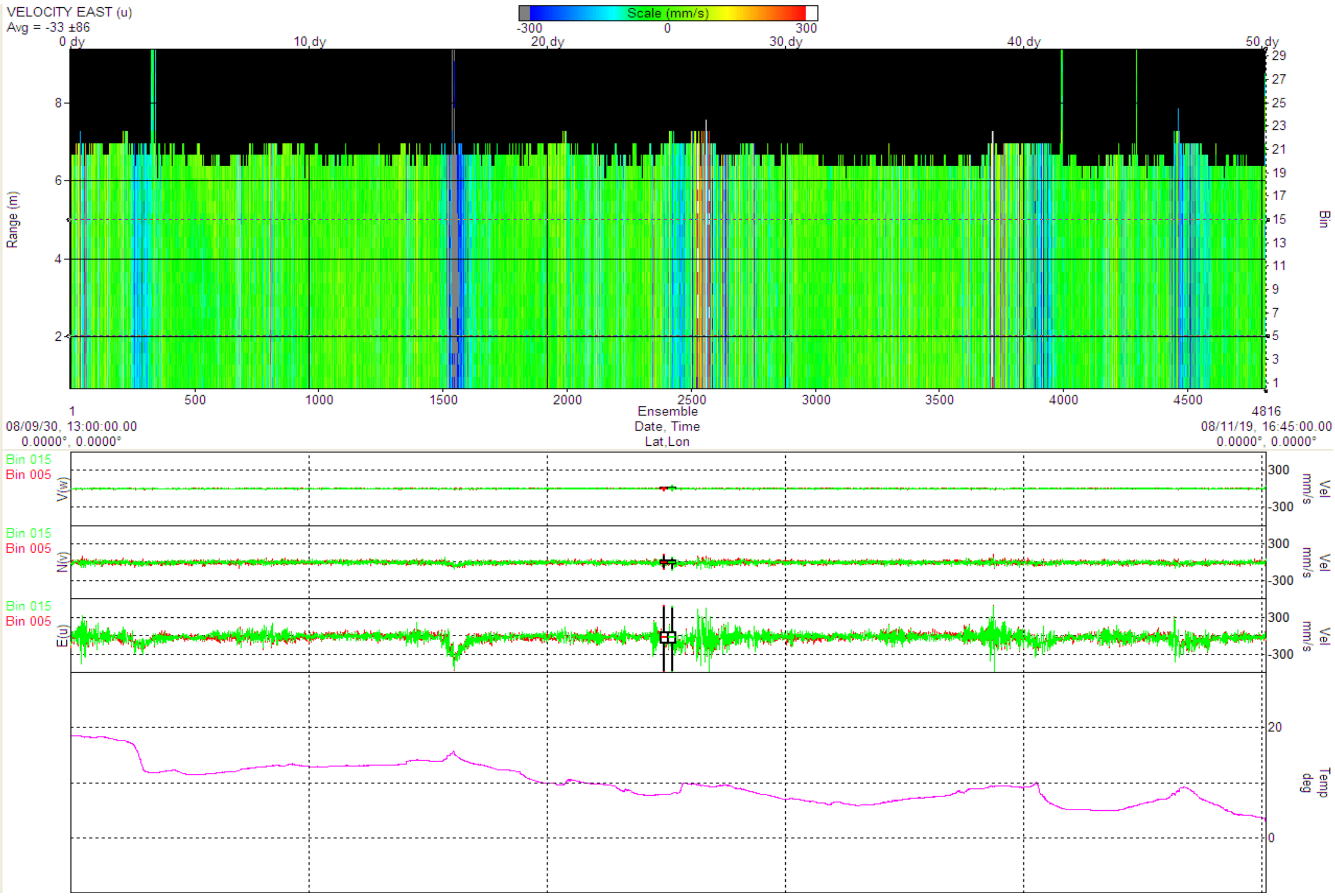
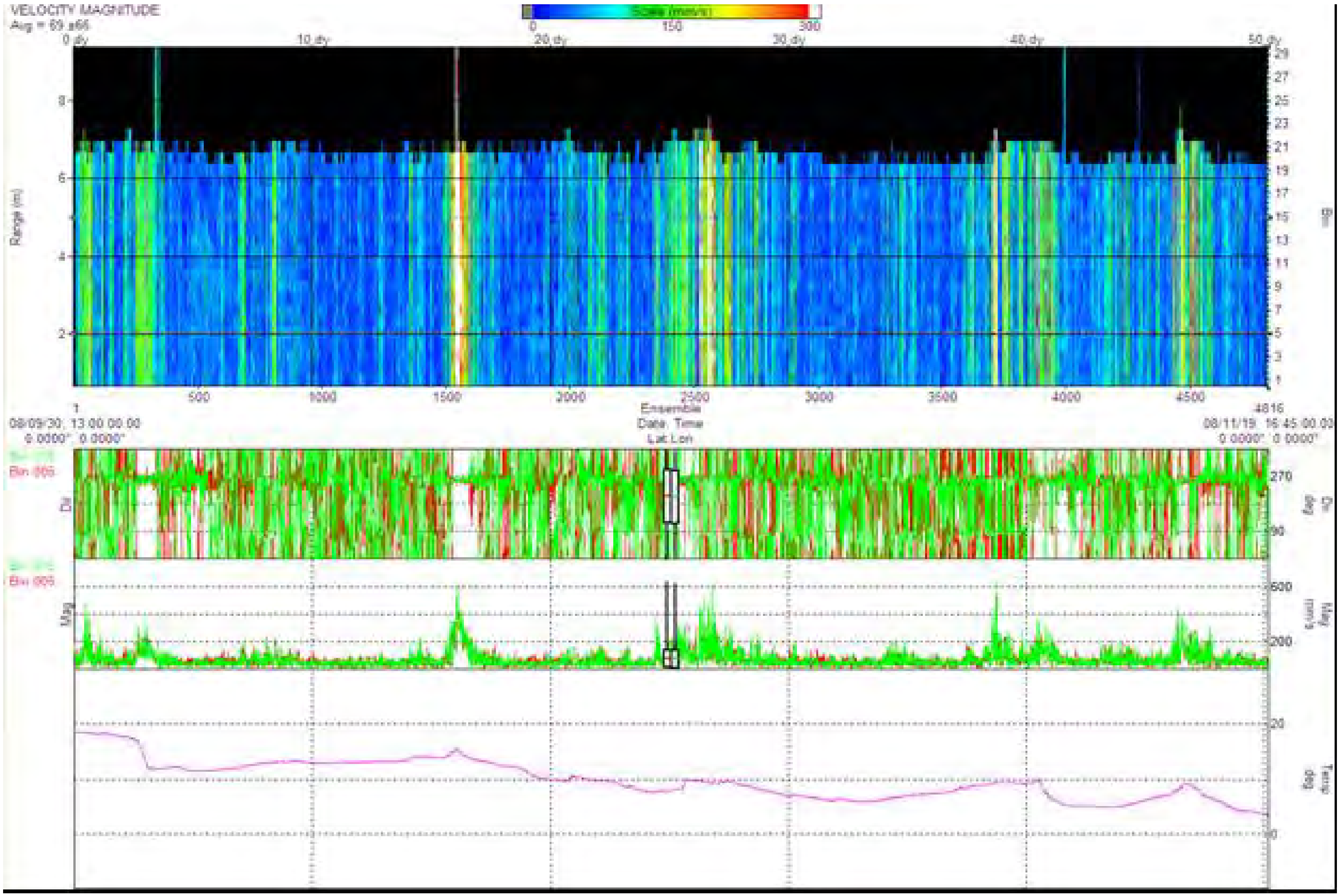
UPSTREAM ADCP DATA (SIDELOOKER)
BUFFALO RIVER, NY

Figure 3-6



ENVIRON MACTEC LimnoTech	UPLOOKER VELOCITY MAGNITUDE IN THE UPSTREAM DIRECTION BUFFALO RIVER, NY	Figure 3-7



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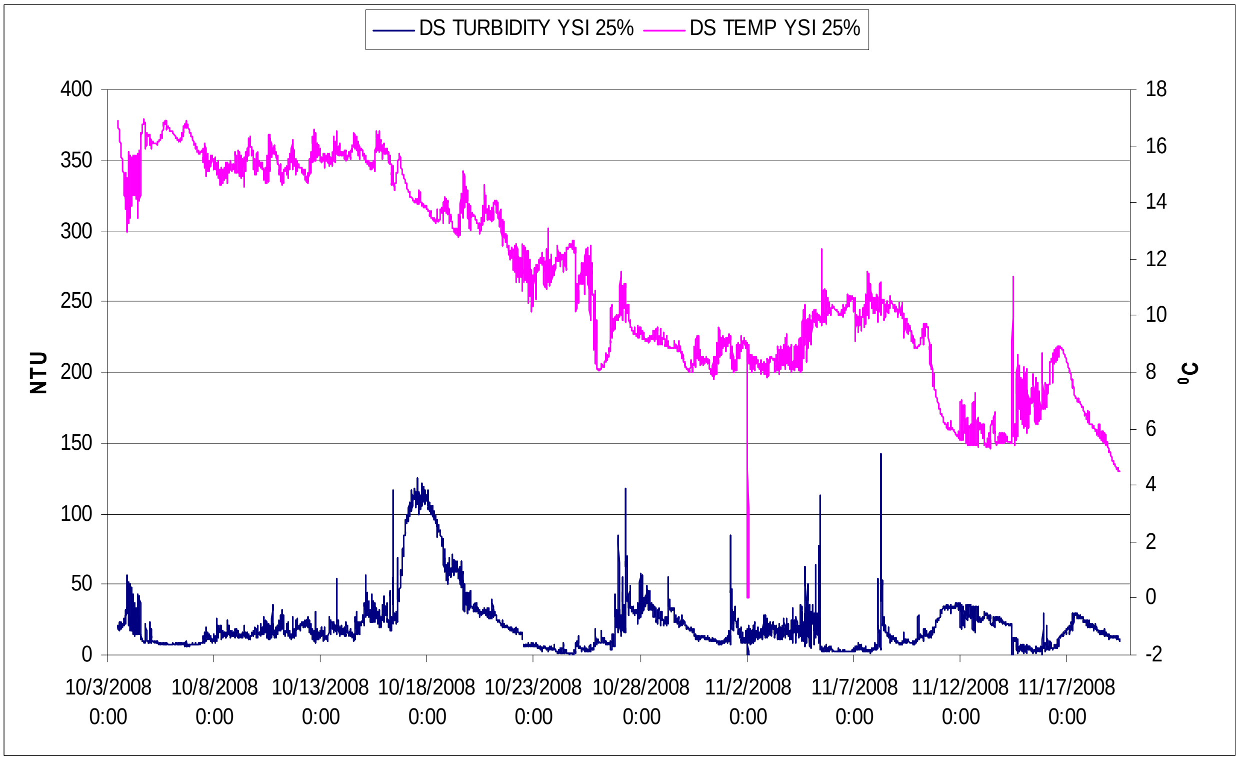
UPLOOKER VELOCITY MAGNITUDE (INDEPENDENT OF FLOW DIRECTION) BUFFALO RIVER, NY

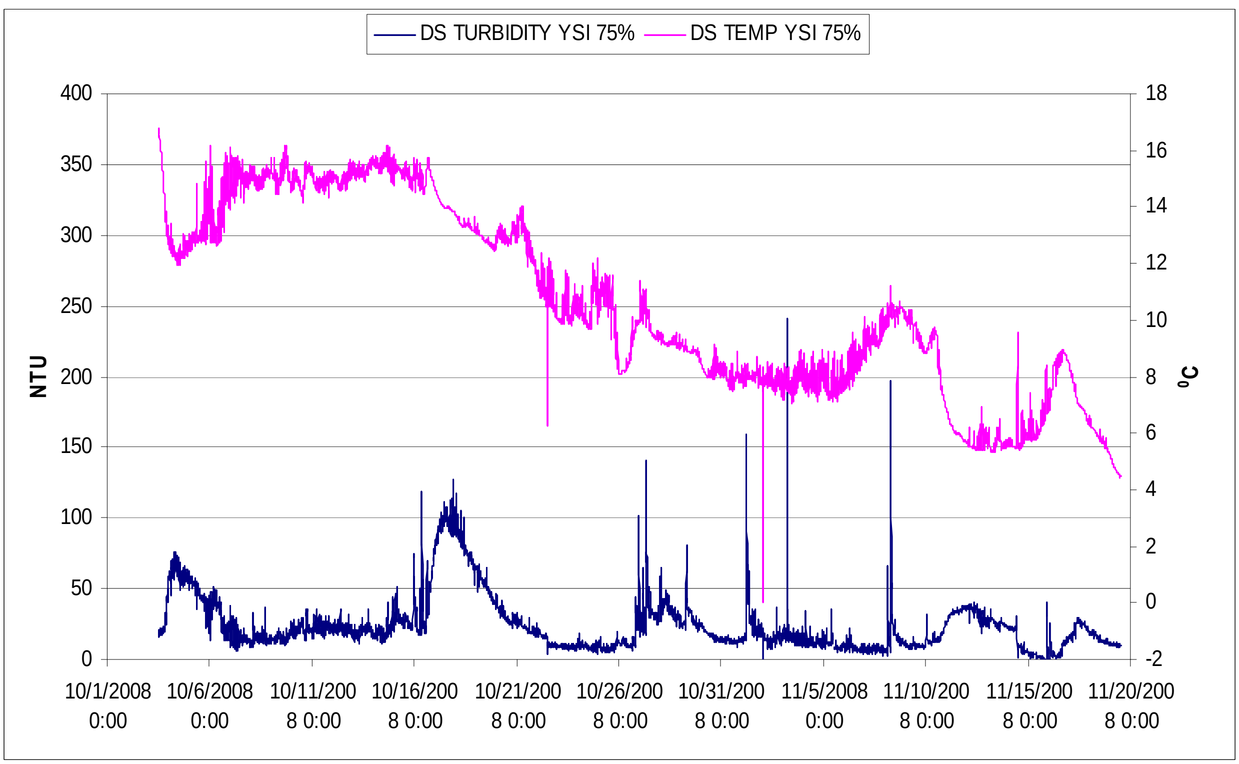
Figure 3-8

ENVIRON MACTEC LimnoTech

UPLOOKER VELOCITY DIRECTION
BUFFALO RIVER, NY

Figure 3-9





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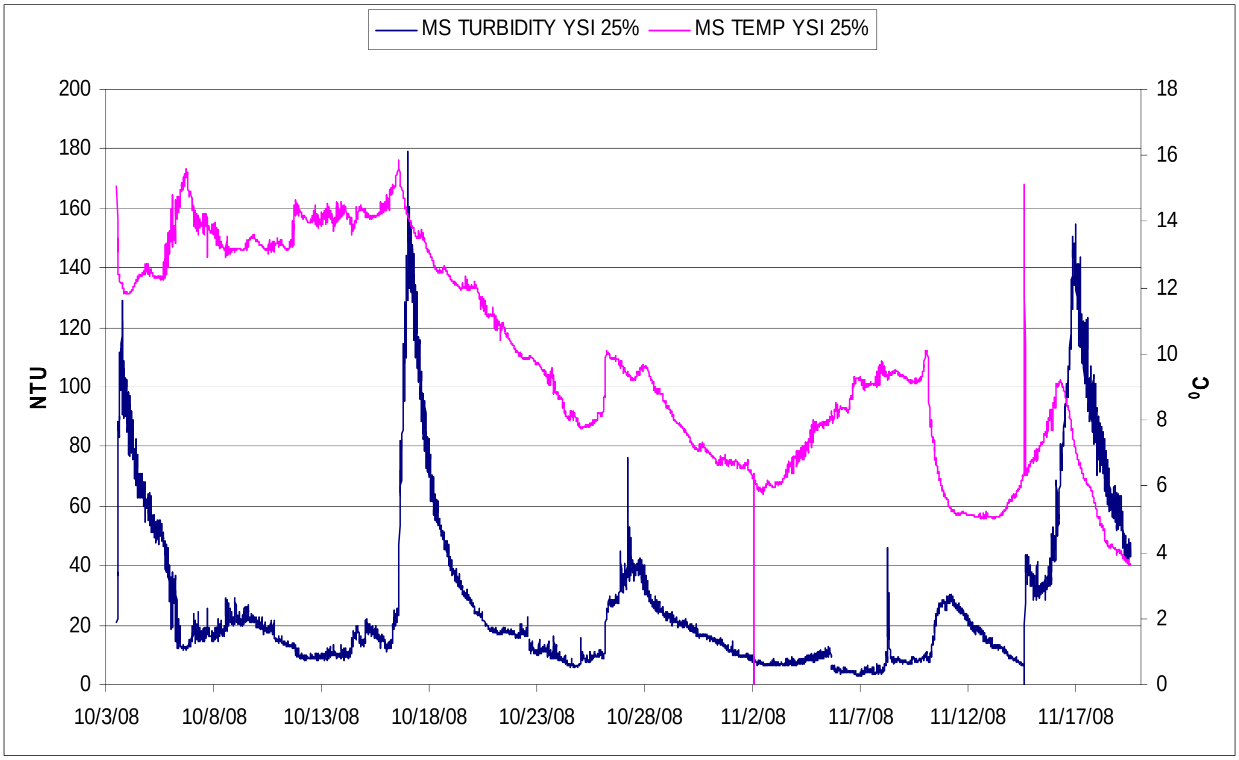
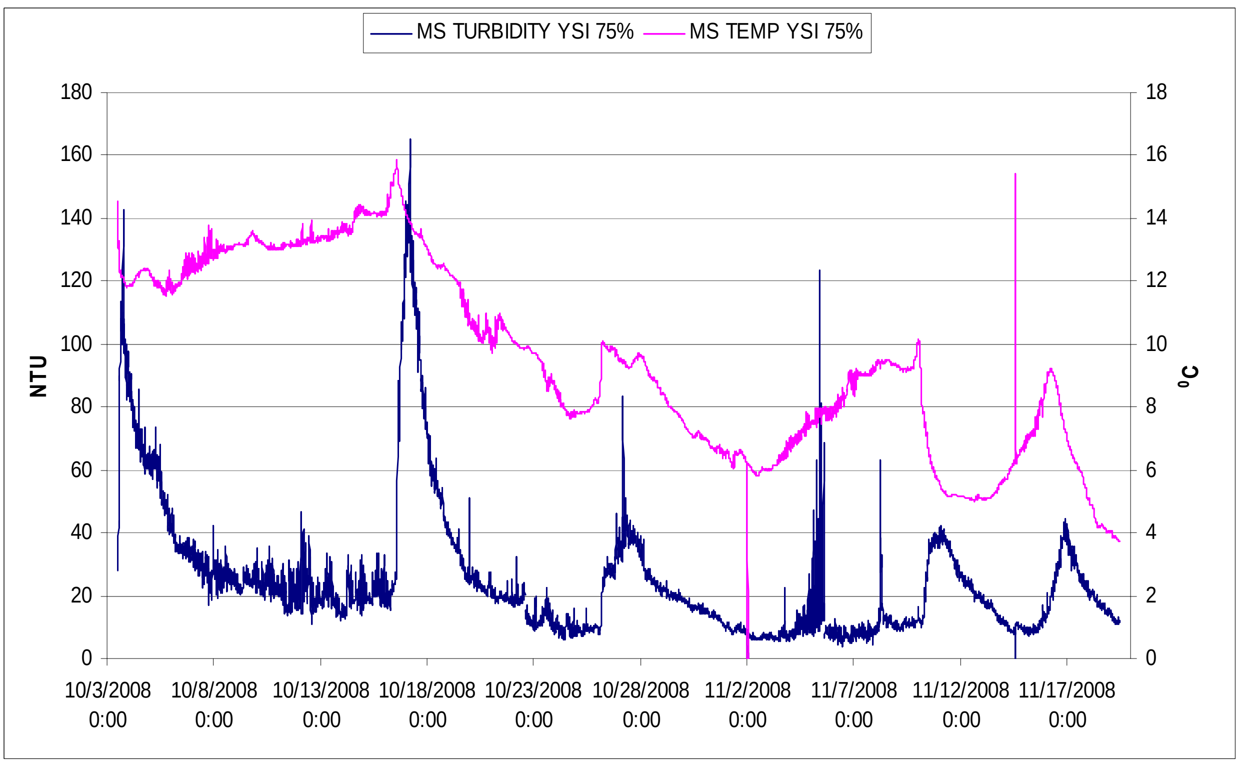
LimnoTech

DOWNSTREAM TURBIDITY/TEMPERATURE AT 25% AND 75% DEPTH (YSI SONDE) BUFFLO RIVER, NY

Figure 3-10





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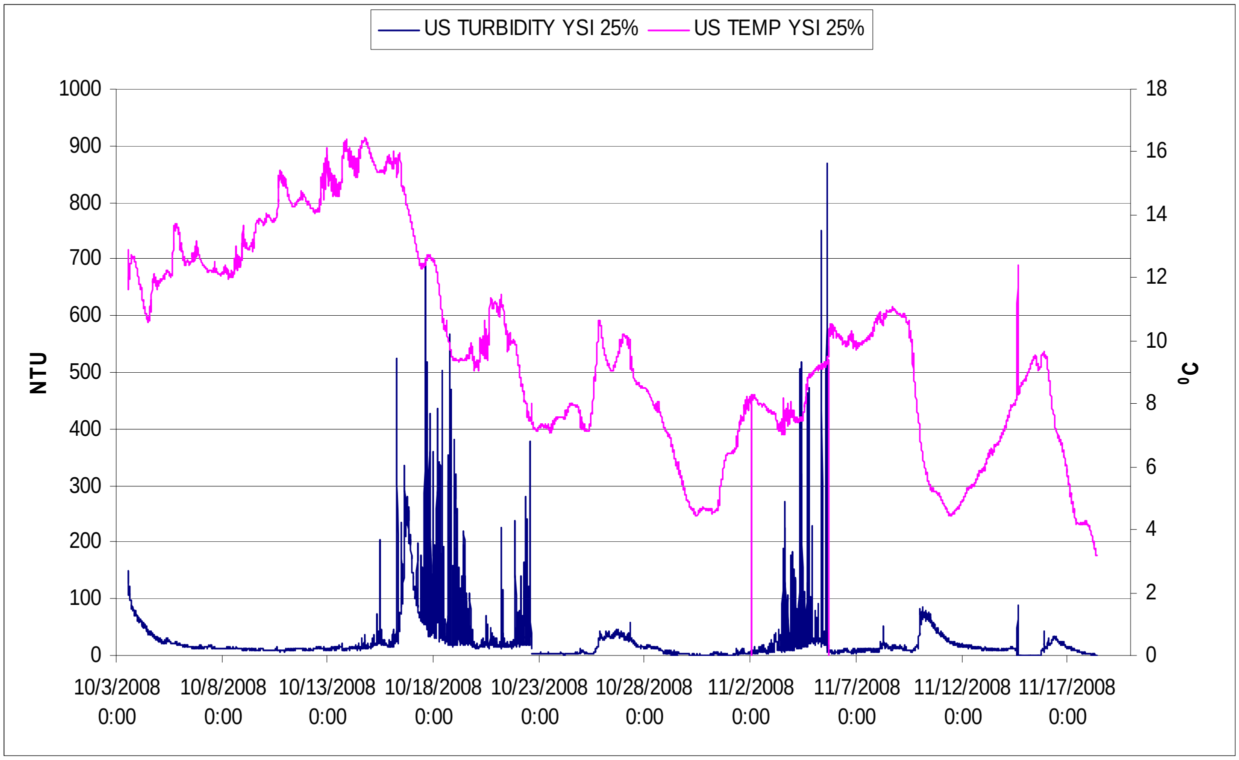
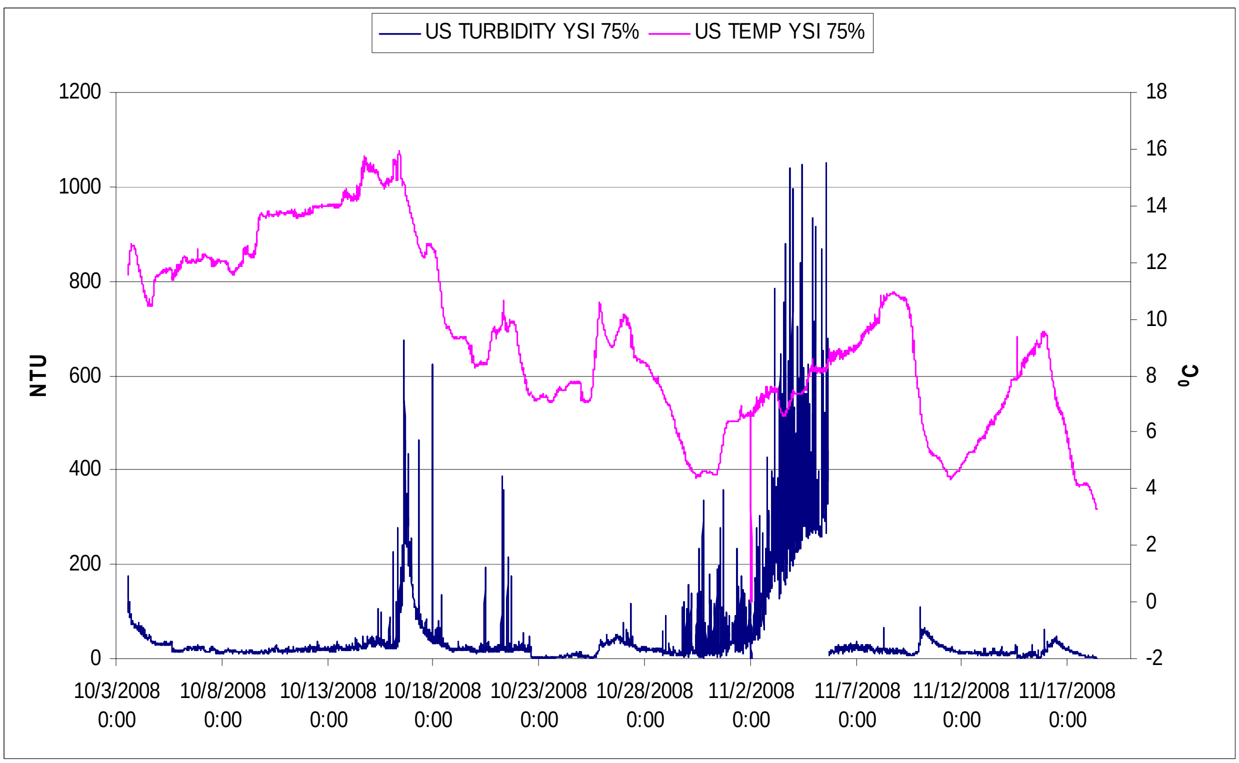
MIDSTREAM TURBIDITY/TEMPERATURE AT 25% & 75% DEPTH (YSI SONDE) BUFFALO RIVER, NY

Figure 3-11





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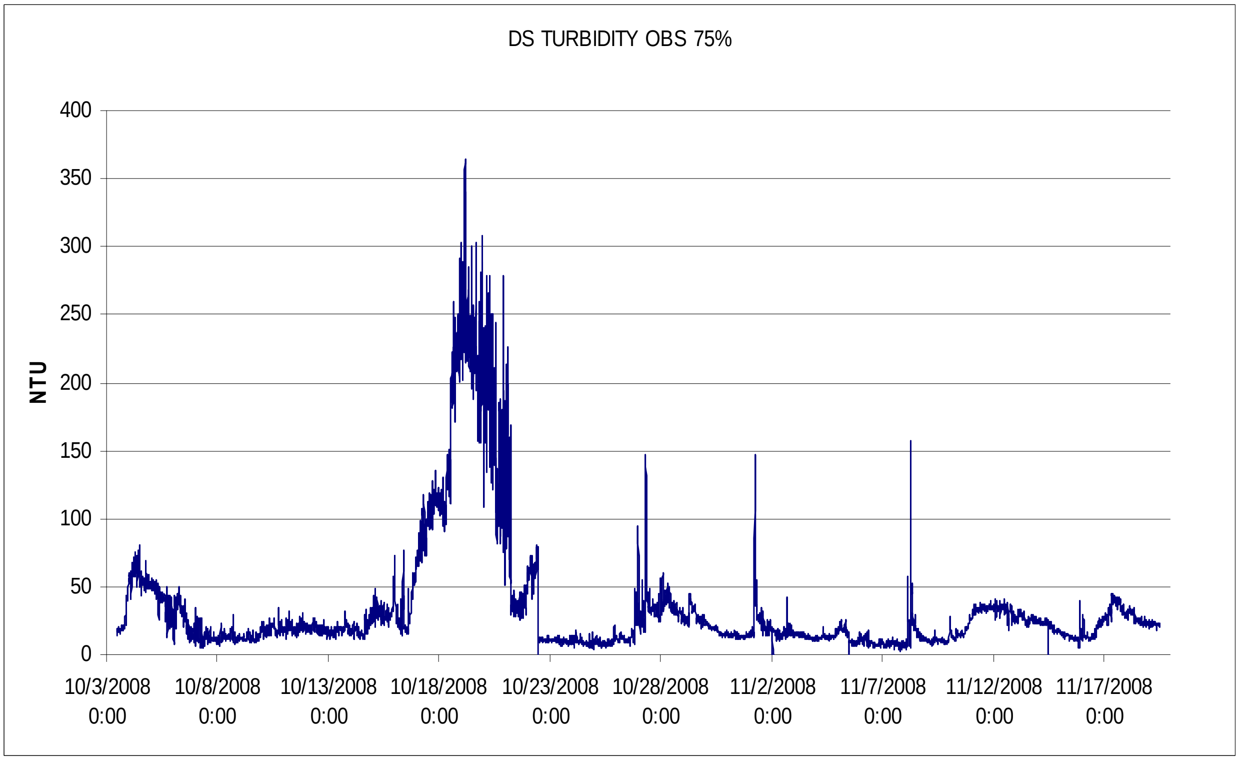
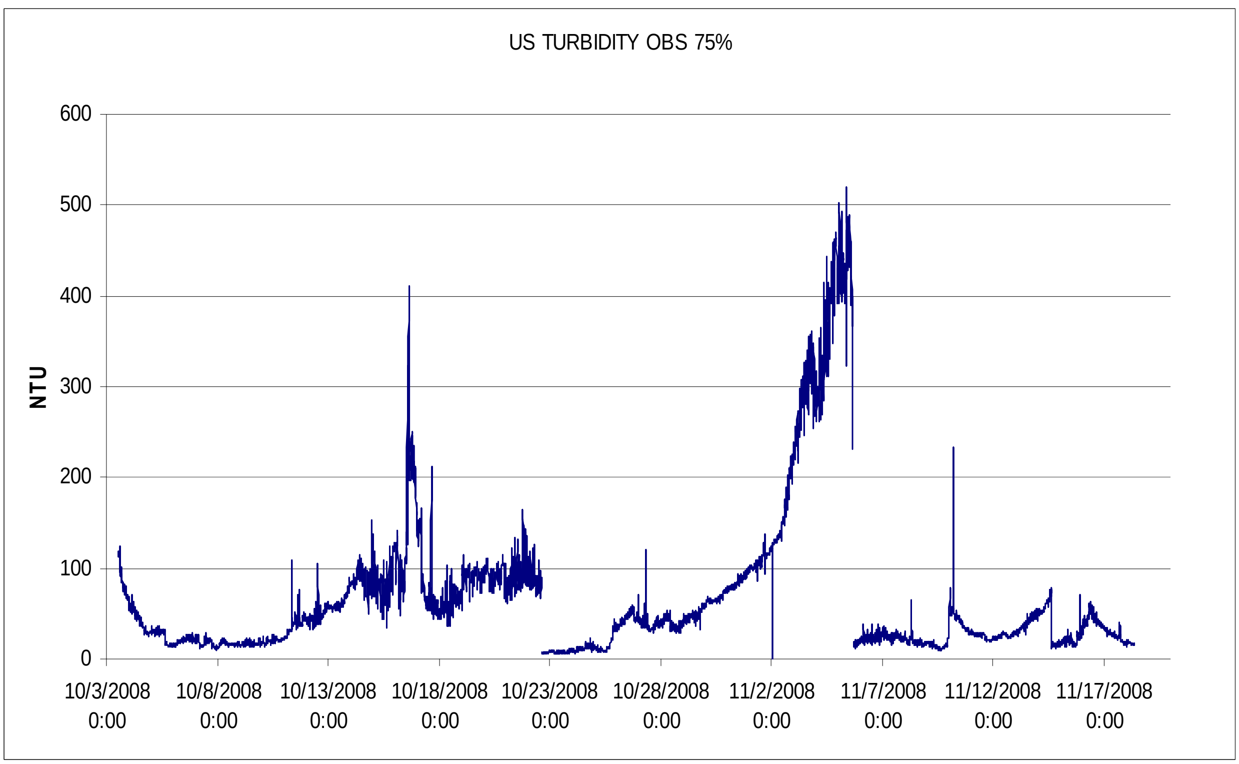
UPSTREAM TURBIDITY/TEMPERATURE AT 25% & 75% DEPTH (YSI SONDE) BUFFALO RIVER, NY

Figure 3-12





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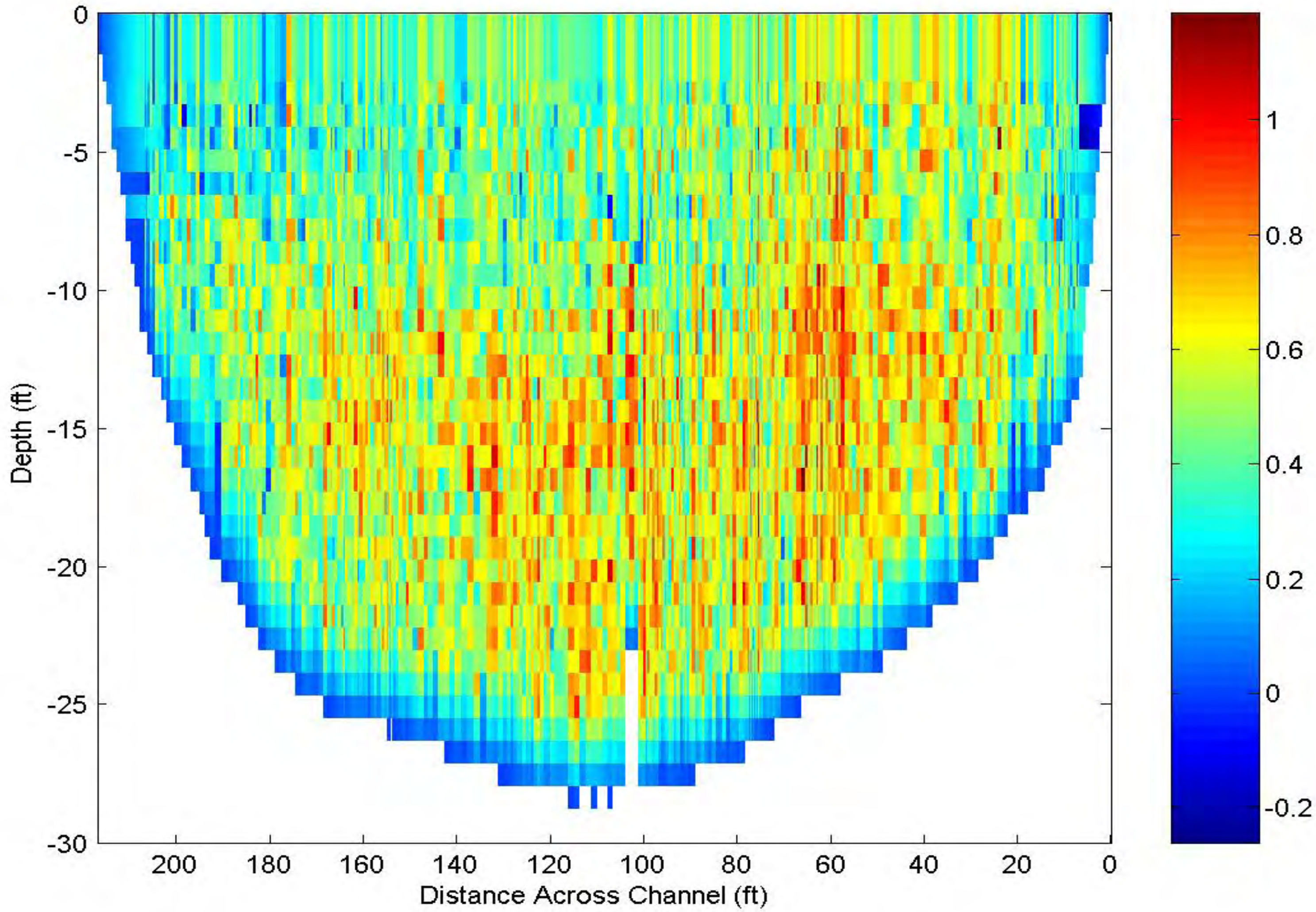
DOWNSTREAM & UPSTREAM TURBIDITY AT 75% DEPTH (OBS) BUFFALO RIVER, NY

Figure 3-13



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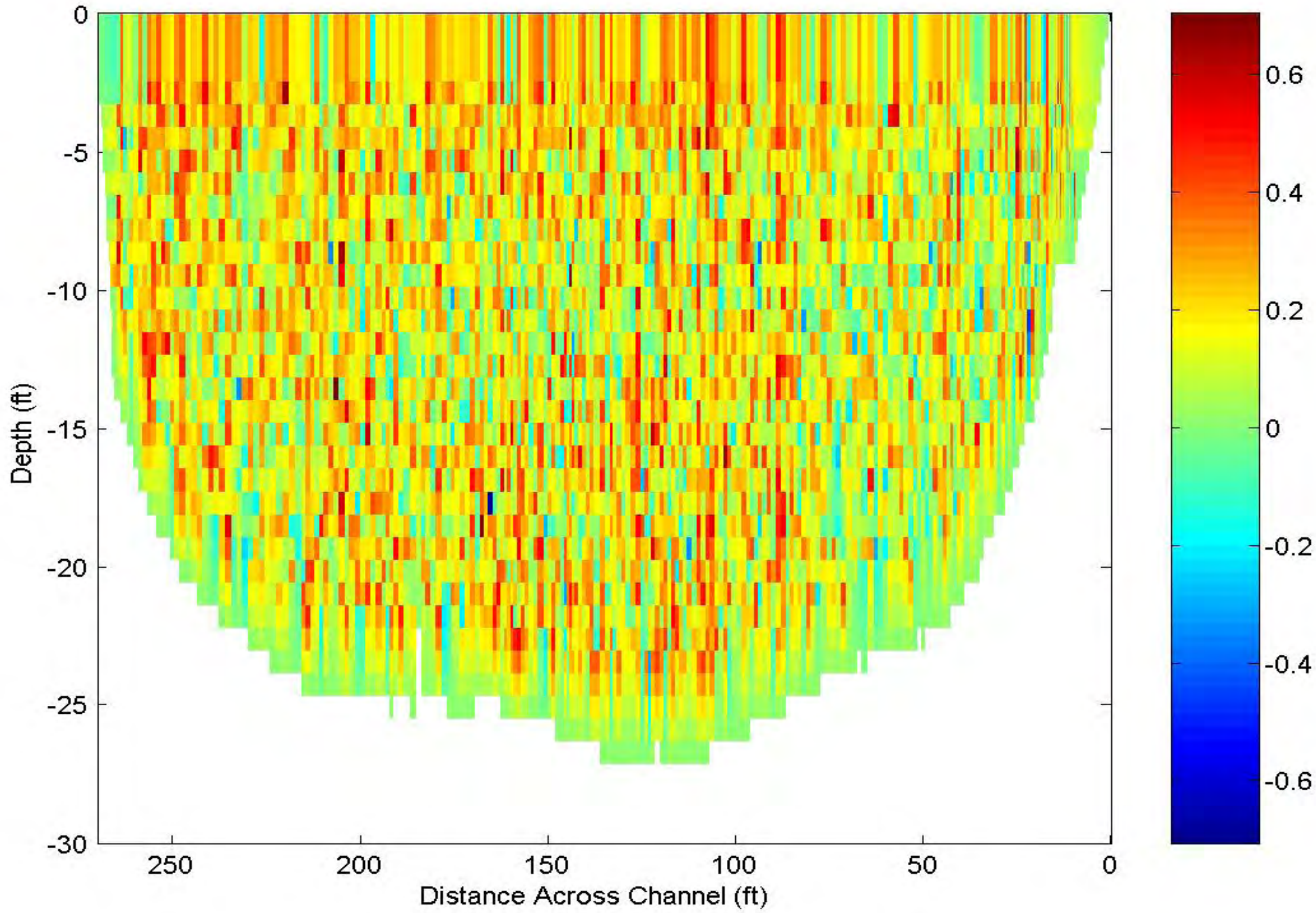
DOWNSTREAM TRANSECT - DOWNSTREAM VELOCITY MAGNITUDE (FT/SEC)

Figure 3-14



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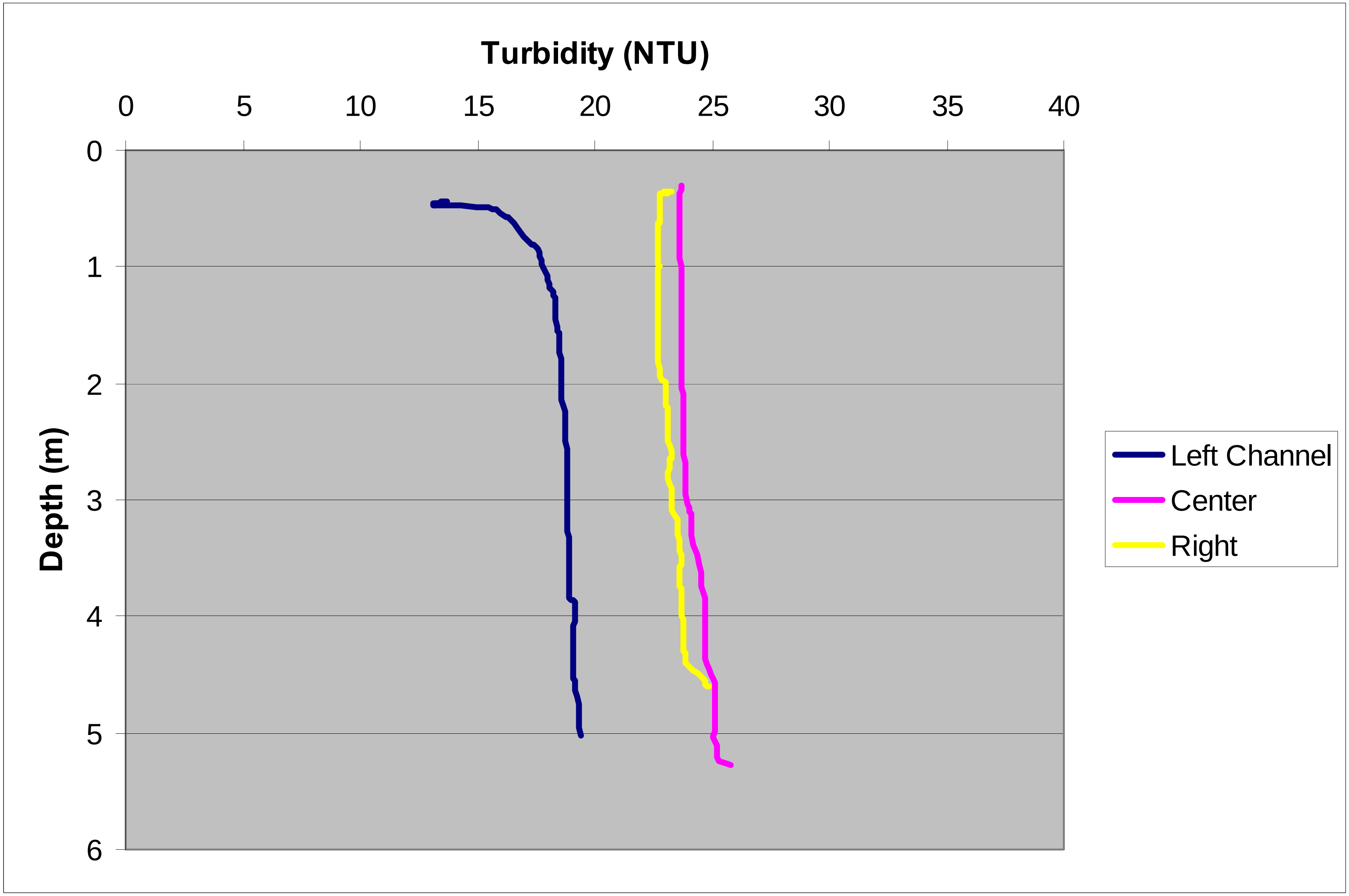
MIDSTREAM TRANSECT - DOWNSTREAM VELOCITY MAGNITUDE (FT/SEC)

Figure 3-15



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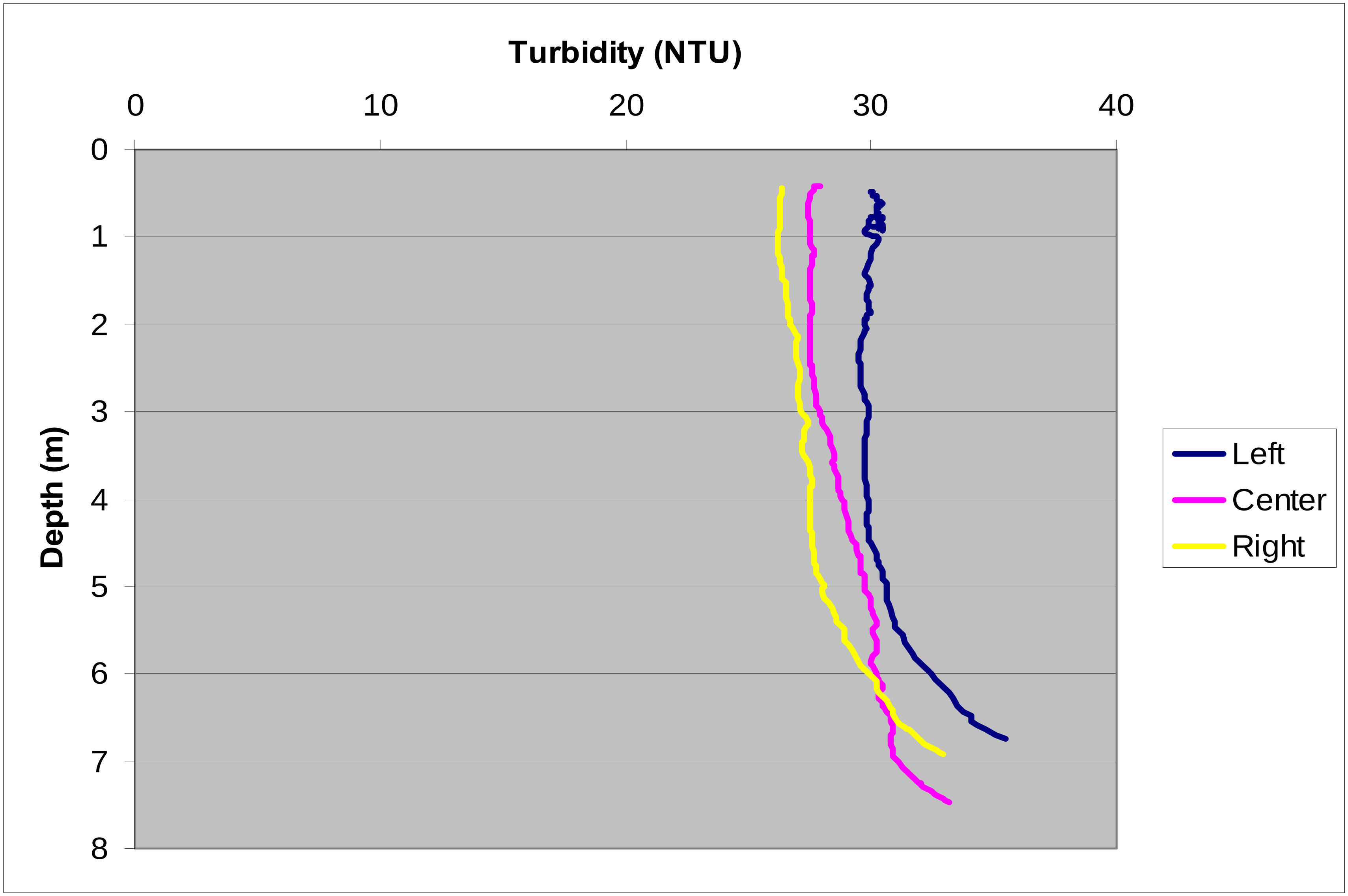
LimnoTech

TURBIDITY PROFILES AT UPSTREAM TRANSECT
BUFFALO RIVER, NY

Figure 3-16



ENVIRON
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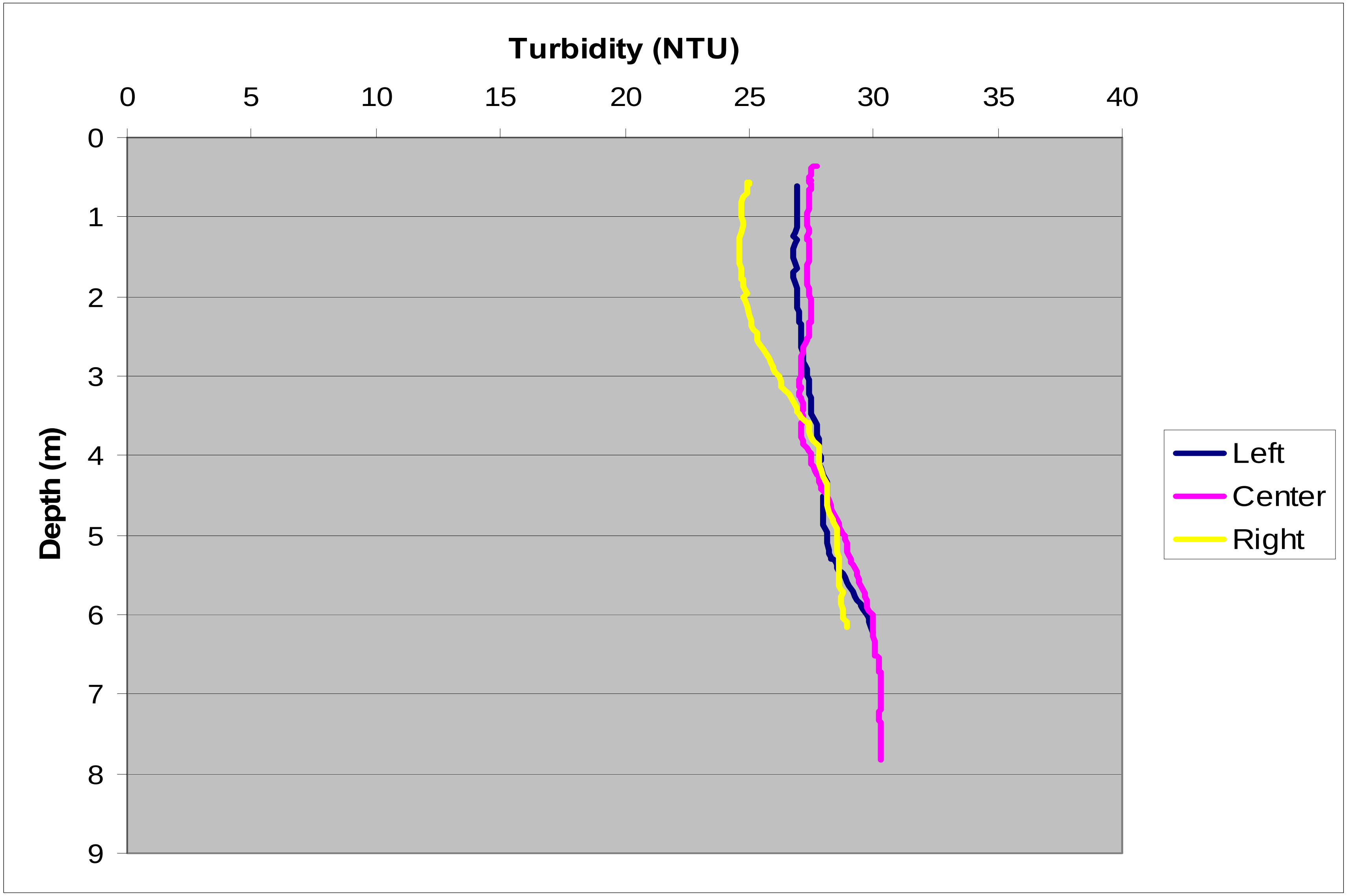
TURBIDITY PROFILES AT MIDSTREAM TRANSECT
BUFFALO RIVER, NY

Figure 3-17



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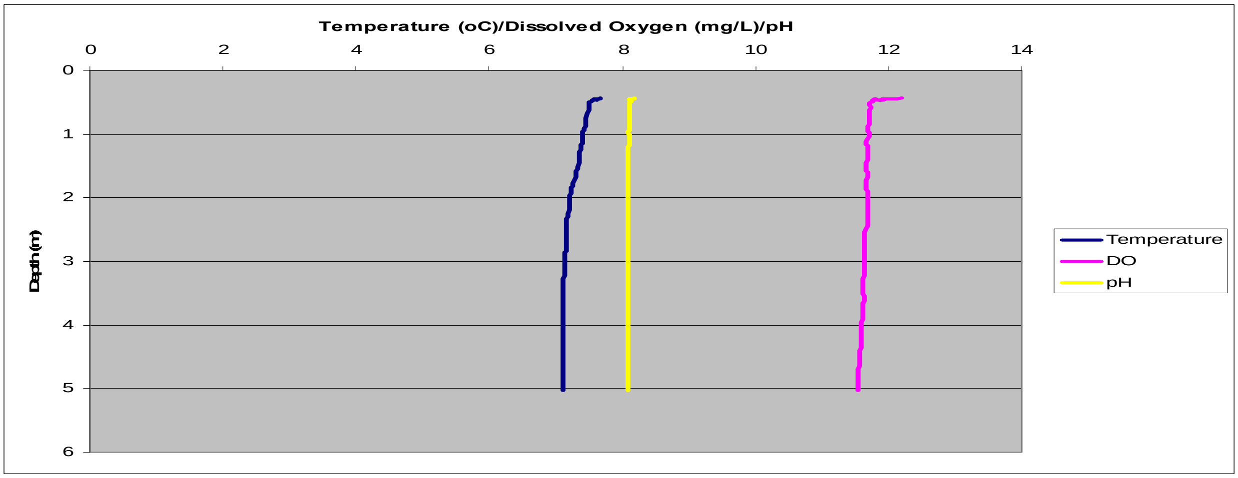
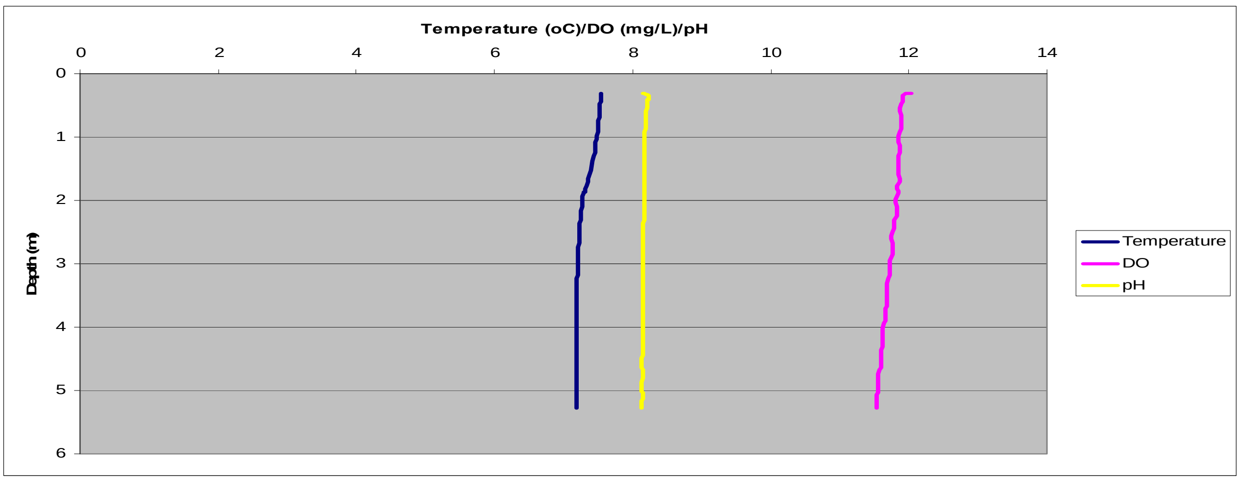
TURBIDITY PROFILES AT DOWNSTREAM TRANSECT
BUFFALO RIVER, NY

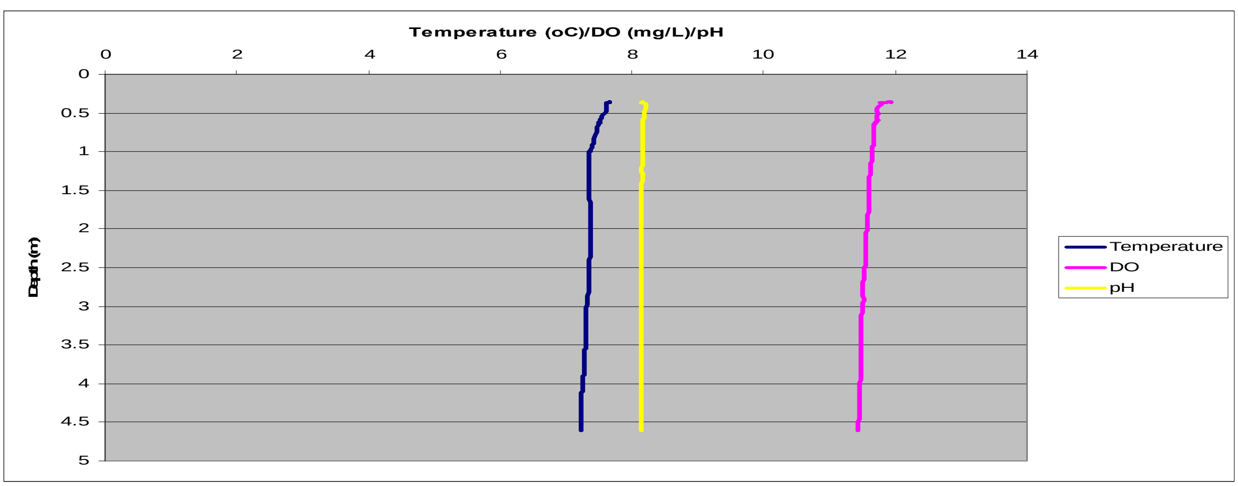
Figure 3-18



LEFT CHANNEL



CENTER CHANNEL



RIGHT CHANNEL

ENVIRON
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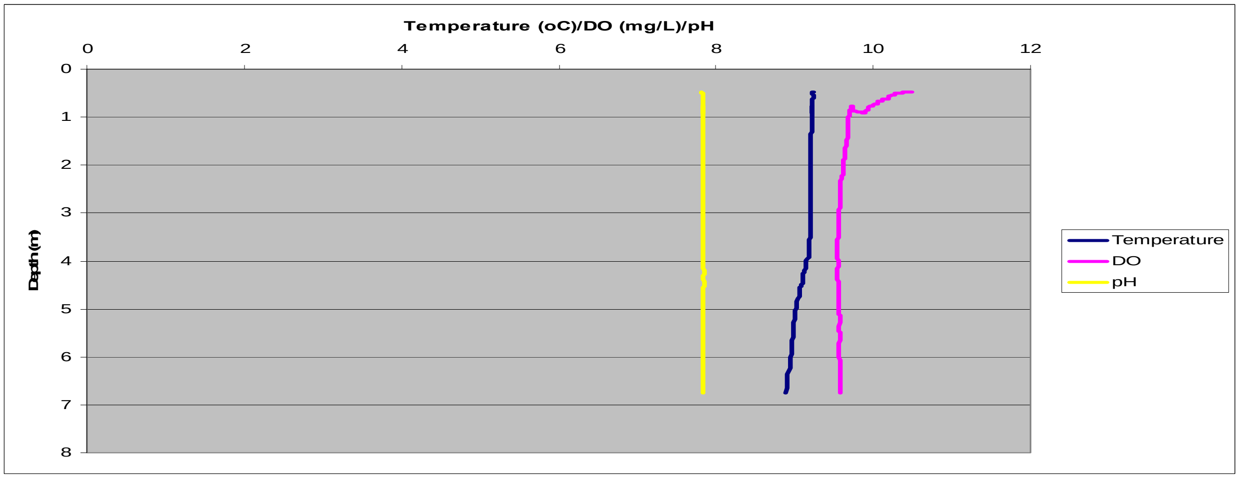
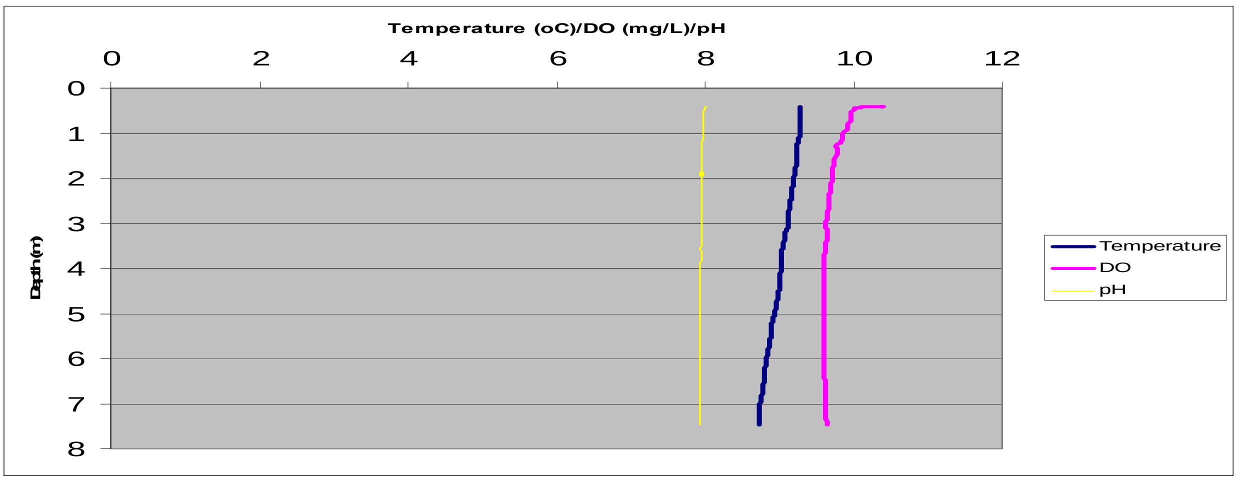
UPSTREAM—TEMPERATURE/DO/pH
BUFFALO RIVER, NY

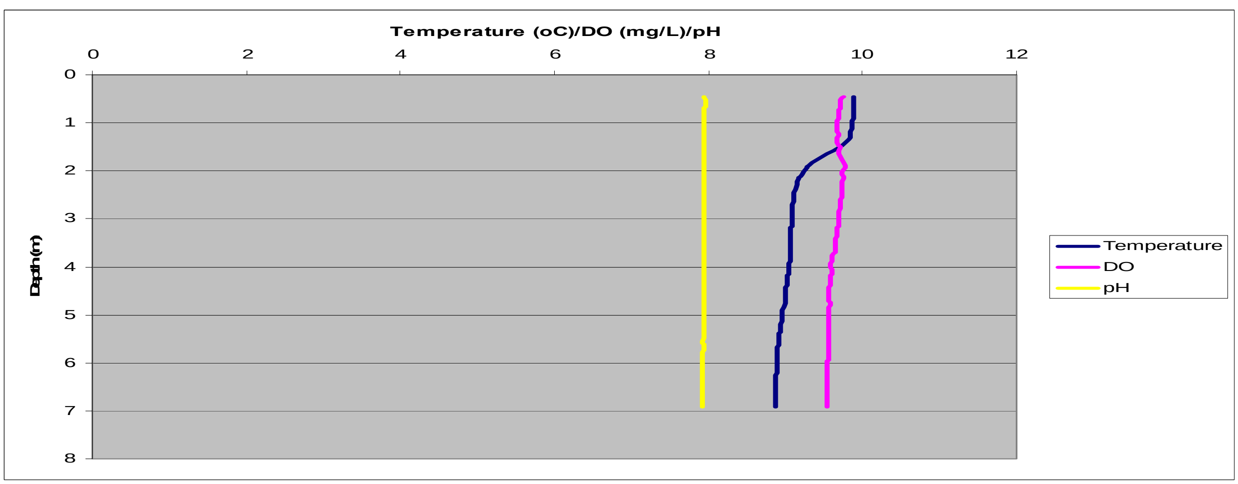
3-19



LEFT CHANNEL

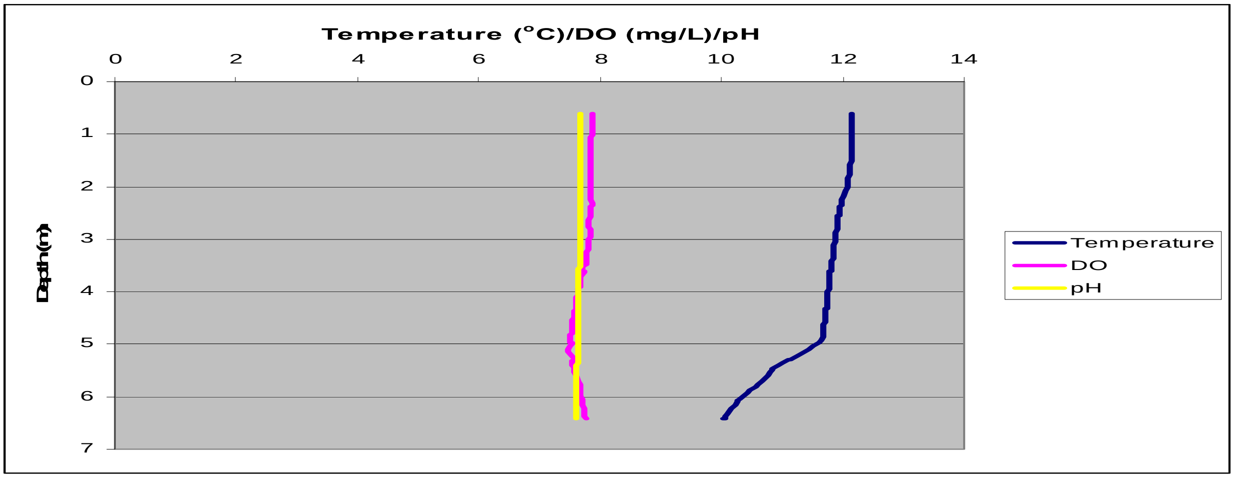


CENTER CHANNEL



RIGHT CHANNEL

ENVIRON MACTEC LimnoTech	MIDSTREAM—TEMPERATURE/DO/pH BUFFALO RIVER, NY	3-20



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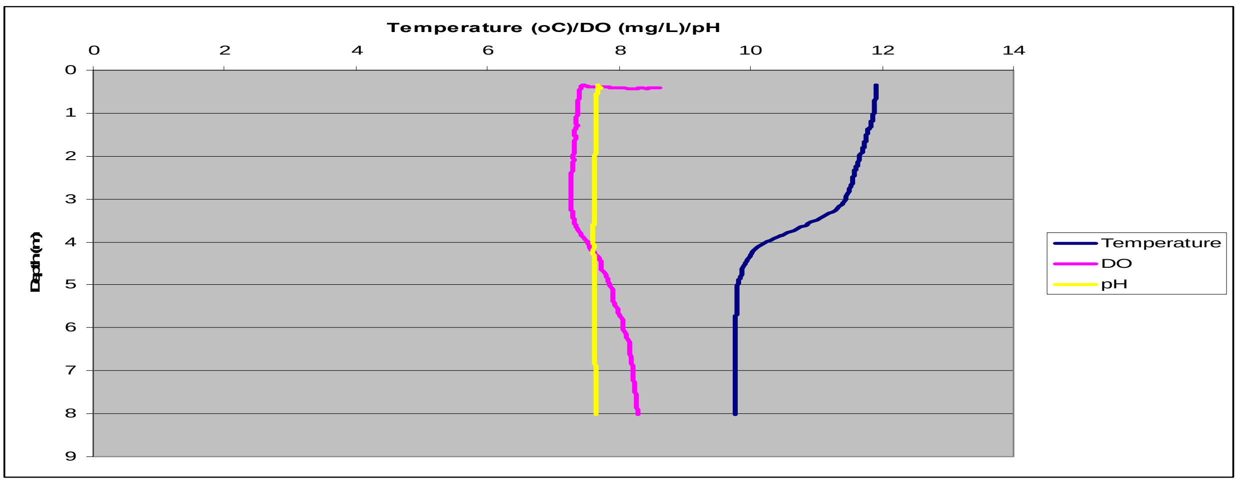
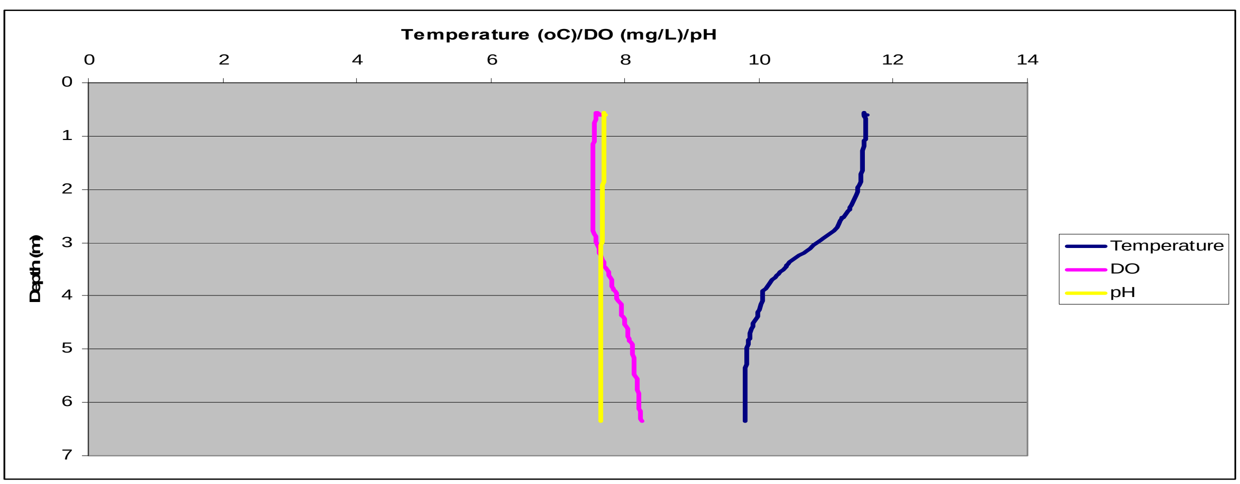


CENTER CHANNEL



RIGHT CHANNEL

ENVIRON
MACTEC
LimnoTech

DOWNSTREAM—TEMPERATURE/DO/pH
BUFFALO RIVER, NY

3-21

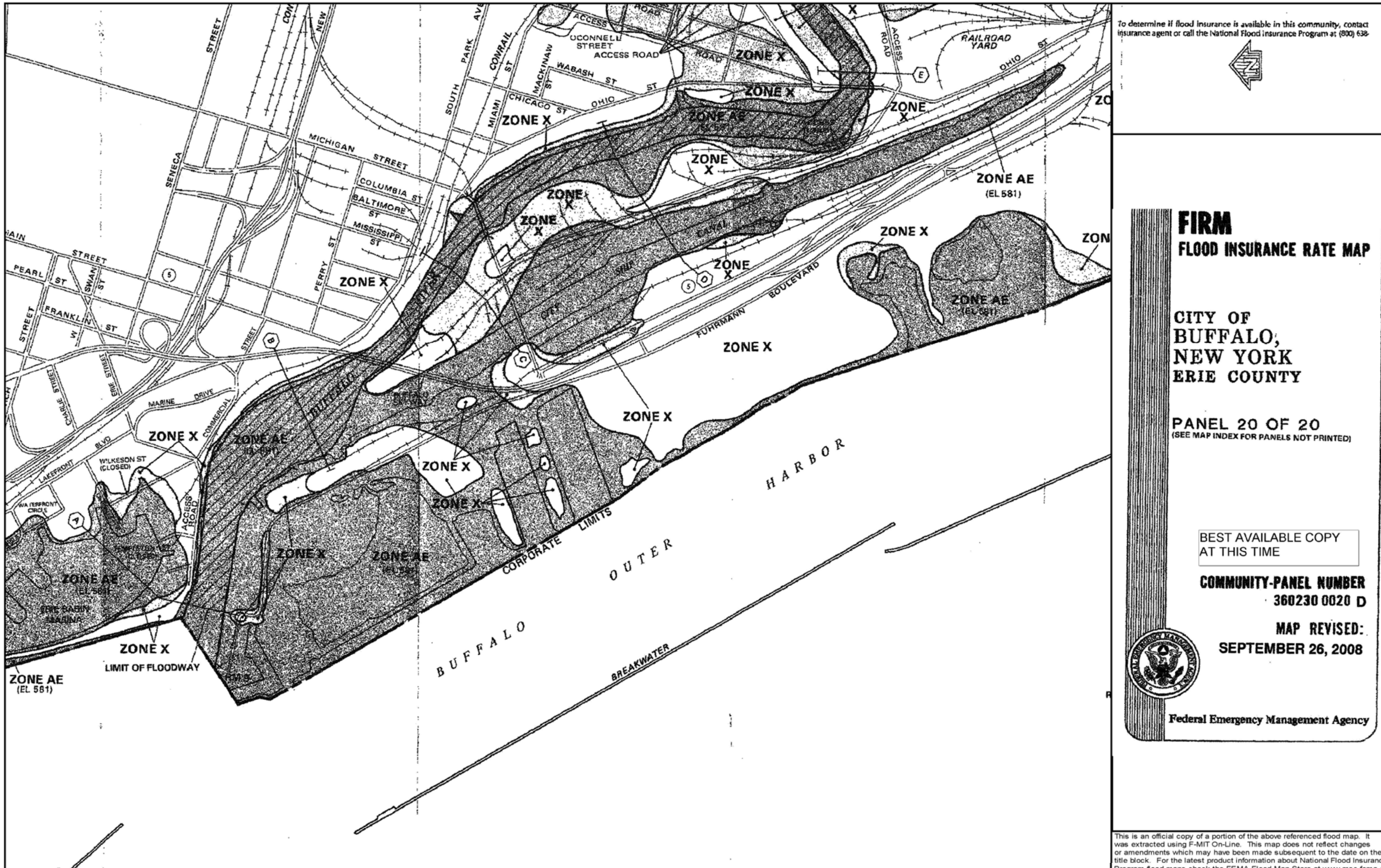


Figure 3-22a

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22a

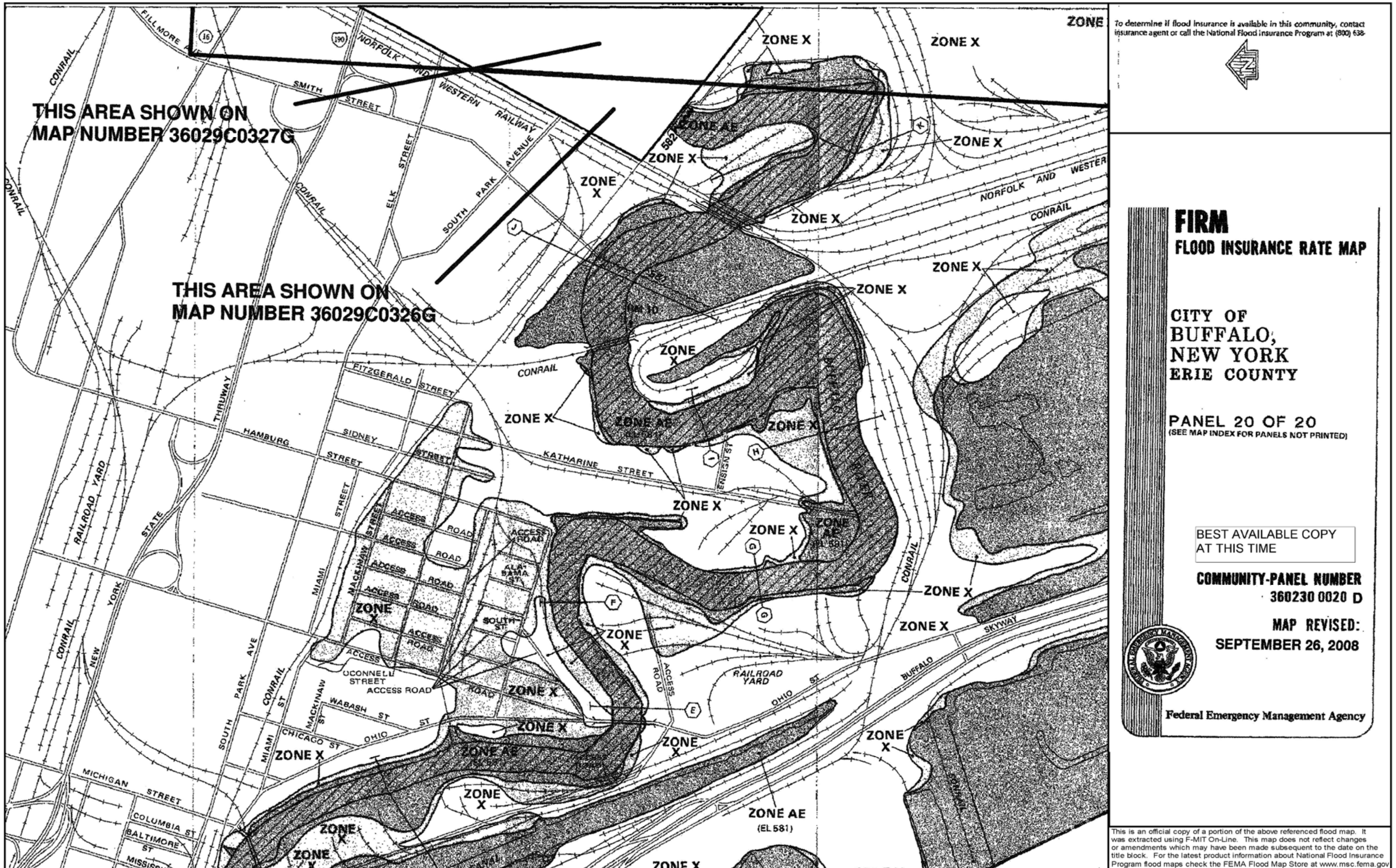


Figure 3-22b

ENVIRON MACTEC LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22b

Figure 3-22c

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22c

Figure 3-22d

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22d

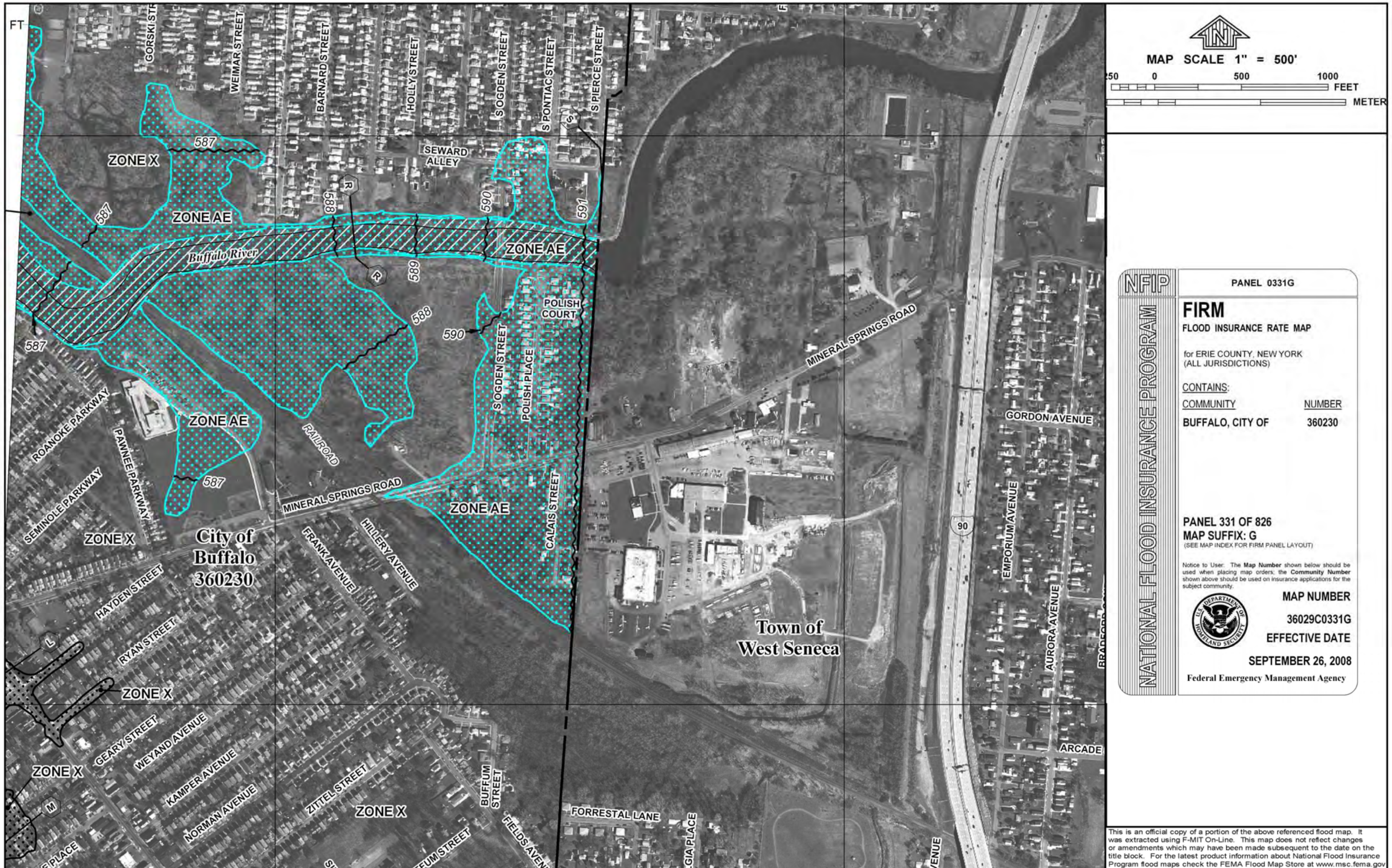


Figure 3-22e

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22e

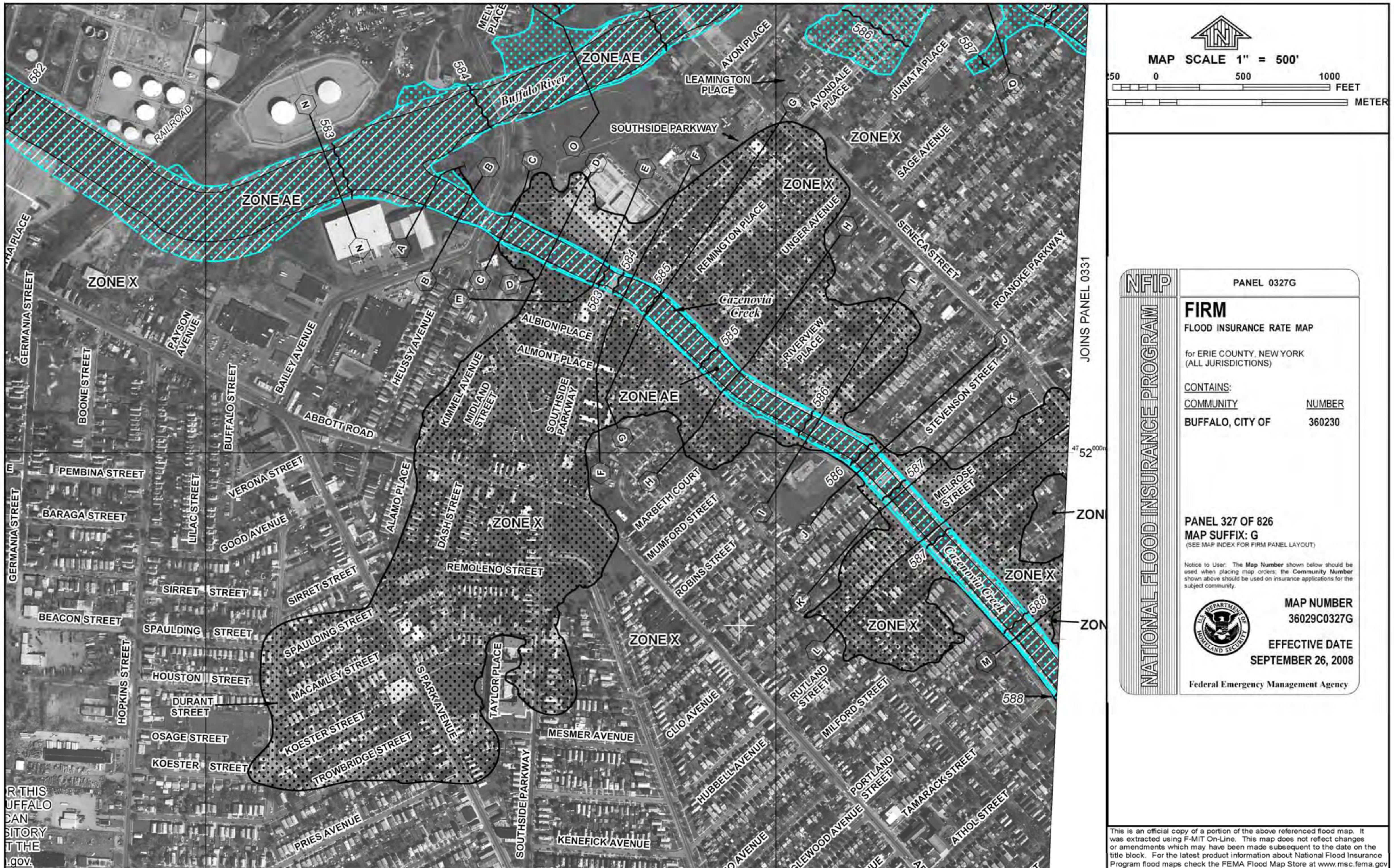


Figure 3-22f

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22f

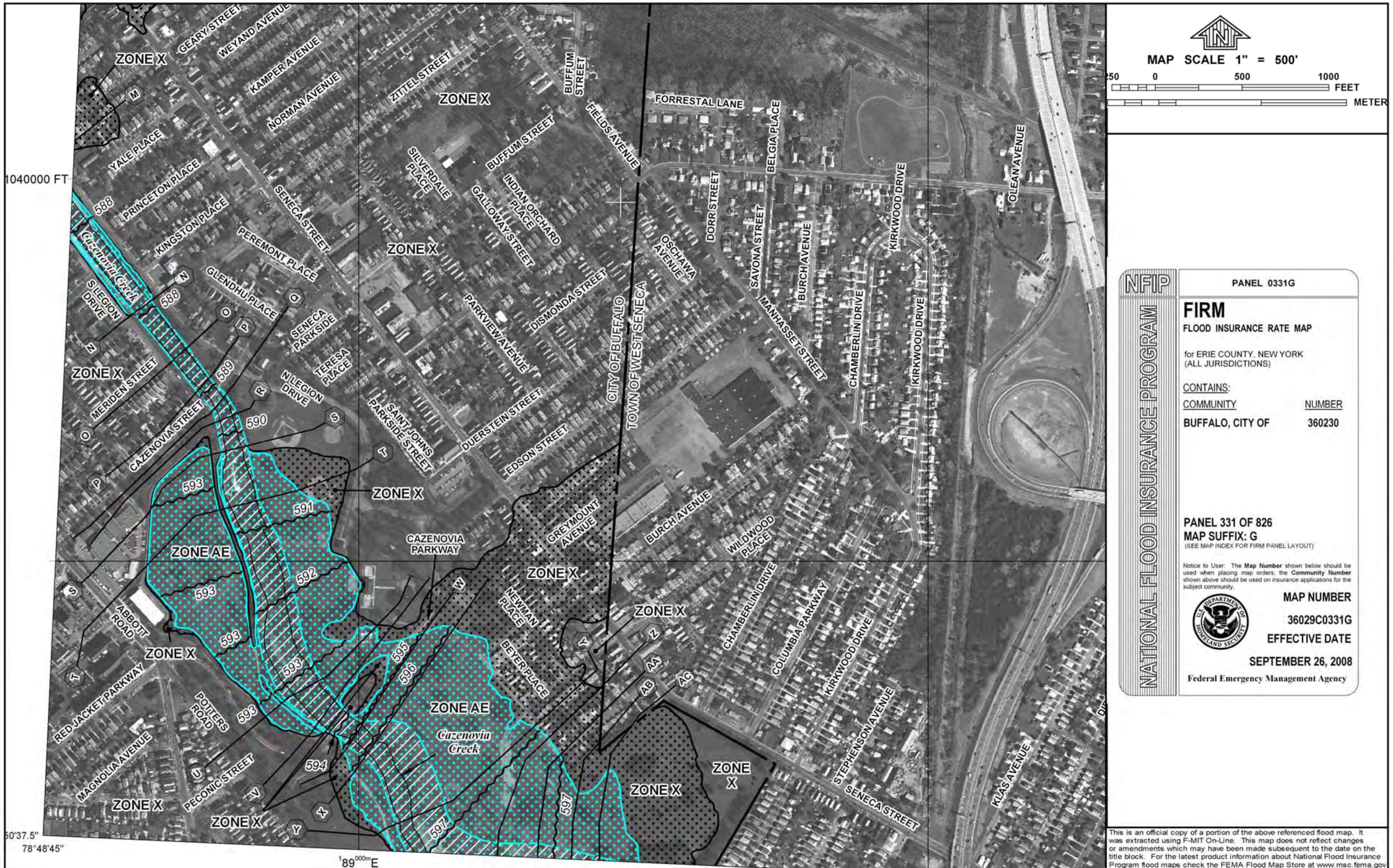


Figure 3-22g

ENVIRON MACTEC LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22g

Figure 3-22h

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22h

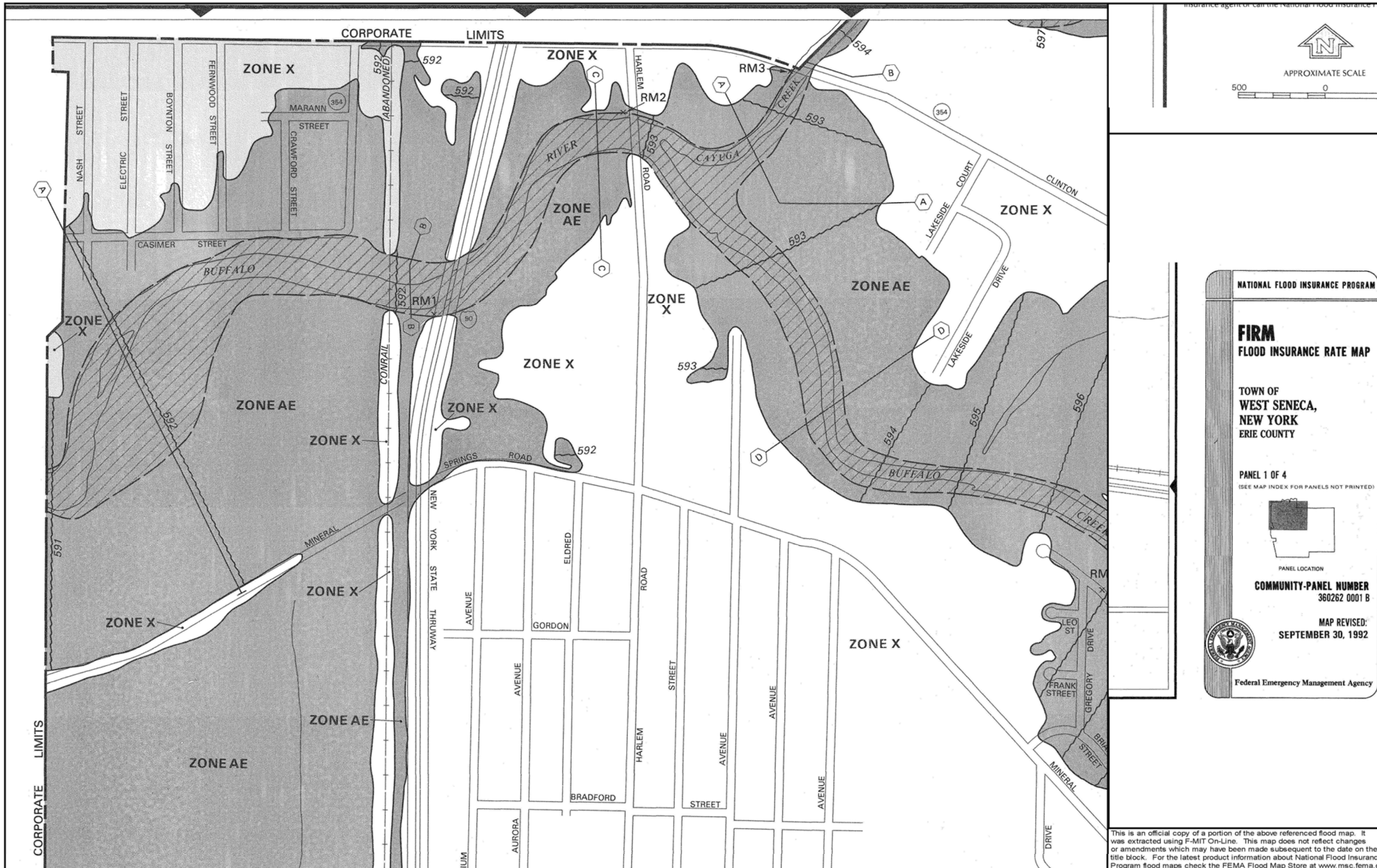


Figure 3-22i

ENVIRON MACTEC LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22i

Figure 3-22j

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22j

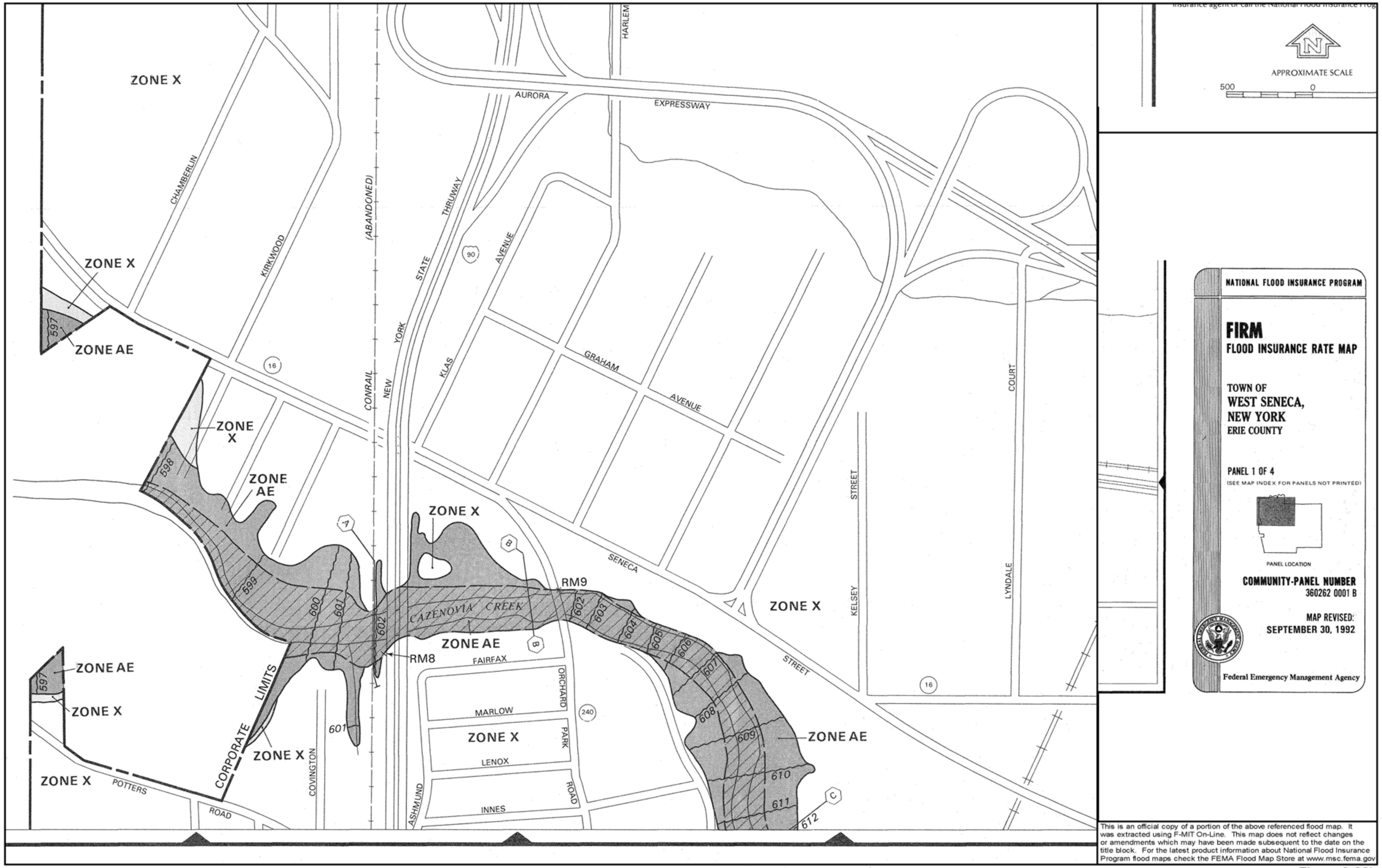


Figure 3-22k

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER AND CAZENOVIA CREEK FLOOD INSURANCE RATE MAPS, SEPTEMBER 2008

Figure 3-22k

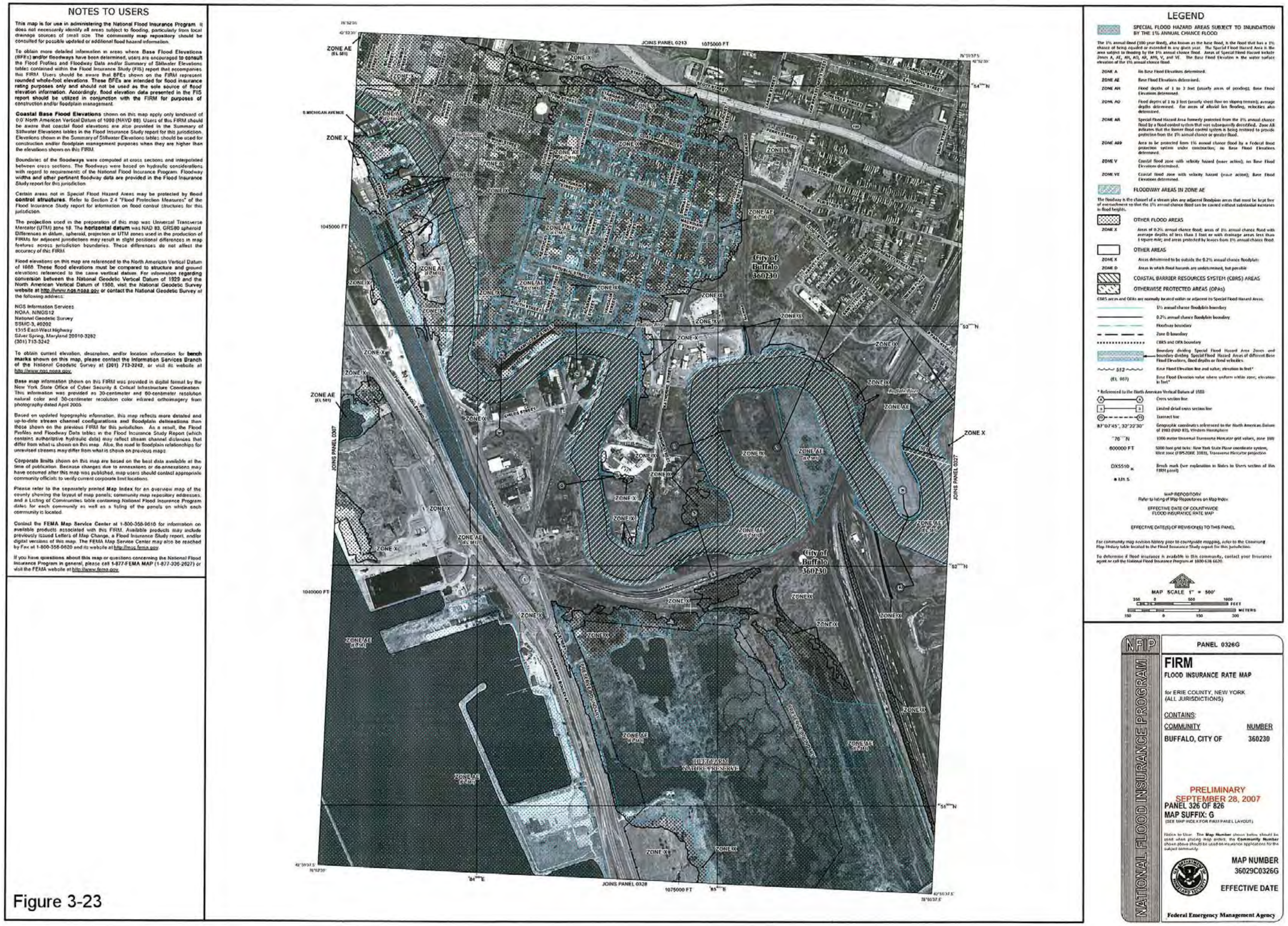
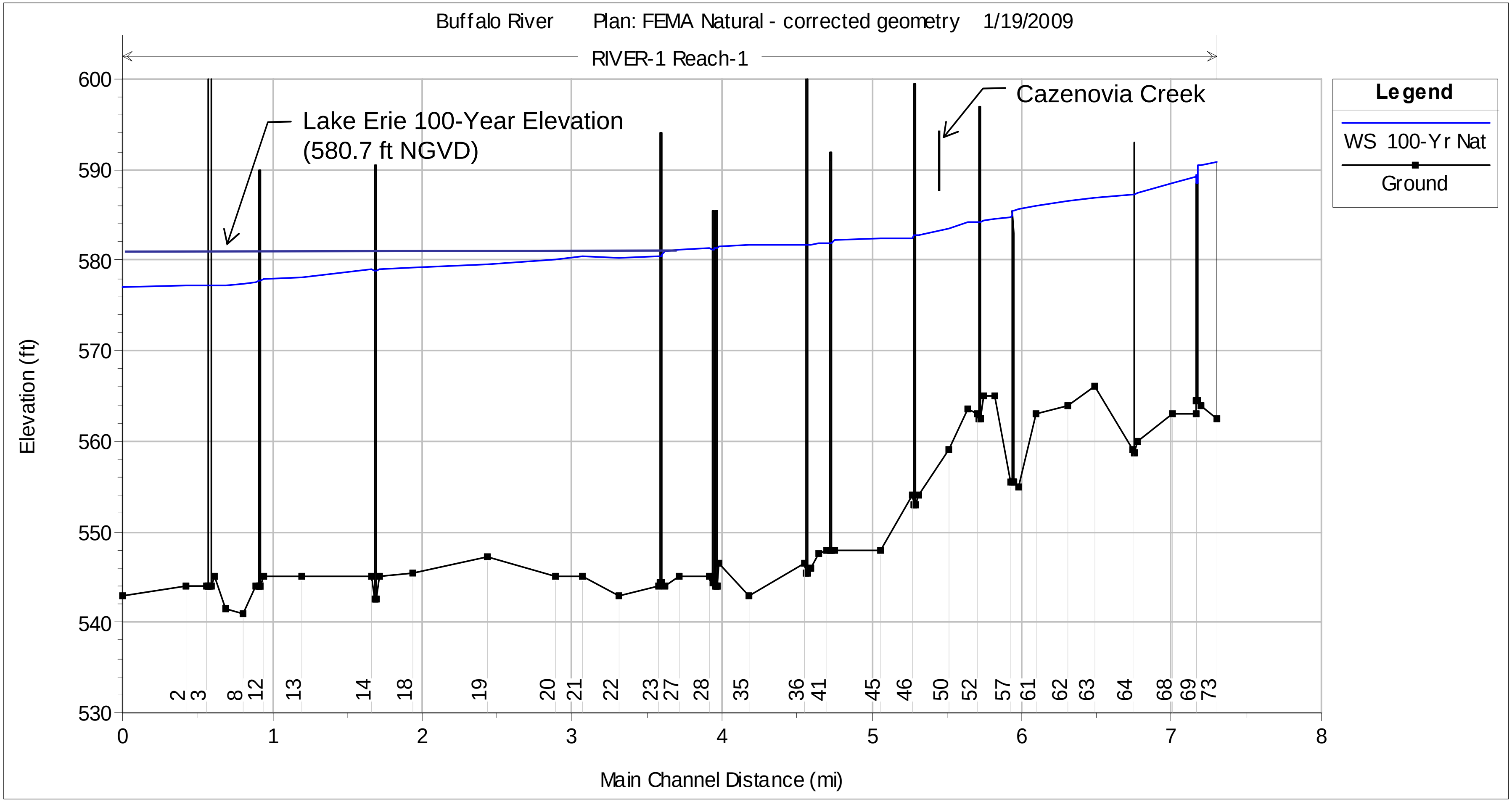


Figure 3-23

ENVIRON
MACTEC
LimnoTech

LOWER BUFFALO RIVER FLOOD INSURANCE RATE MAP, SEPTEMBER 2007

Figure 3-23



Elevation Datum is NGVD 1929 (approximately 0.5 ft higher than NAVD 1988 Datum); FEMA HEC-2 Model converted to HEC-RAS

ENVIRON
MACTEC
LimnoTech

BUFFALO RIVER WATER SURFACE PROFILE – 100-YEAR FLOOD

Figure 3-24

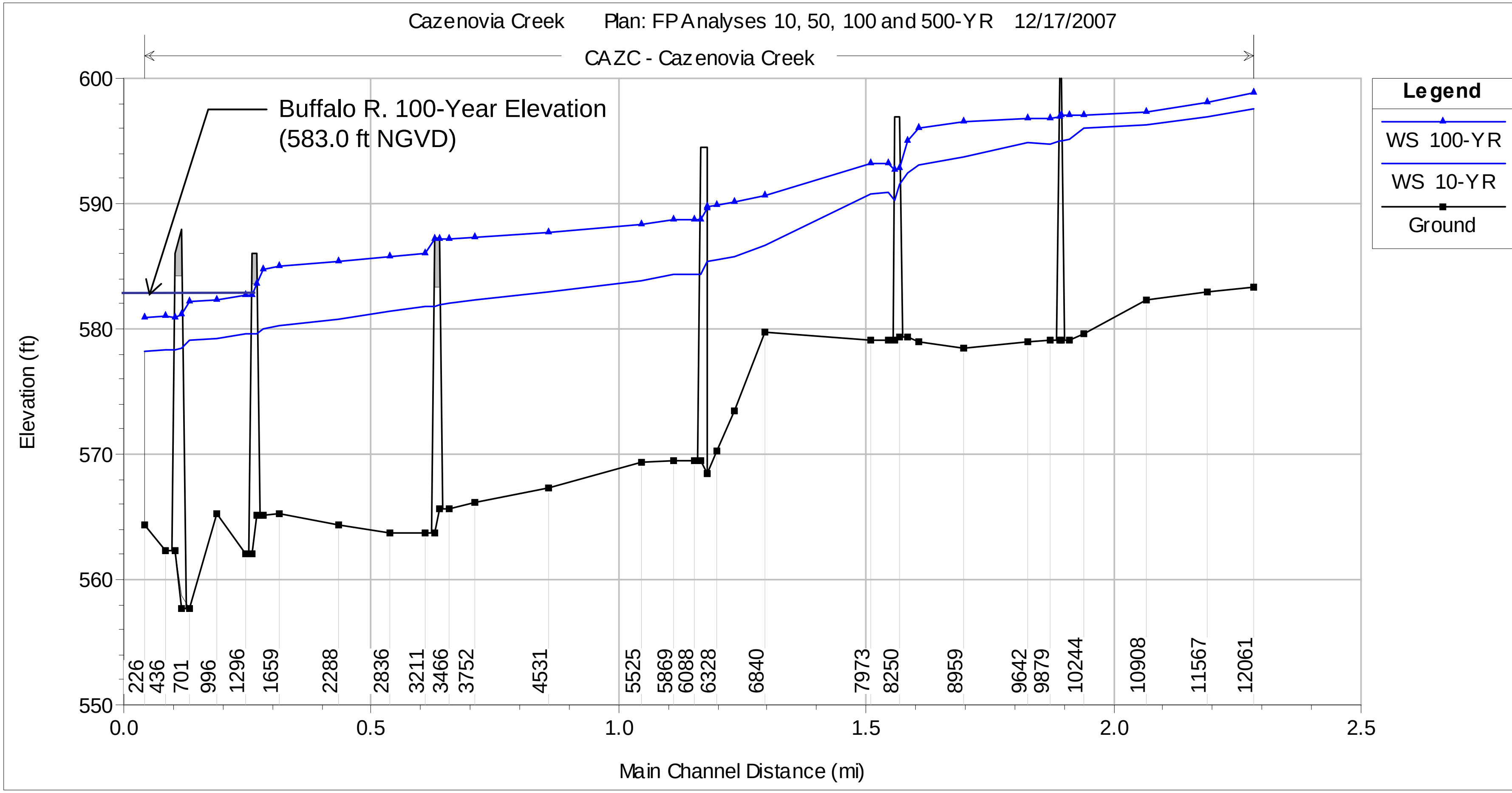
File Name: Figure 3-24.pdf

Figure 3-25

ENVIRON
MACTEC
LimnoTech

FLOOD INSURANCE RATE MAP, 1999

Figure 3-25



Elevation Datum is NAVD 1988 (approximately 0.5 ft lower than NGVD 1929 Datum); FEMA HEC-RAS Model

ENVIRON
MACTEC
LimnoTech

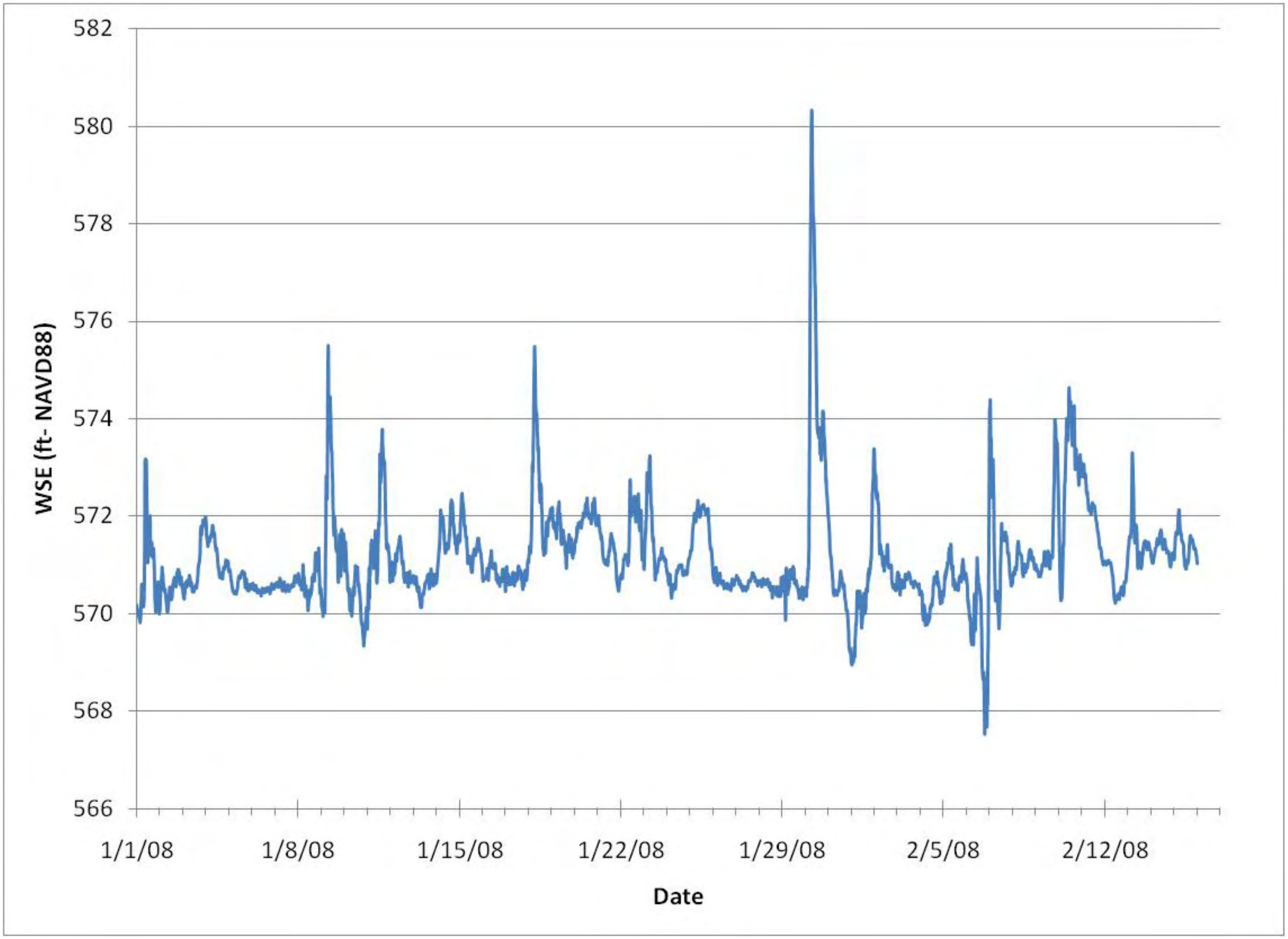
CAZENOVIA CREEK WATER SURFACE PROFILES –

10- AND 100-YEAR FLOODS

Figure

3-26

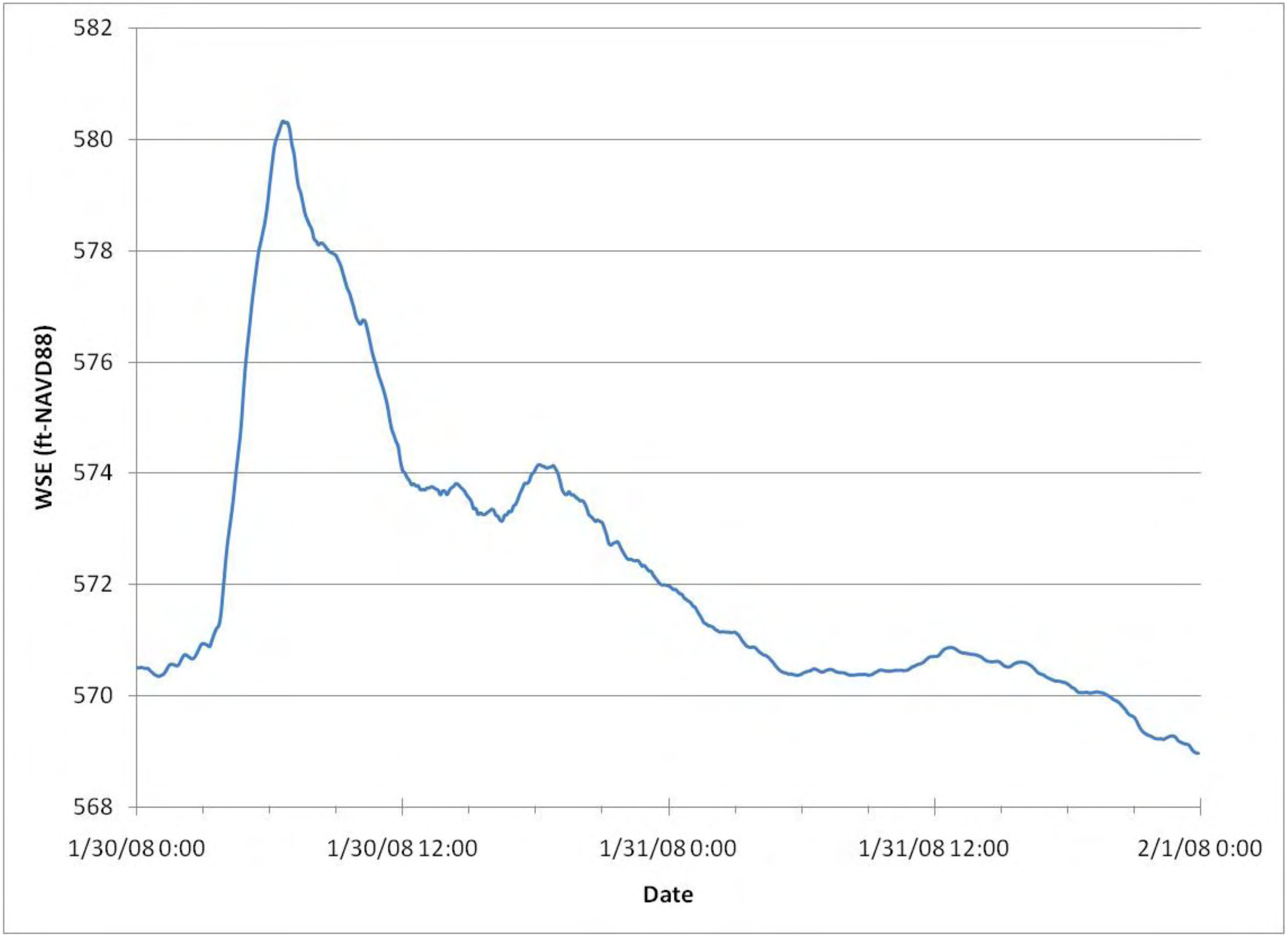
File Name: Figure 3-26.pdf



ENVIRON
MACTEC
LimnoTech

WATER SURFACE EVALUATION MEASUREMENTS RECORDED AT THE MOUTH OF THE BUFFALO RIVER FROM 1/1/08 THROUGH 2/15/08

Figure 3-27



ENVIRON MACTEC LimnoTech

JANUARY 30 SEICHE EVENT WATER SURFACE EVALUATIONS MEASURED AT THE MOUTH OF THE BUFFALO RIVER

Figure 3-28

ENVIRON
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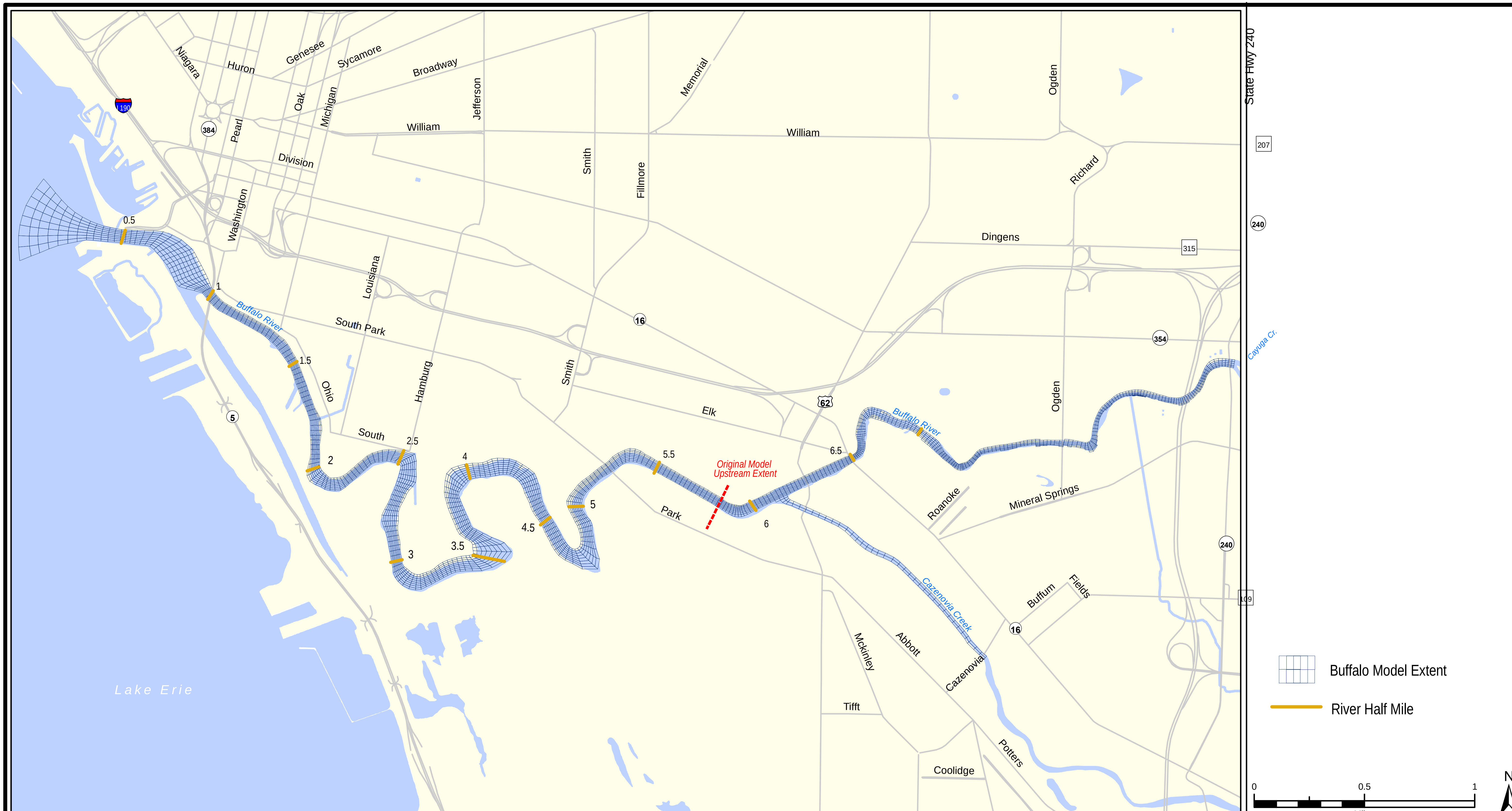
LimnoTech

PORTION OF 1ST WARD NEIGHBORHOOD PREDICTED TO FLOOD UNDER A 1.2 YEAR RECURRENCE INTERVAL EVENT ASSUMING THE PEAK JANUARY 30 SEICHE WATER SURFACE EVALUATION

Figure 3-29



ENVIRON
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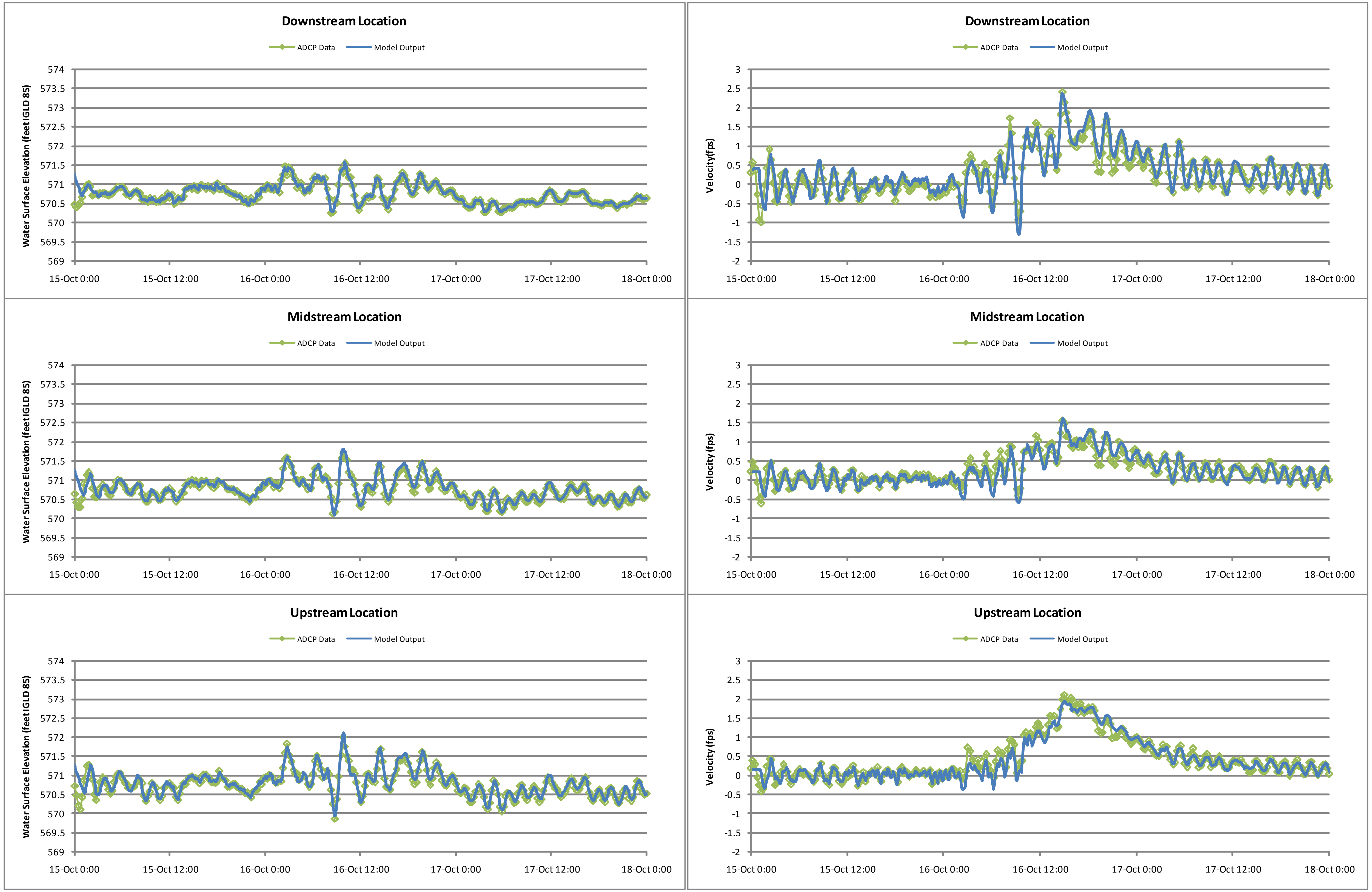
LimnoTech

EXTENT OF EFDC MODEL GRID

VERTICAL PROFILES

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_27_Extent_Model_Grid.mxd

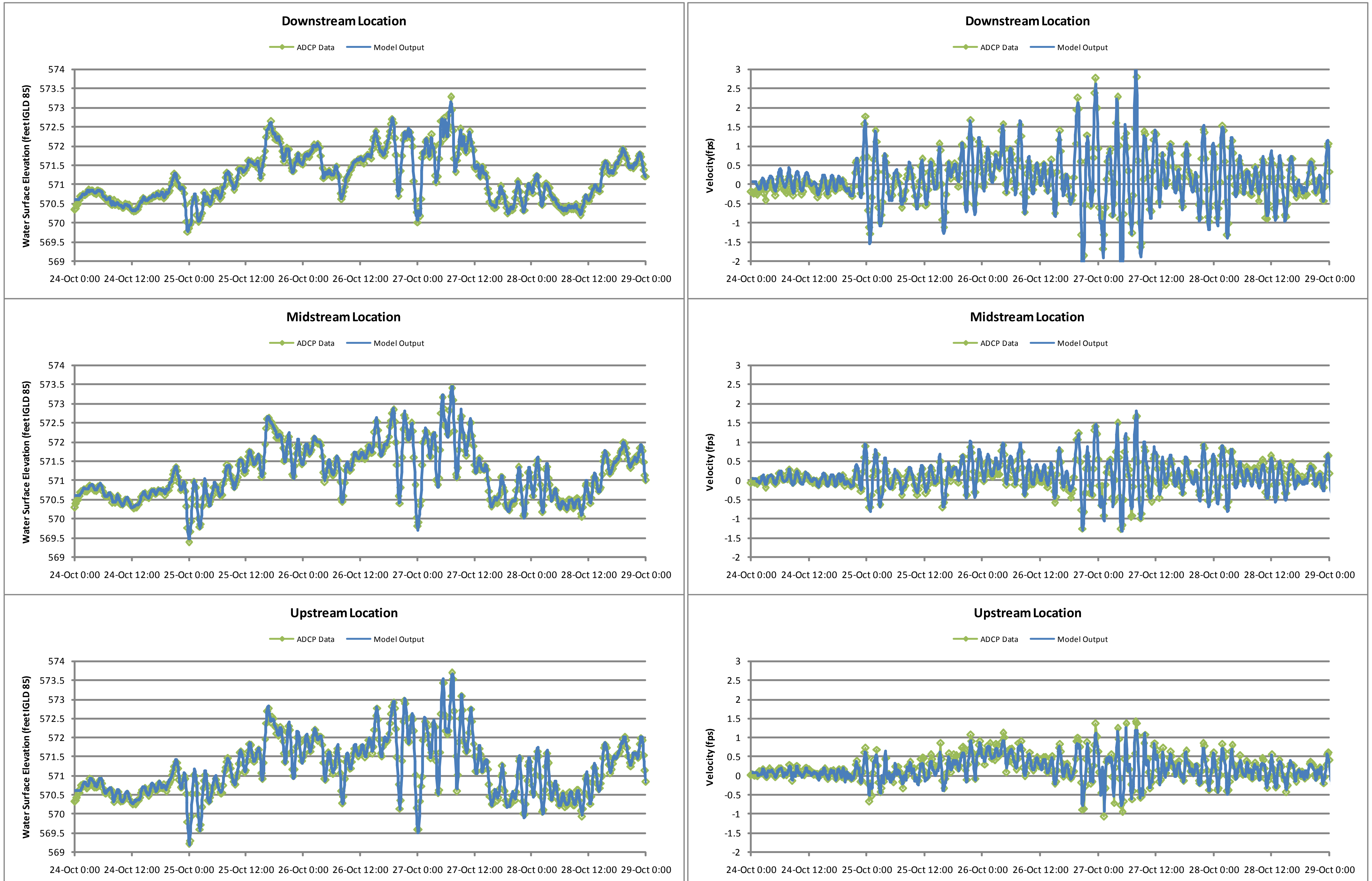


ENVIRON
MACTEC
LimnoTech

Model to Data Comparison of Water Surface Elevations and Velocities for Calibration Period A (10/15/2008 - 10/18/2008)

Figure
3-31

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_28_CalibrationA.mxd



ENVIRON

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Model to Data Comparison of Water Surface Elevations and Velocities for Calibration Period B (10/24/2008 - 10/29/2008)

Figure 3-32

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_29_CalibrationB.mxd

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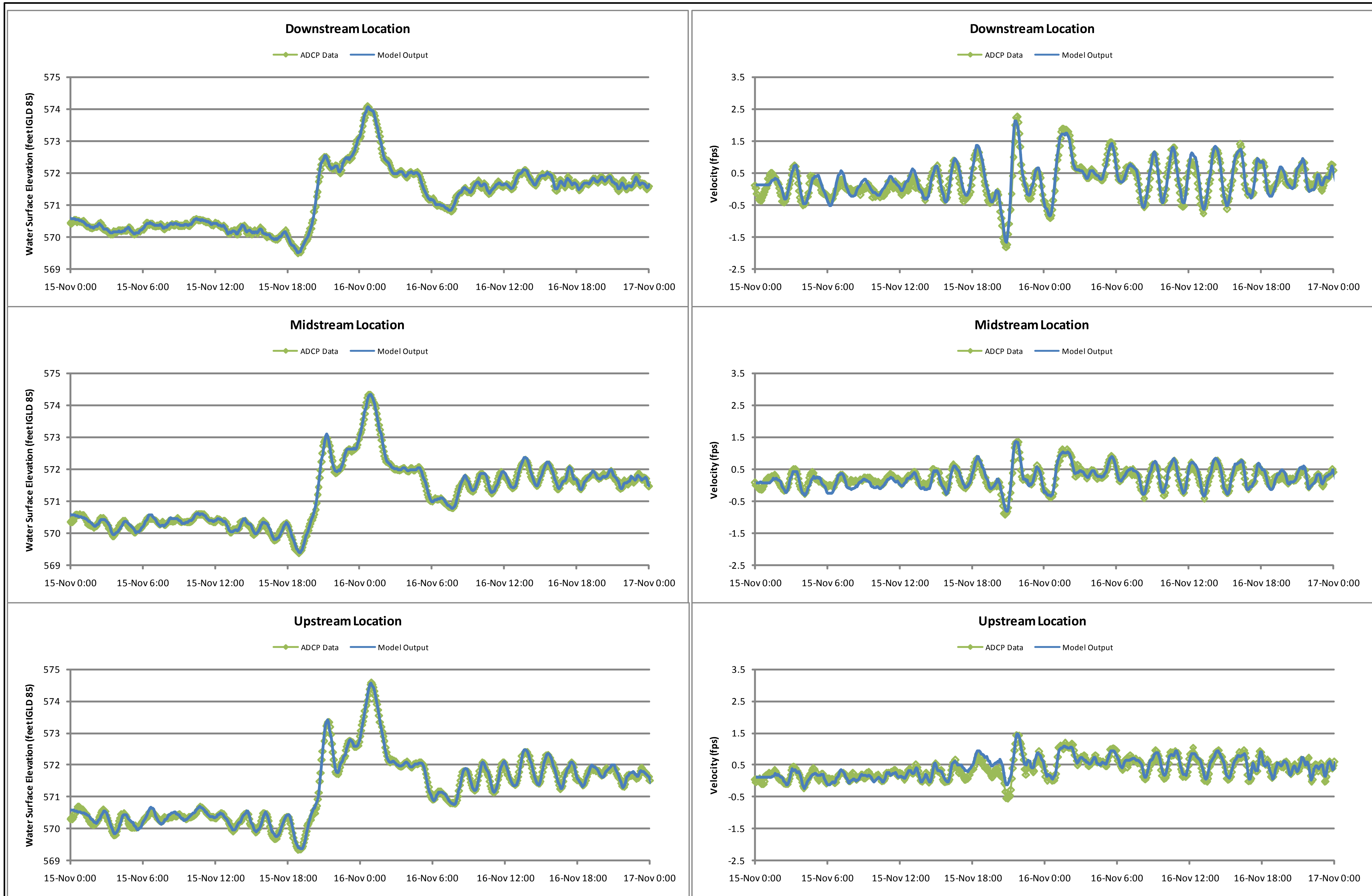
Model to Data Comparison of Water Surface Elevations and Velocities for Calibration Period C (11/6/2008 - 11/9/2008)

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_30_CalibrationC.mxd

VERTICAL PROFILES



Model to Data Comparison of Water Surface Elevations and Velocities for Calibration Period D (11/15/2008 - 11/17/2008)

VERTICAL PROFILES

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_31_CalibrationD.mxd

ENVIRON
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LimnoTech

Buffalo River Model Predicted Velocity at Low Flow with Minimal Seiche Influence (11/6/2008 16:00)

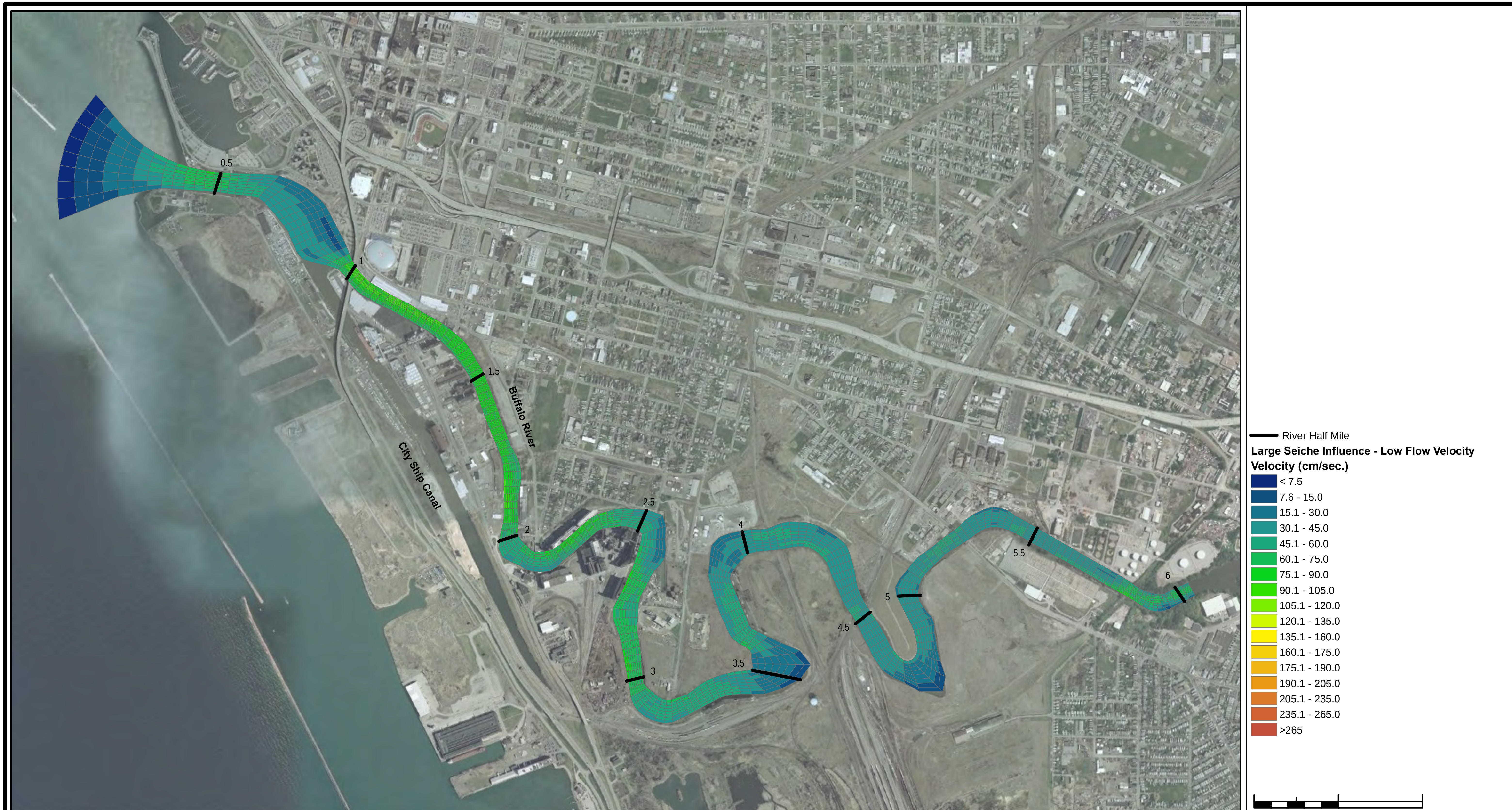
VERTICAL PROFILES

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_32_Velocity_LowFlow_Minimal.mxd

ENVIRON
MACTEC
LimnoTech

Buffalo River Model Predicted Shear Stress at Low Flow with Minimal Seiche Influence (11/6/2008 16:00)

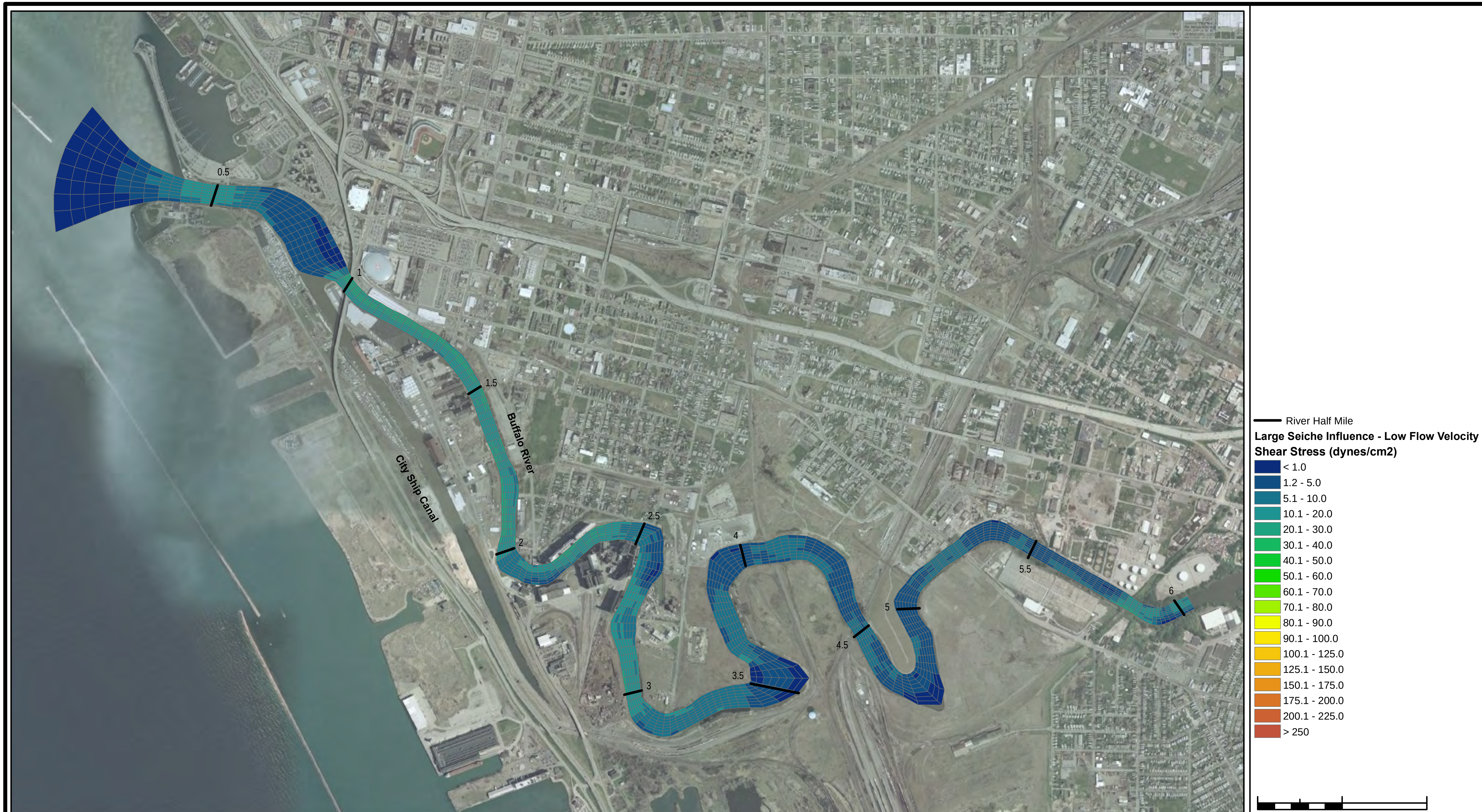
VERTICAL PROFILES



ENVIRON MACTEC LimnoTech

Buffalo River Model Predicted Velocity at Low Flow with Large Seiche Influence (11/8/2008 7:00)

VERTICAL PROFILES



ENVIRON
MACTEC
LimnoTech

Buffalo River Model Predicted Bottom Shear Stress at Low Flow with Large Seiche Influence (11/8/2008 7:00)

Figure
3-38

ENVIRON
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Buffalo River Model Predicted Velocity at the Peak of the October 16, 2008 High Flow Event (1-year Recurrence Interval)

Figure 3-39

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_36_Velocity_HigFlow_Peak_1yr.mxd

River Half Mile

One Year Recurrence Interval - Peak High Flow Shear Stress

Shear Stress (dynes/cm2)

- < 1.0
- 1.01 - 1.04
- 1.05 - 5.00
- 5.01 - 10.00
- 10.01 - 20.00
- 20.01 - 30.00
- 30.01 - 40.00
- 40.01 - 50.00
- 50.01 - 60.00
- 60.01 - 70.00
- 70.01 - 80.00
- 80.01 - 90.00
- 90.01 - 100.00
- 100.01 - 125.00
- 125.01 - 150.00
- 150.01 - 175.00
- 175.01 - 200.00
- > 250

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Buffalo River Model Predicted Bottom Shear Stress at the Peak of the October 16, 2008 High Flow Event (1-year Recurrence Interval)

Figure 3-40

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LimnoTech

Buffalo River Model Predicted Velocity at the Peak of the January 29, 2002 High Flow Event (10-year Recurrence Interval)

Figure 3-41

Drafter: A. Motzny
Contract Number: BUFHON
File Name: Fig3_38_Velocity_HigFlow_Peak_10yr.mxd

ENVIRON
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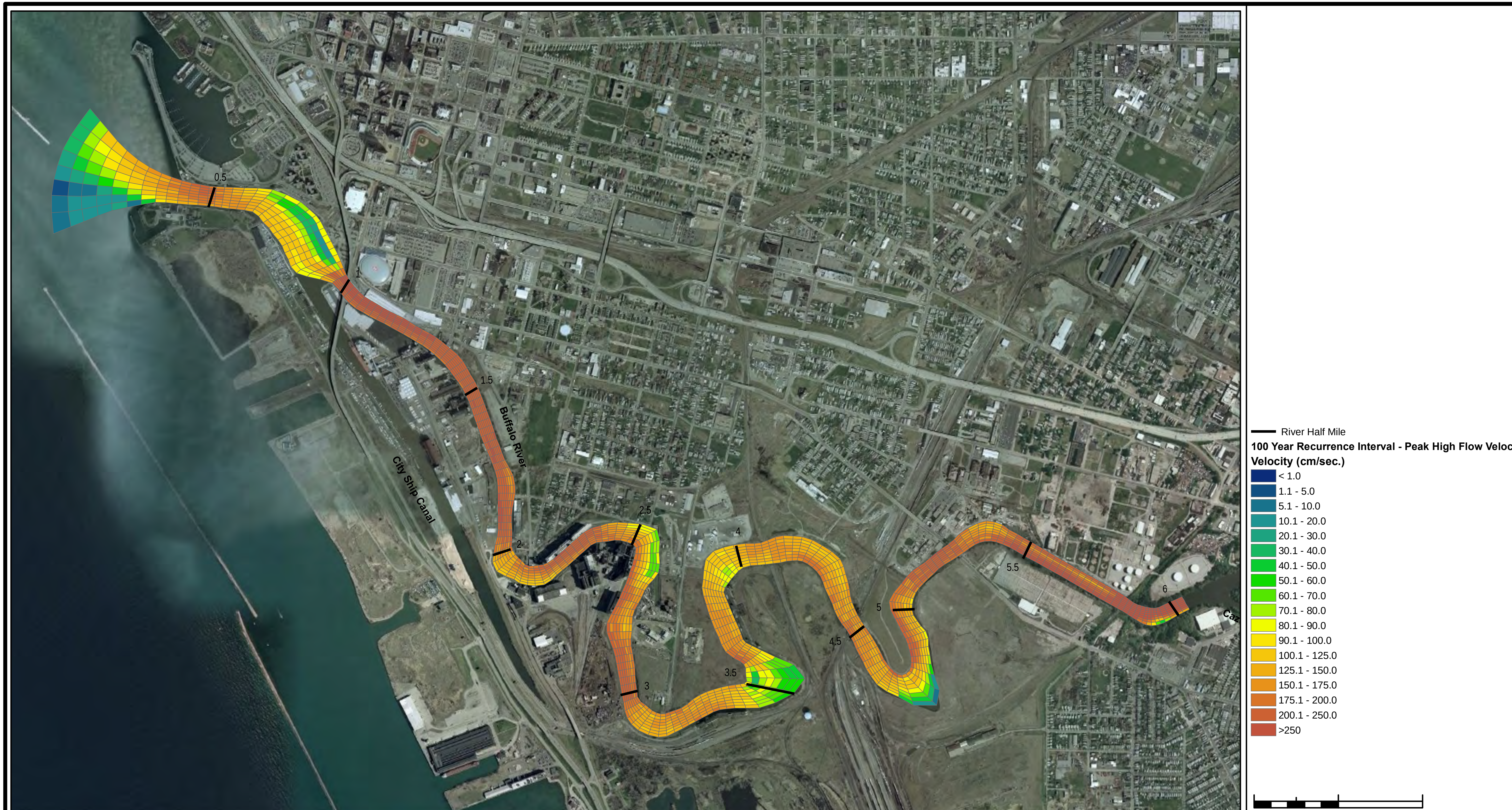
Buffalo River Model Predicted Bottom Shear Stress at the Peak of the January 29, 2002 High Flow Event (10-year Recurrence Interval)

Figure
3-42



ENVIRON
MACTEC
LimnoTech

Buffalo River Model Predicted Velocity at the Peak of the September 7, 2004 High Flow Event (100-year Recurrence Interval)

Figure 3-43

Legend

River Half Mile

100 Year Recurrence Interval - Peak High Flow Velocity Shear Stress (dynes/cm2)

- < 1.0
- 1.1 - 5.0
- 5.1 - 5.0
- 5.1 - 10.0
- 10.1 - 20.0
- 20.1 - 30.0
- 30.1 - 40.0
- 40.1 - 50.0
- 50.1 - 60.0
- 60.1 - 70.0
- 70.1 - 80.0
- 80.1 - 90.0
- 90.1 - 100.0
- 100.1 - 125.0
- 125.1 - 150.0
- 150.1 - 175.0
- 175.1 - 200.0

0 0.2 0.4

Miles

N

ENVIRON

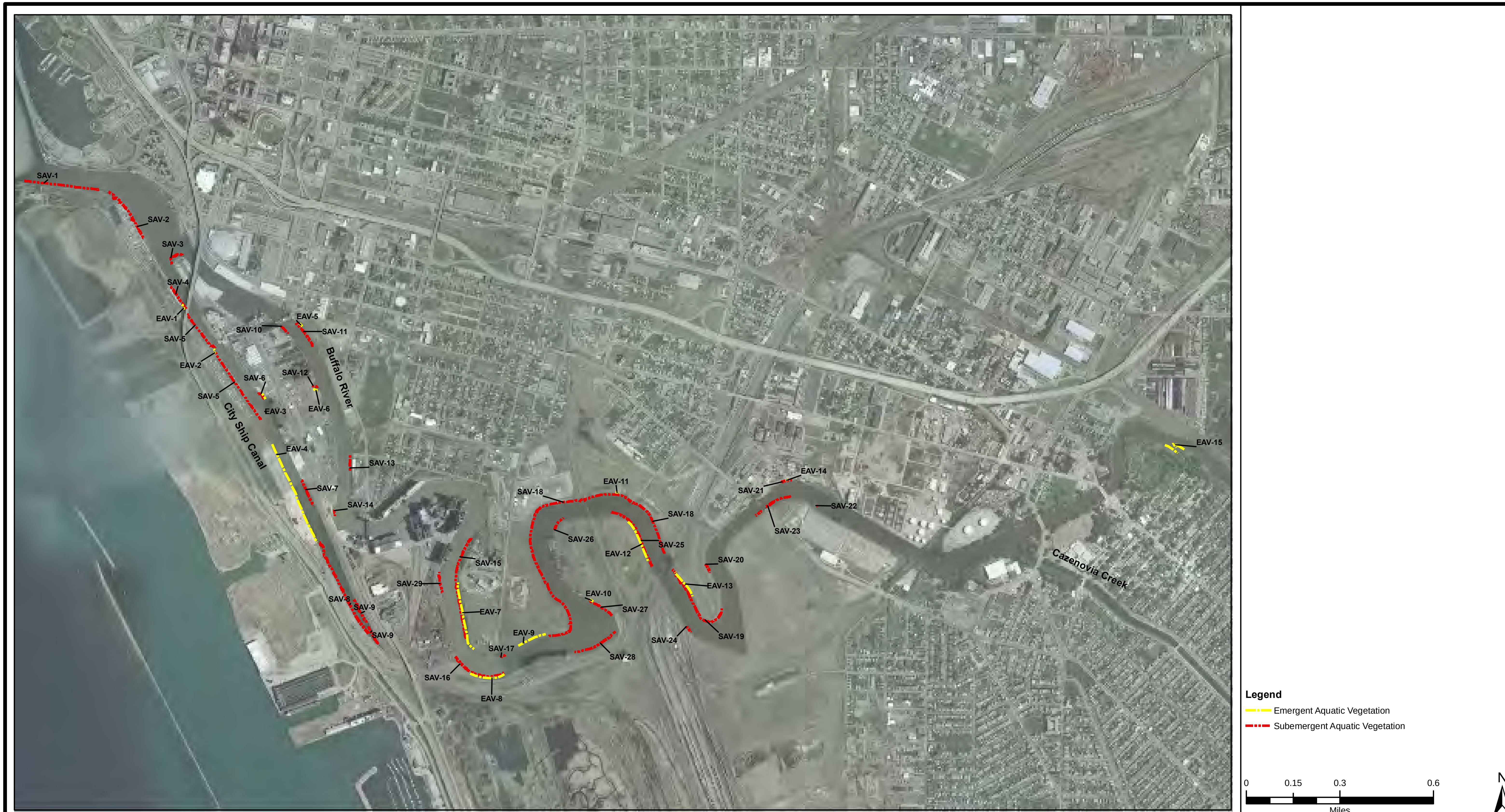
MACTEC

LimnoTech

Buffalo River Model Predicted Bottom Shear Stress at the Peak of the September 7, 2004 High Flow Event (100-year Recurrence Interval)

Figure 3-44

Drafter: A Motzny
Contract Number: BUFHON
File Name: Fig3_41_Shear_HigFlow_Peak_100yr.mxd



ENVIRON
MACTEC

AQUATIC VEGETATION
BUFFALO RIVER, NY

Figure 4-1a

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20081218_AquaticVegetation.mxd

Legend

- Emergent Aquatic Vegetation
- Subemergent Aquatic Vegetation

Shoreline
Designation Descriptions

- Concrete Cap
- Natural
- Old Timber Pilings
- Retaining Structure
- Stone

Note: Aquatic vegetation data provided by MACTEC 2008. Shoreline Characteristic data provided by USACE. 2008. Draft Buffalo River Environmental Dredging Feasibility Study, Geotechnical and Structural. May

0 0.15 0.3 0.6
Miles

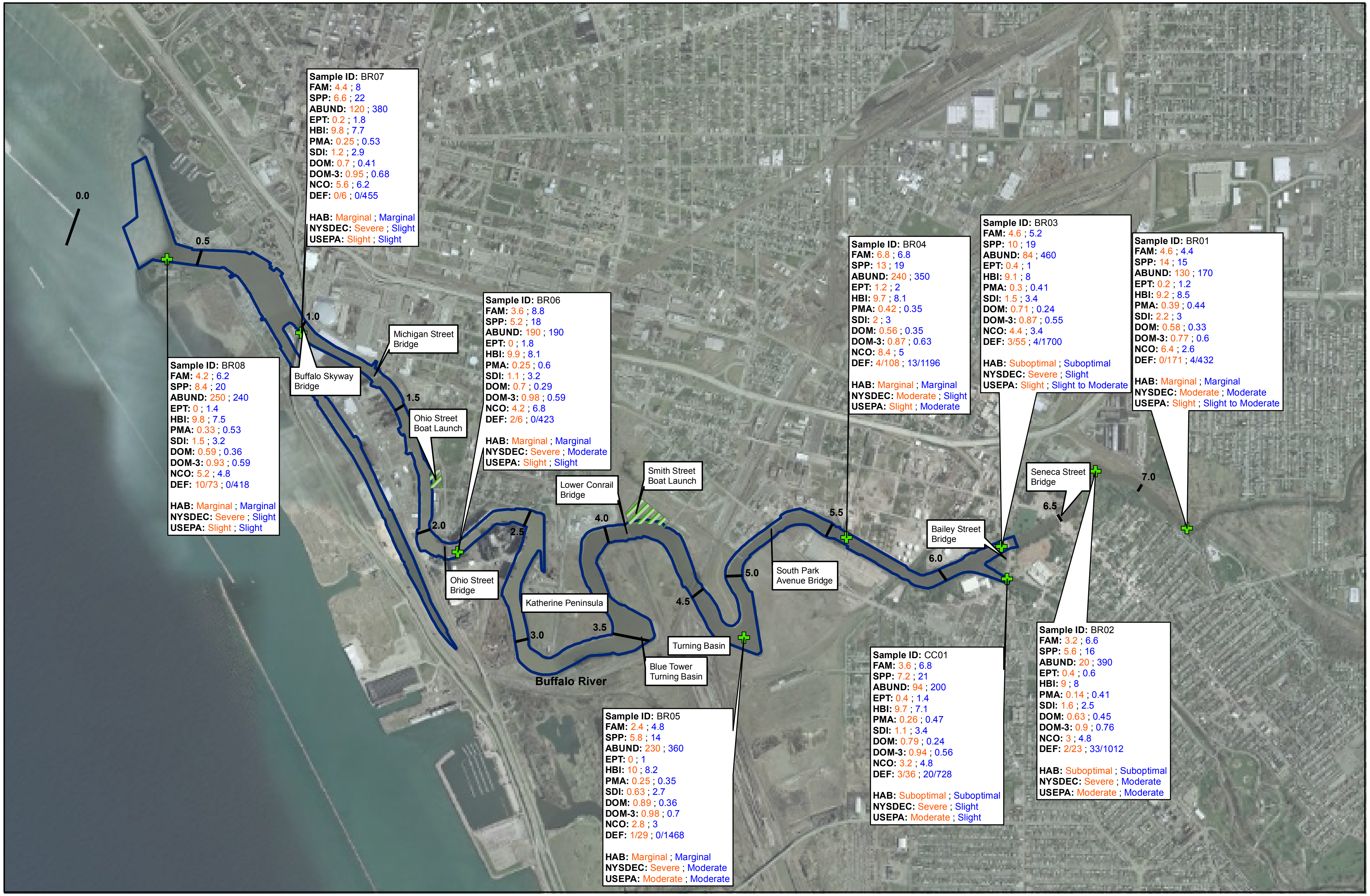
N

ENVIRON
MACTEC

AQUATIC VEGETATION AND SHORELINE CHARACTERISTICS
BUFFALO RIVER, NY

Figure 4-1b

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20081218_AquaticVegetation.mxd



Legend

- Buffalo River Boundary Area of Concern
- Mile Mark Designations
- Benthic Community Sampling Locations
- Boat Launch Areas

FAM	Mean family richness in number of taxa.
SPP	Mean species richness in number of taxa.
ABUND	Mean abundance in number of organisms.
EPT	Mean Ephemeropter-Plecoptera-Trichoptera richness in number of taxa.
HBI	Mean Hilsenhoff Biotic Index (unitless).
PMA	Mean Percent Model Affinity in percent.
SDI	Mean Shannon Diversity Index (base 2, unitless).
DOM	Mean Dominance in percent.
DOM-3	Mean Dominance of 3 most numerous taxa in percent.
NCO	Mean Non-Chironomid/Oligochaete richness in number of taxa.
DEF	Total Number of Deformities/ Total Number of Chironomids.
HAB	Rapid bioassessment protocol habitat assessment ranking (optimal>suboptimal>marginal).
NYSDEC	NYSDEC water quality impairment determination (moderate>severe, see table).
USEPA	USEPA water quality impairment determination compared to a reference location (slight>moderate>severe, see table)

Values in orange represent Sediment Grab Samples
Values in blue represent Hester Dendy Samples

0 0.25 0.5 1
Miles
N

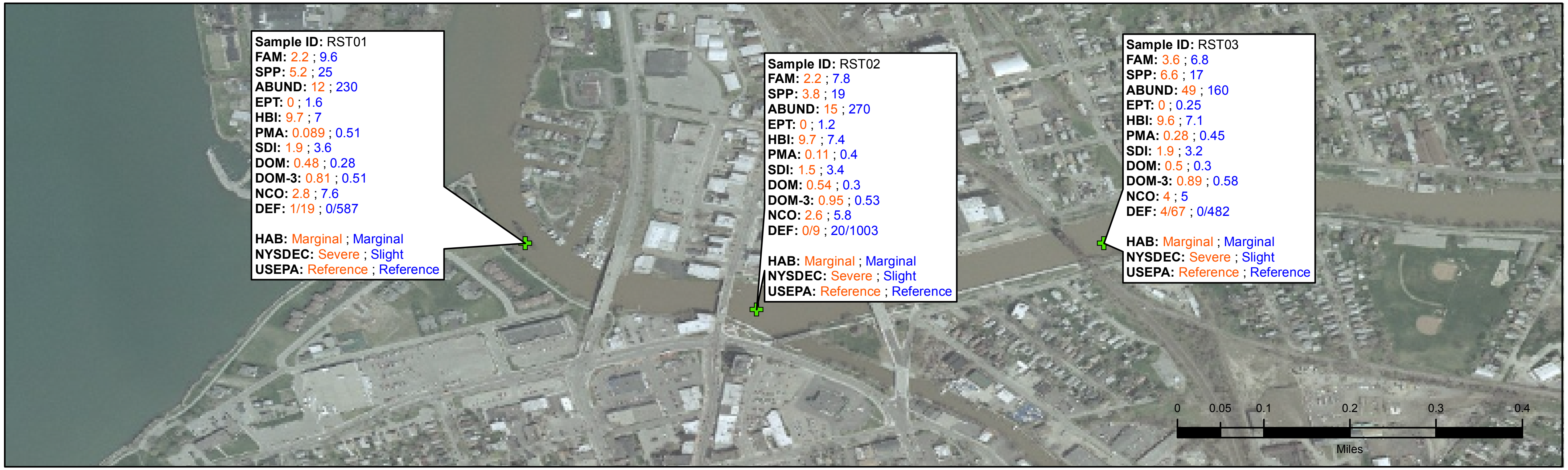
ENVIRON
MACTEC

BENTHIC COMMUNITY METRICS WITHIN BUFFALO RIVER AND CAZENOVIA CREEK

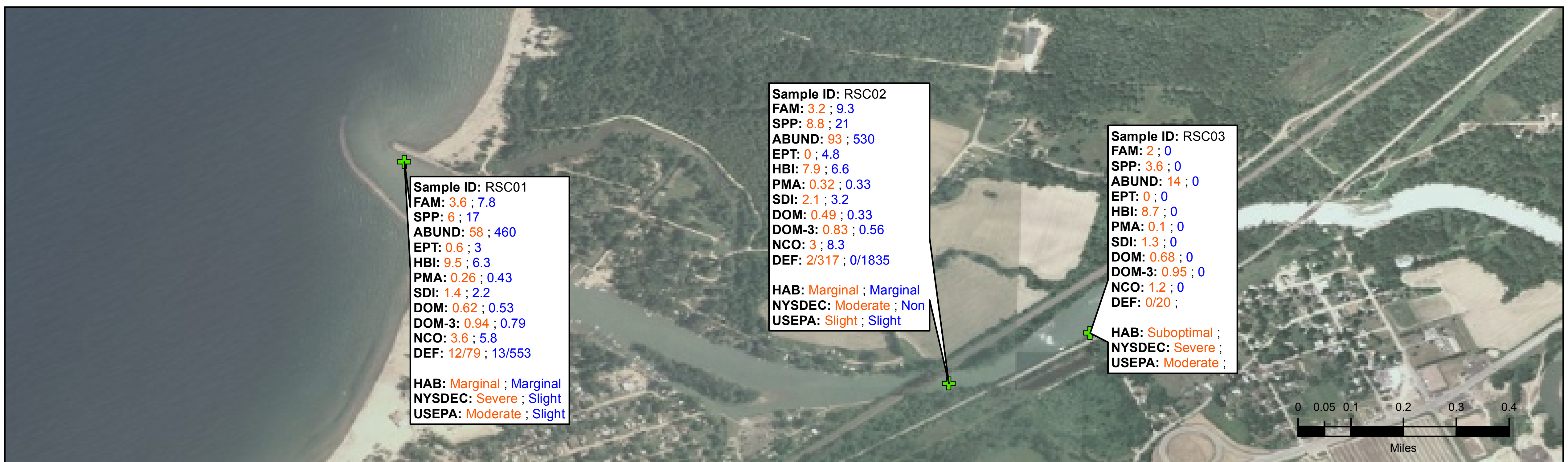
Figure 4-2a

Drafter: B. Radakovich
Date: 01/26/2009
File Name: 20090126_Benthos_BuffaloRiver.mxd

Tonawanda Creek



Cattaraugus Creek



Legend

Benthic Community Sampling Locations

FAM	Mean family richness in number of taxa.
SPP	Mean species richness in number of taxa.
ABUND	Mean abundance in number of organisms.
EPT	Mean Ephemeropter-Plecoptera-Trichoptera richness in number of taxa.
HBI	Mean Hilsenhoff Biotic Index (unitless).
PMA	Mean Percent Model Affinity in percent.
SDI	Mean Shannon Diversity Index (base 2, unitless).
DOM	Mean Dominance in percent.
DOM-3	Mean Dominance of 3 most numerous taxa in percent.
NCO	Mean Non-Chironomid/Oligochaete richness in number of taxa.
DEF	Total Number of Deformities/ Total Number of Chironomids.
HAB	Rapid bioassessment protocol habitat assessment ranking (optimal>suboptimal>marginal).
NYSDEC	NYSDEC water quality impairment determination (moderate>severe, see table).
USEPA	USEPA water quality impairment determination compared to a reference location (slight>moderate>severe, see table)

Values in orange represent Sediment Grab Samples
Values in blue represent Hester Dendy Samples

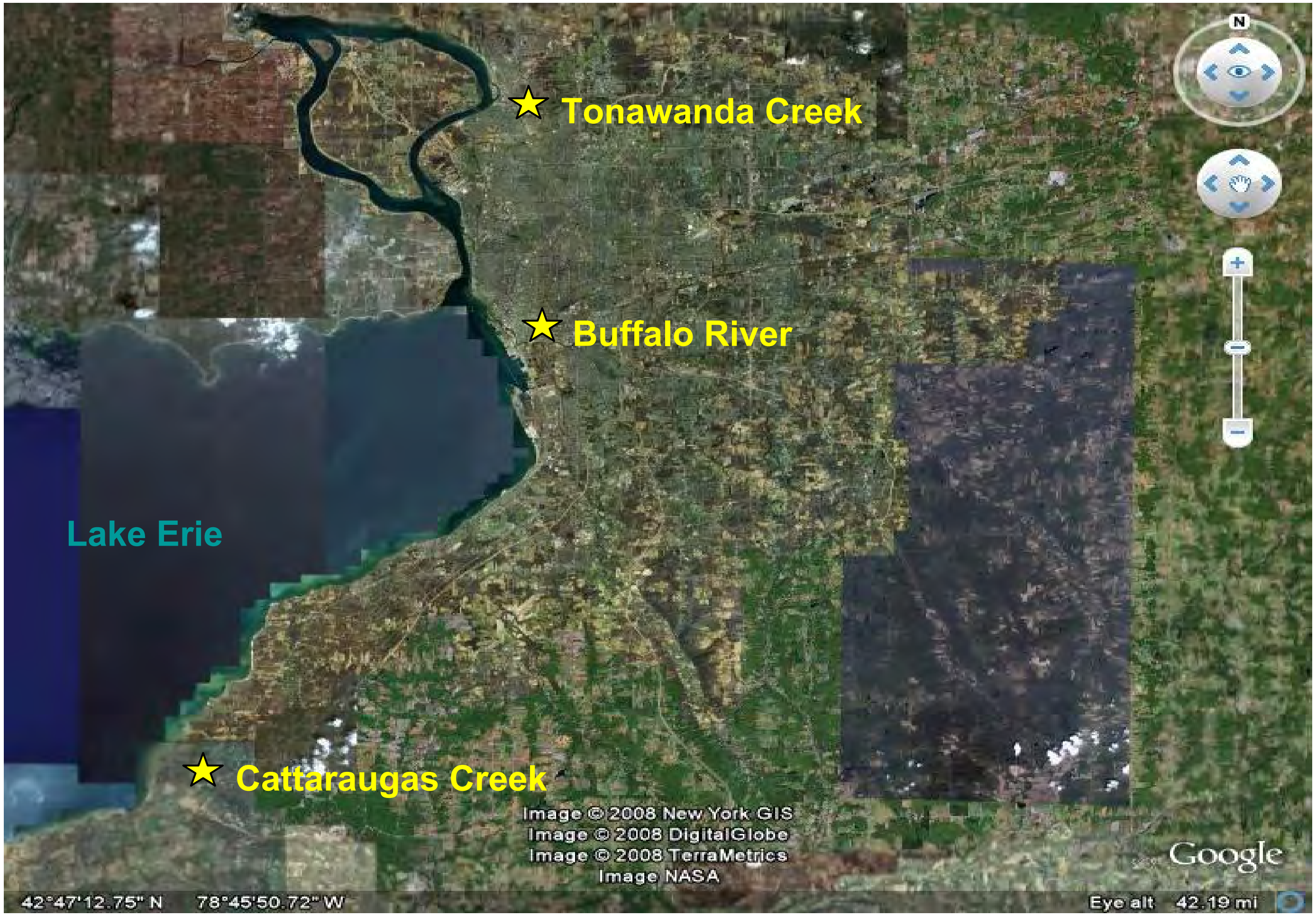
N

ENVIRON
MACTEC

BENTHIC COMMUNITY METRICS WITHIN CATTARAUGUS CREEK AND TONAWANDA CREEK

Figure 4-2b

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20090126_BenthosReference.mxd

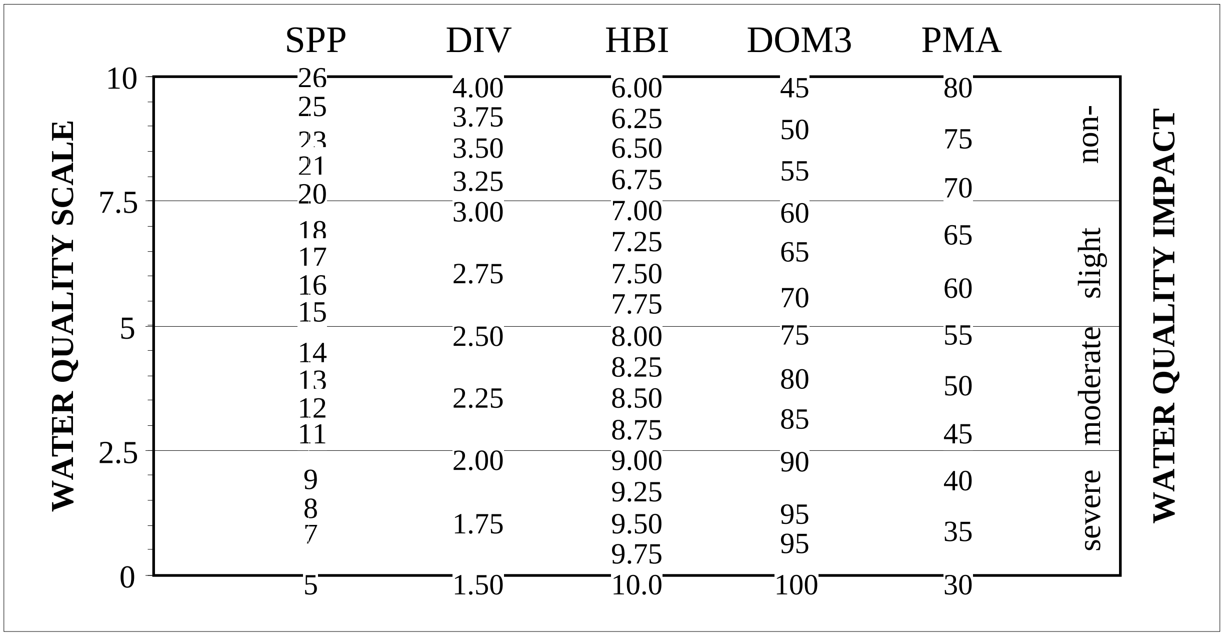


ENVIRON

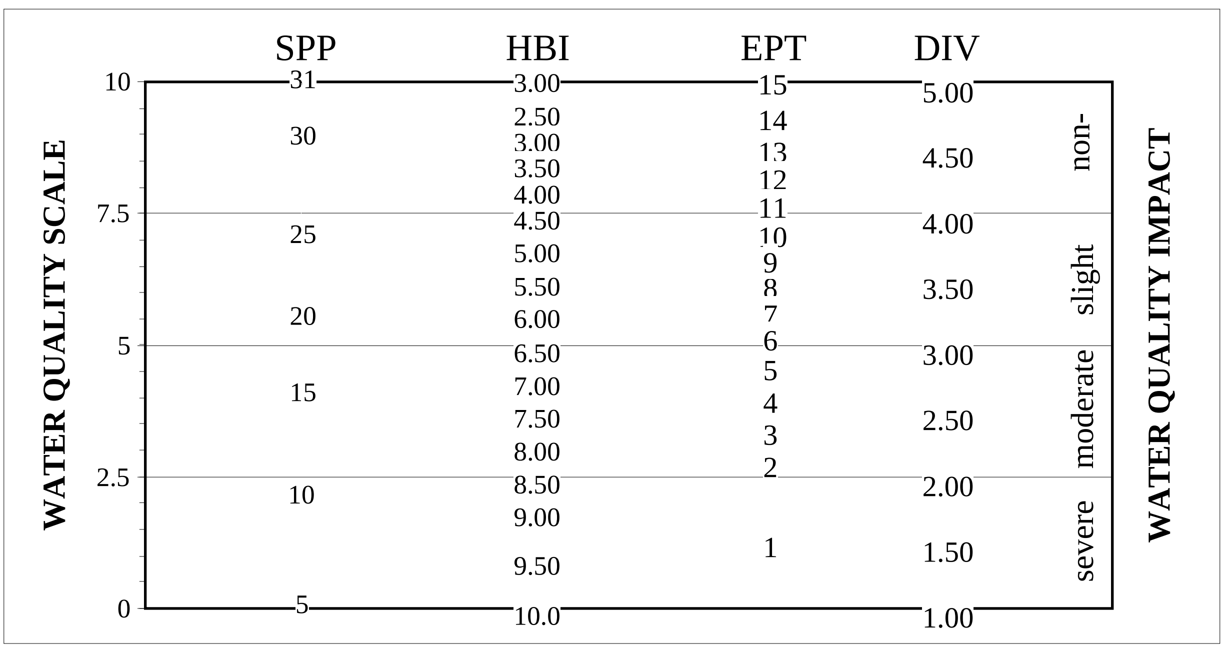
Location of Reference Creeks Relative to Buffalo River

Figure 4-2c

NYSDEC Benthic Index for Sediment Grab Samples



NYSDEC Benthic Index for Hester-Dendy Samples

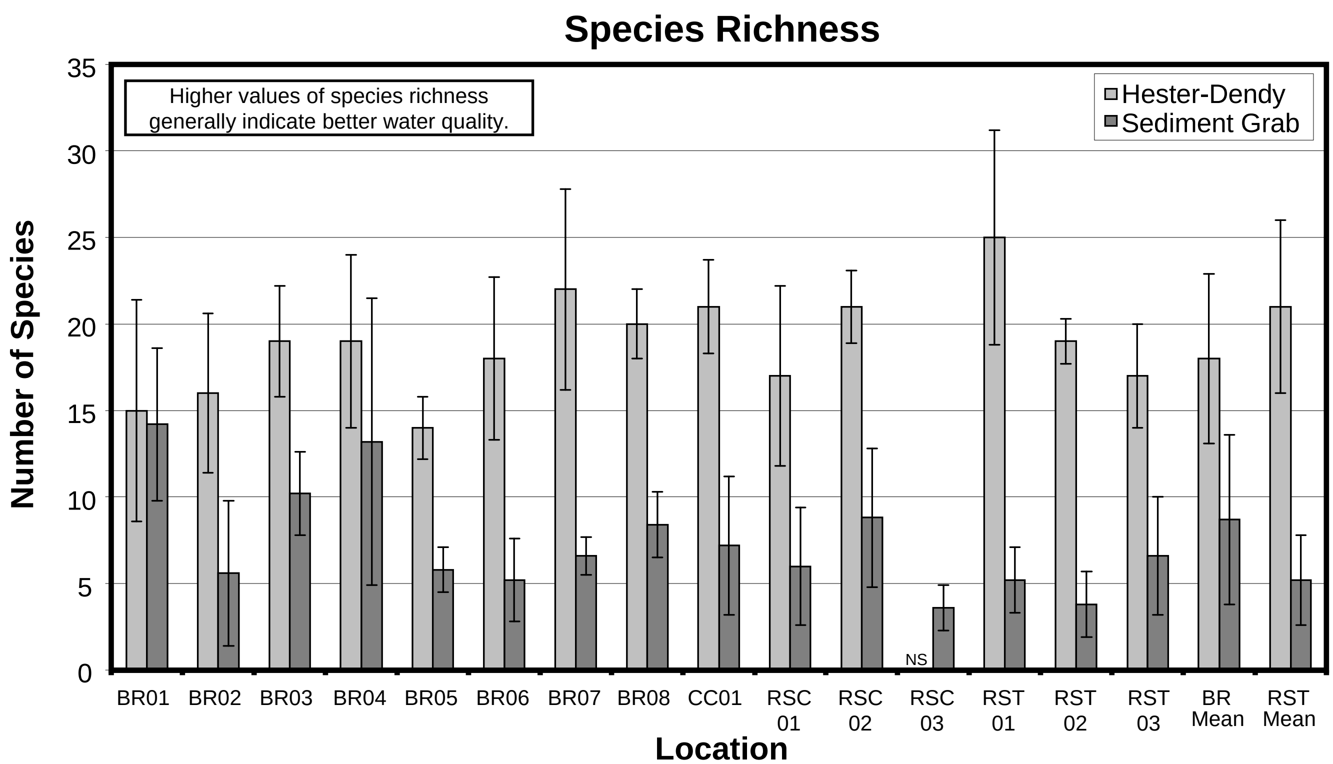


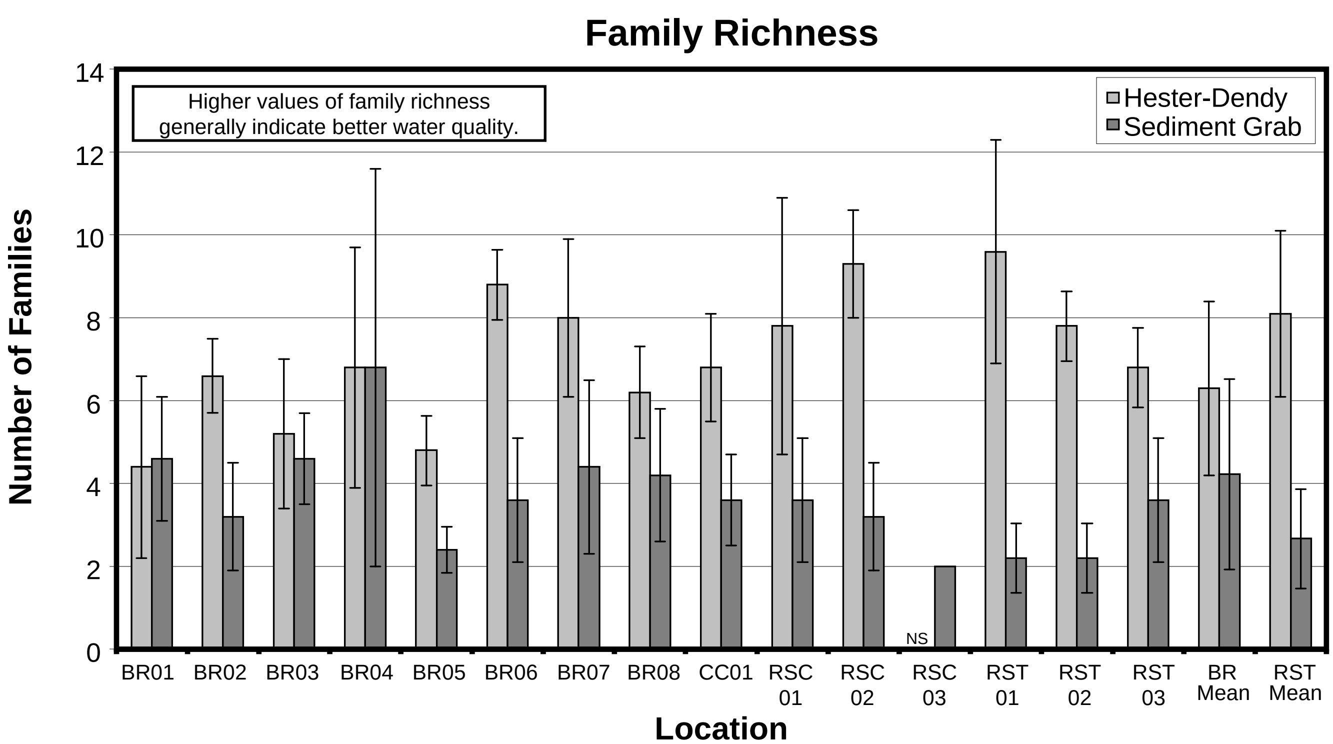
DIV	Diversity.
DOM3	Mean dominance of 3 most numerous taxa in percent.
EPT	Mean Ephemeroptera-Plectoptera-Trichoptera in number of taxa.
HBI	Mean Hilsenhoff Biotic Index.
NYSDEC	New York State Department of Environmental Conservation.
PMA	Mean Percent Model Affinity in percent.
SPP	Mean species richness in number of taxa.

ENVIRON

NYSDEC Benthic Index

Figure 4-2d



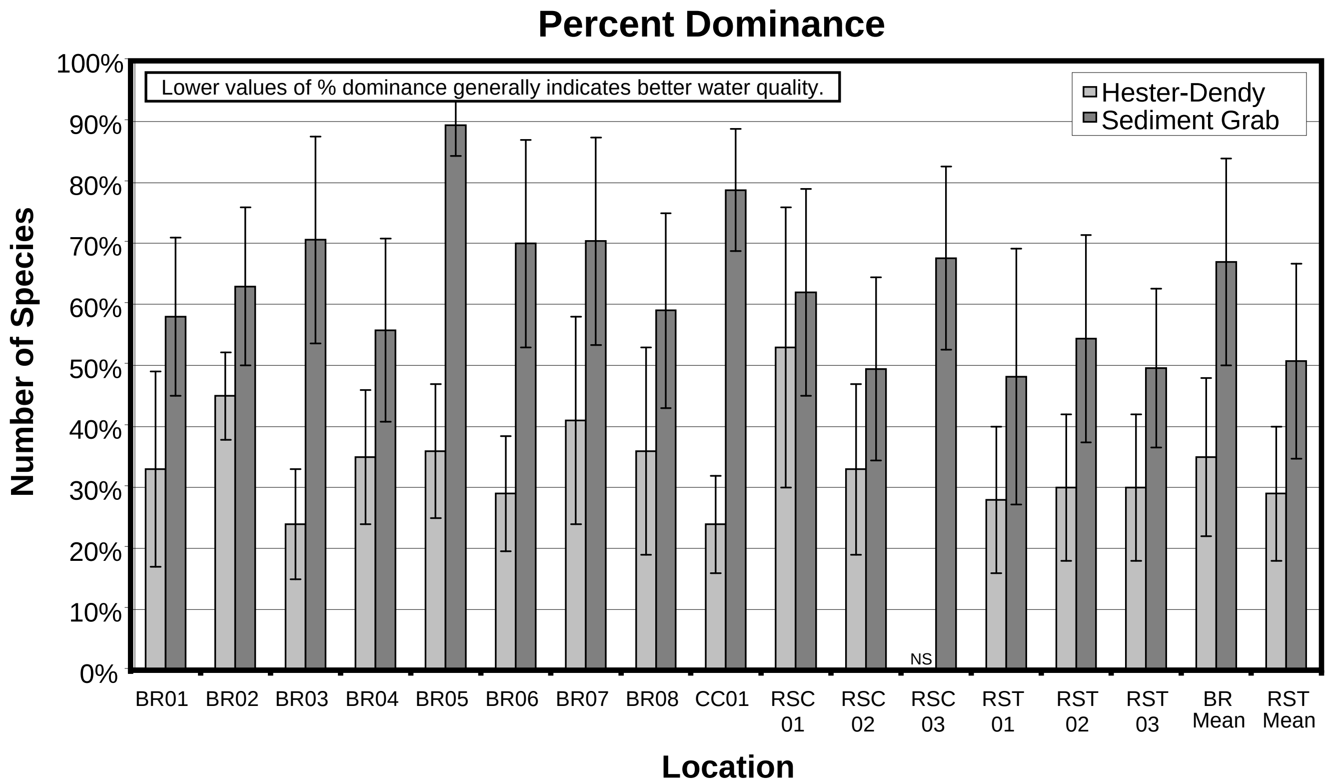


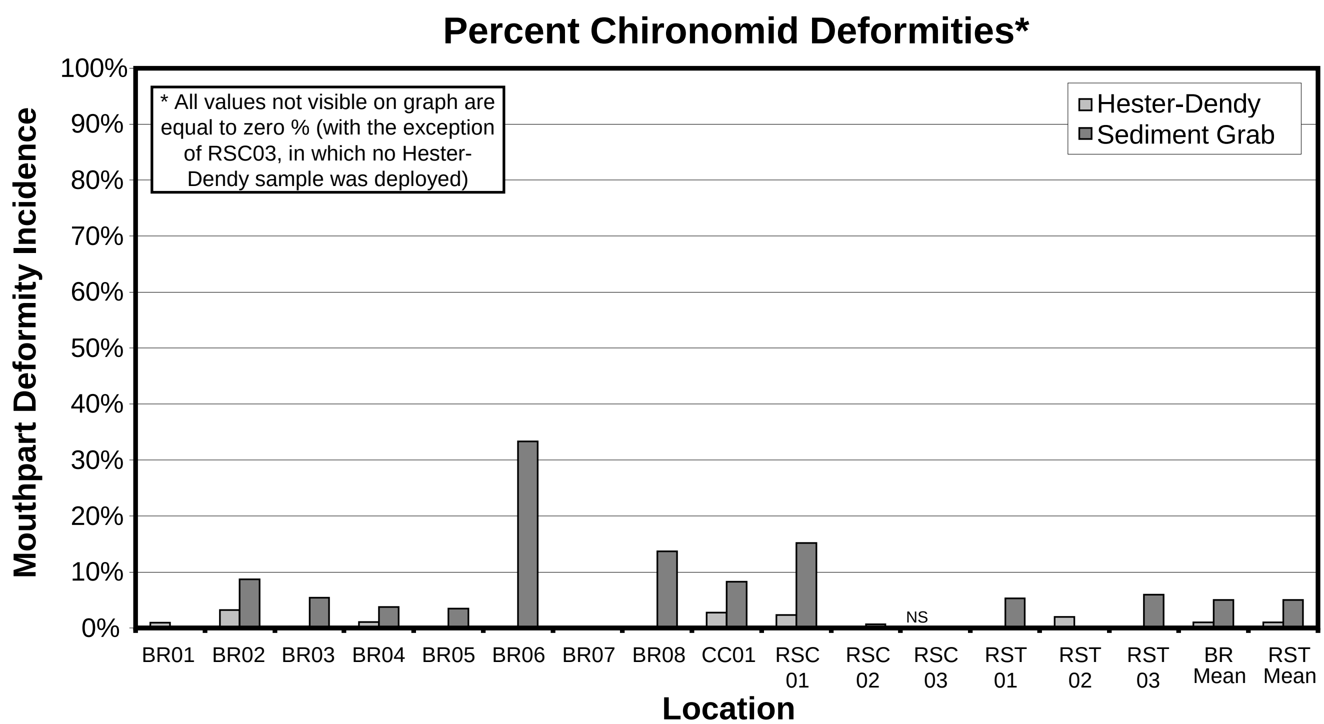
BR	Buffalo River	RSC	Reference Location Cattaraugus
CC	Cazenovia Creek	RST	Reference Location Tonawanda
NS	Not sampled		

ENVIRON MACTEC

Comparison of Sediment Grab and Hester-Dendy Metrics: Species and Family Richness

Figure 4-2e



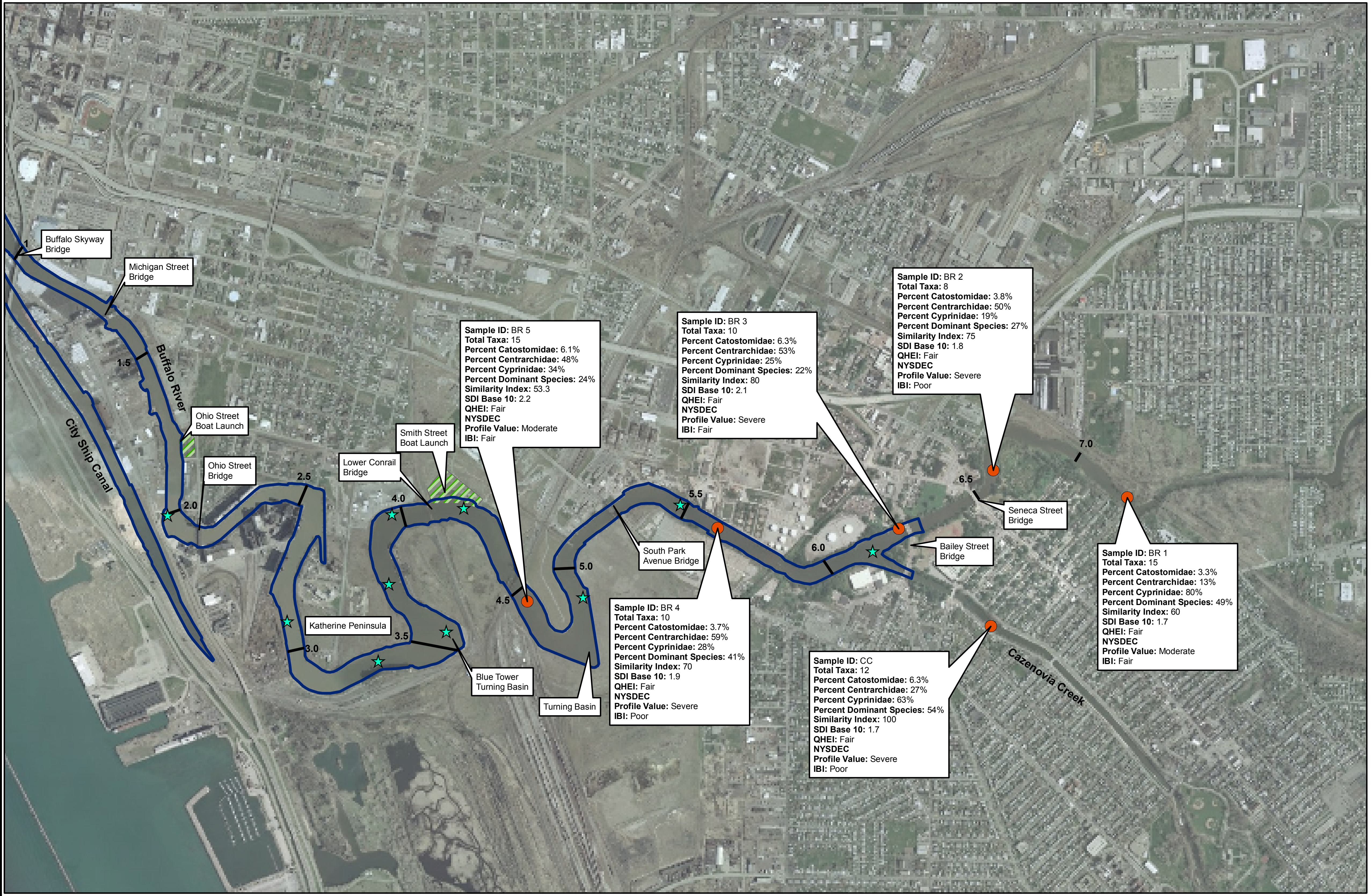


BR	Buffalo River	RSC	Reference Location Cattaraugus
CC	Cazenovia Creek	RST	Reference Location Tonawanda
NS	Not Sampled		

ENVIRON MACTEC

Comparison of Sediment Grab and Hester-Dendy Metrics: Percent Dominance and Chironomid Deformities

Figure 4-2f



Legend

- Buffalo River Boundary Area of Concern
- Boat Launch Areas
- Mile Mark Designations
- Fish Community Assessment Metrics
- Irvine et al. 5005 (fish and benthic locations)

NYSDEC – NYSDEC water quality impairment determination (see table)
IBI – Index of Biotic Integrity determination based on Irvine et al. (2005) and Greer et al. (2002)

Note:
Sampling locations my be offset based on field conditions

0 0.2 0.4 0.8
Miles

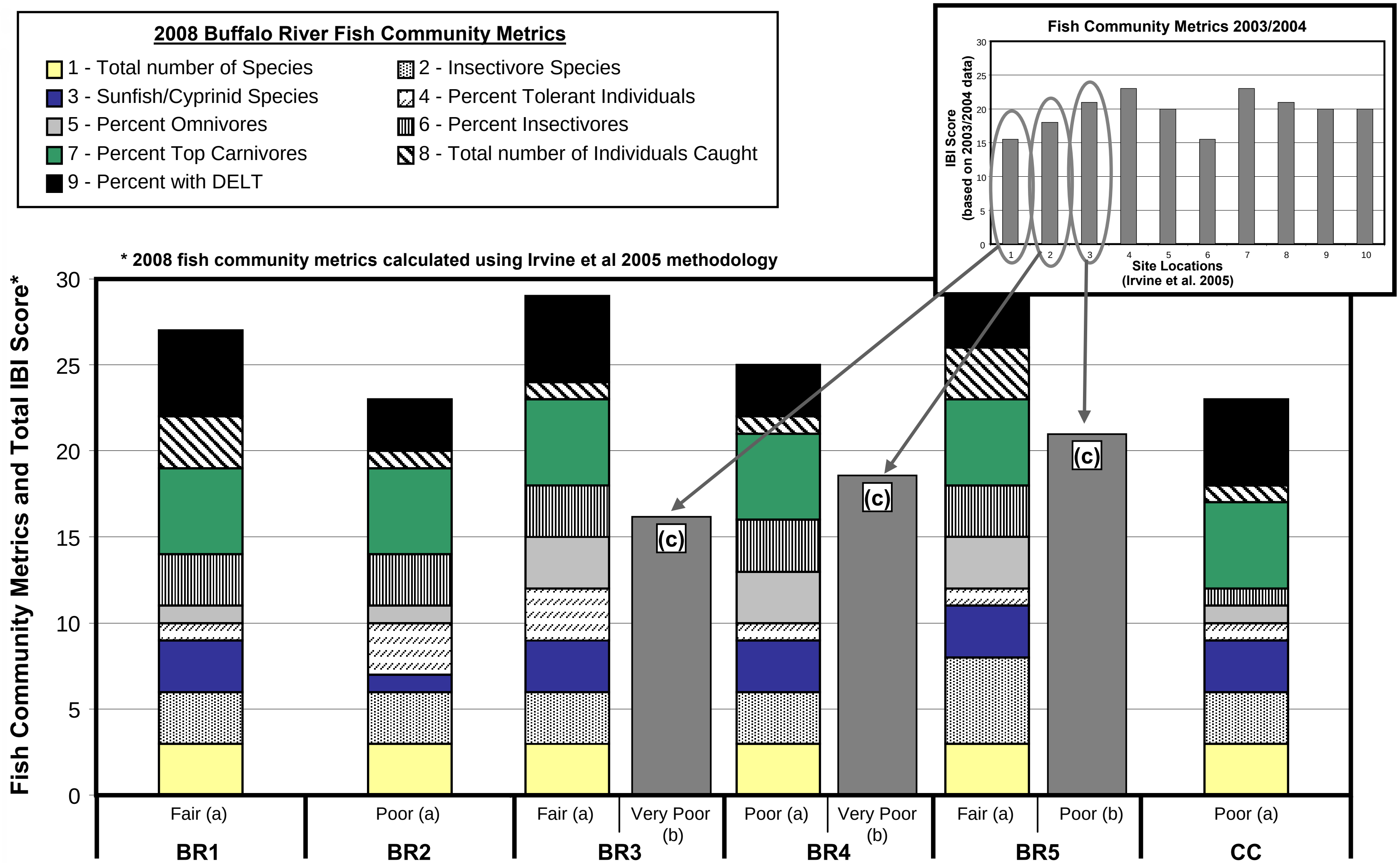
N

ENVIRON
MACTEC

BUFFALO RIVER AOC
FISH COMMUNITY METRICS WITHIN BUFFALO RIVER AND CAZENOVIA CREEK

Figure 4-3

Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20081215_FishMetrics.mxd



BR	Buffalo River
CC	Cazenovia Creek
DELT	Deformities, Erosions, Lesions, Tumors
IBI	Index of Biotic Integrity

(a) IBI rating 2008.

(b) IBI rating for 2003/2004 Irvine et al study where locations with 2008 study overlapped. *Note*: Total IBI is presented because metric data were not available.

(c) Where locations overlap, 2008 IBIs slightly exceed those seen in Irvine et al 2005).

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2008 Fish Community Metrics
Compared to 2003/2004 Irvine et al. Results

Figure 4-4

Legend

Brown Bullhead Survey Zone

Water Bodies

River Mile Segments

n= sample size

Metrics are presented as percentages of individuals collected from each reach.

Somatic indices and DELTSs are non-discriminatory descriptors that are not used as BUI listing criteria. Because DELTs are not BUI listing criteria they were not confirmed by histopathology. Therefore, the somatic indices and DELTs in this figure should be considered as representative but not quantitative indicators of fish health.

Values (%) presented are calculated per individual reach.

0 0.2 0.4 0.8

Miles

N

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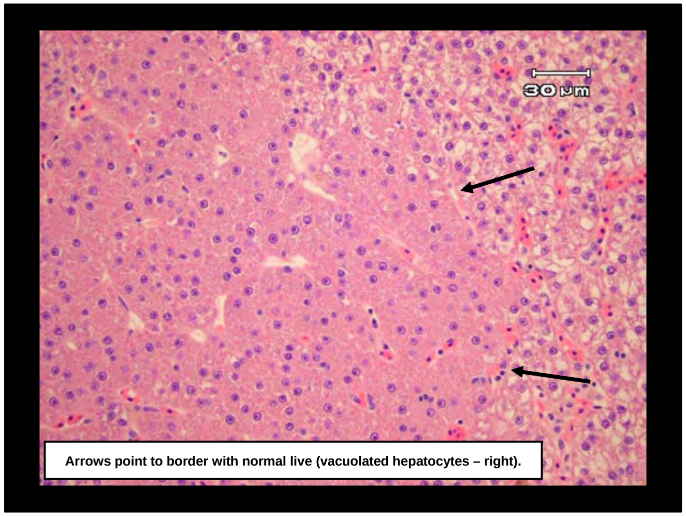
BUFFALO RIVER AOC
BROWN BULLHEAD SOMATIC INDICES AND DELT PREVALENCE

Figure 4-5b

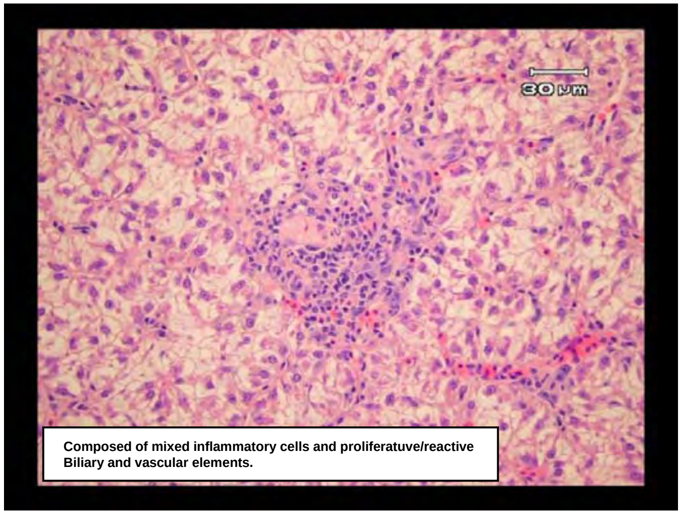
Drafter: B. Radakovich
Contract Number: 02-20873A2
File Name: 20090129_BullheadSomatic_4-5b.mxd

Normal Bullhead Liver Surrounding an Exocrine Pancreas and Blood Vessel (10x objective)



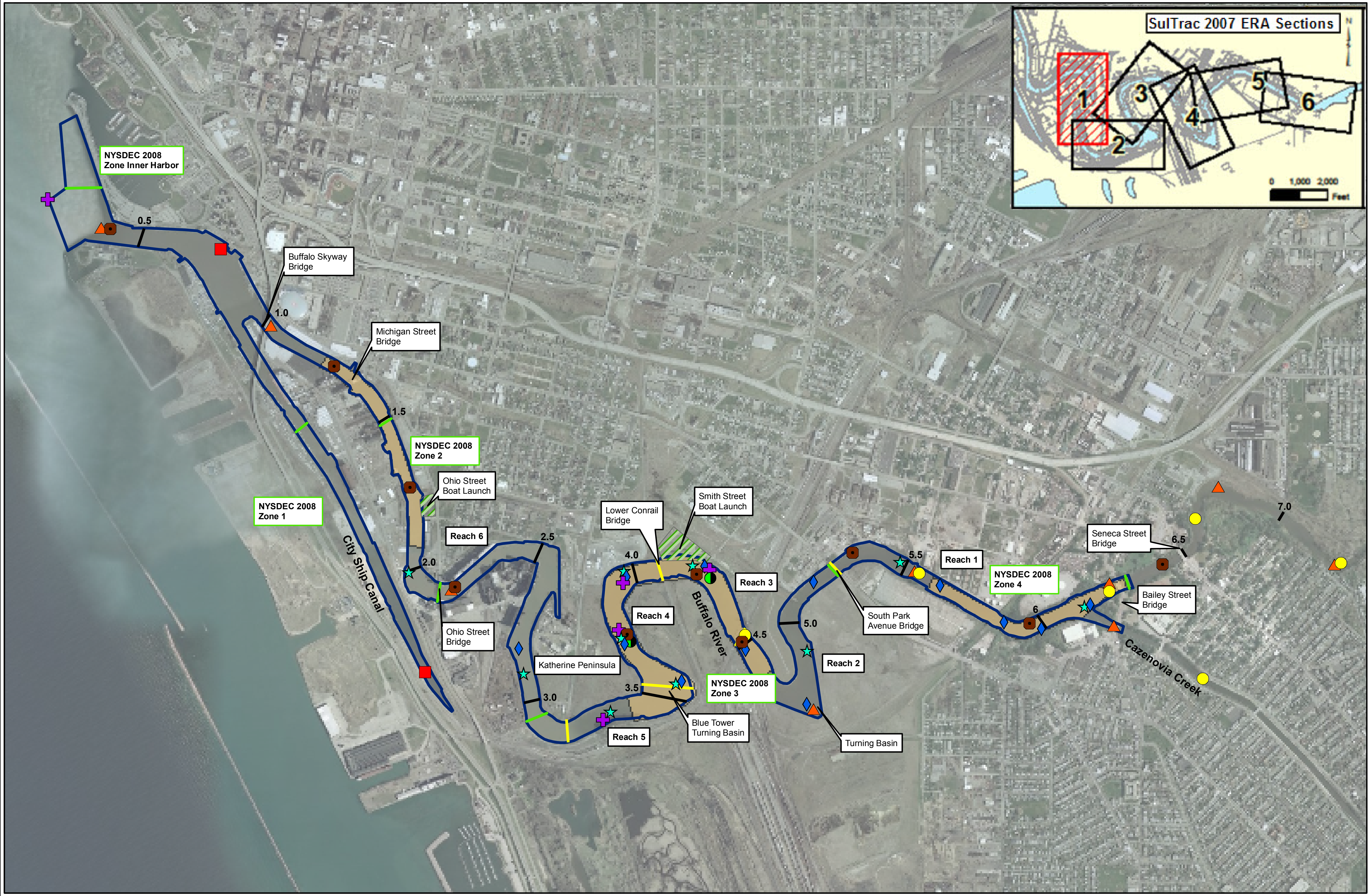
Hepatocellular Carcinoma (40x objective)

Trematode Inside Bile Duct (40x objective)



Small, Discrete, Reactive/Inflammatory Focus (40x objective)

ENVIRON MACTEC	**Fish Histopathology Illustrations**	**Figure 4-5c**



Legend

- Buffalo River Boundary Area of Concern
- Brown Bullhead Assessment Zones
- NYSDEC 2008 (fish collection zones)
- Boat Launch Areas
- AOC Reaches
- Mile Mark Designations

Historic Sampling Locations

- ENV-INV (BR01 - BR08, CC01)
- ENV-FISH (BR1 - BR5, CC1)
- ENV-PAH TU > 1 2008 (plotted if TU>1)
- ENV-SEM-AVS
- NYSDEC 2008 (ASci toxicity testing)
- NYSDEC 2006 (ASci toxicity testing)
- Irvine et al. 2005 (fish and benthic locations)
- Diggings and Snyder 2003

Notes:
Historic sample locations are approximate.

SEM-AVS: Simultaneously extracted metals - Acid Volatile Sulfides
INV: Invertebrate
ENV: ENVIRON
TU: Toxic Unit
NYSDEC: New York State Department of Environmental Conservation

0 0.2 0.4 0.8
Miles
N

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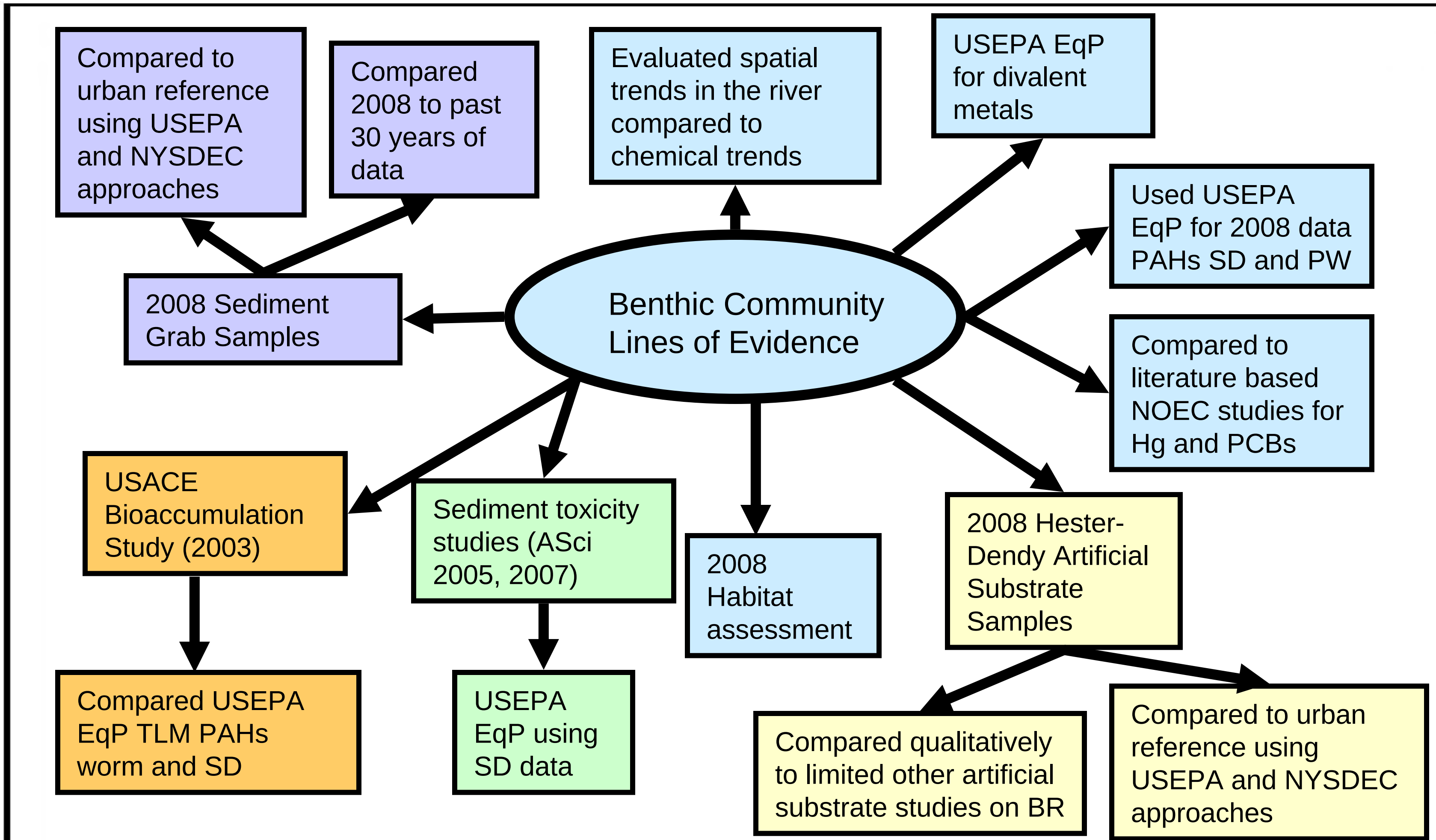
ECOLOGICAL STUDY MAP
BUFFALO RIVER, NY

Figure 5-1

Drafter: B. Radakovich
Date: 01/07/2009
File Name: 20090112_EcologicalIndicators.mxd



TU Toxic units
EqP Equilibrium partitioning
TLM Target lipid model
ERA Ecological risk assessment

NOEC No effect concentration
PAH Polycyclic aromatic hydrocarbons
USEPA US Environmental Protection Agency
USACE US Corps of Engineers

SD Sediment
PW Pore water

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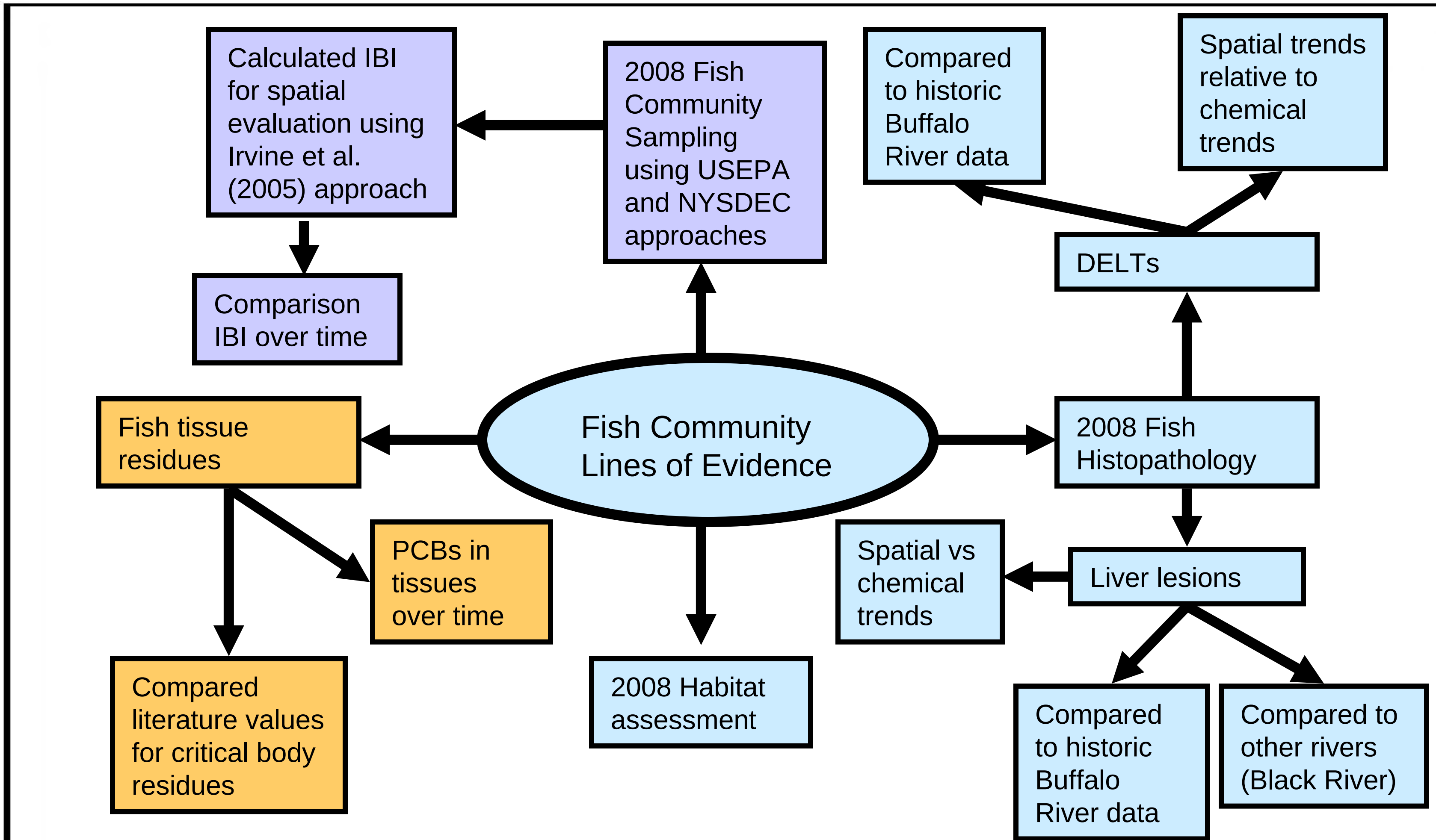
Benthic Community Lines of Evidence That Inform the Feasibility Study of the Buffalo River

Figure 5-2a



IBI	Index of Biological Integrity
DELTs	Deformities, eroded fins, and tumors
NOEC	No effect concentration
PCB	Polychlorinated biphenyls
USEPA	US Environmental Protection Agency

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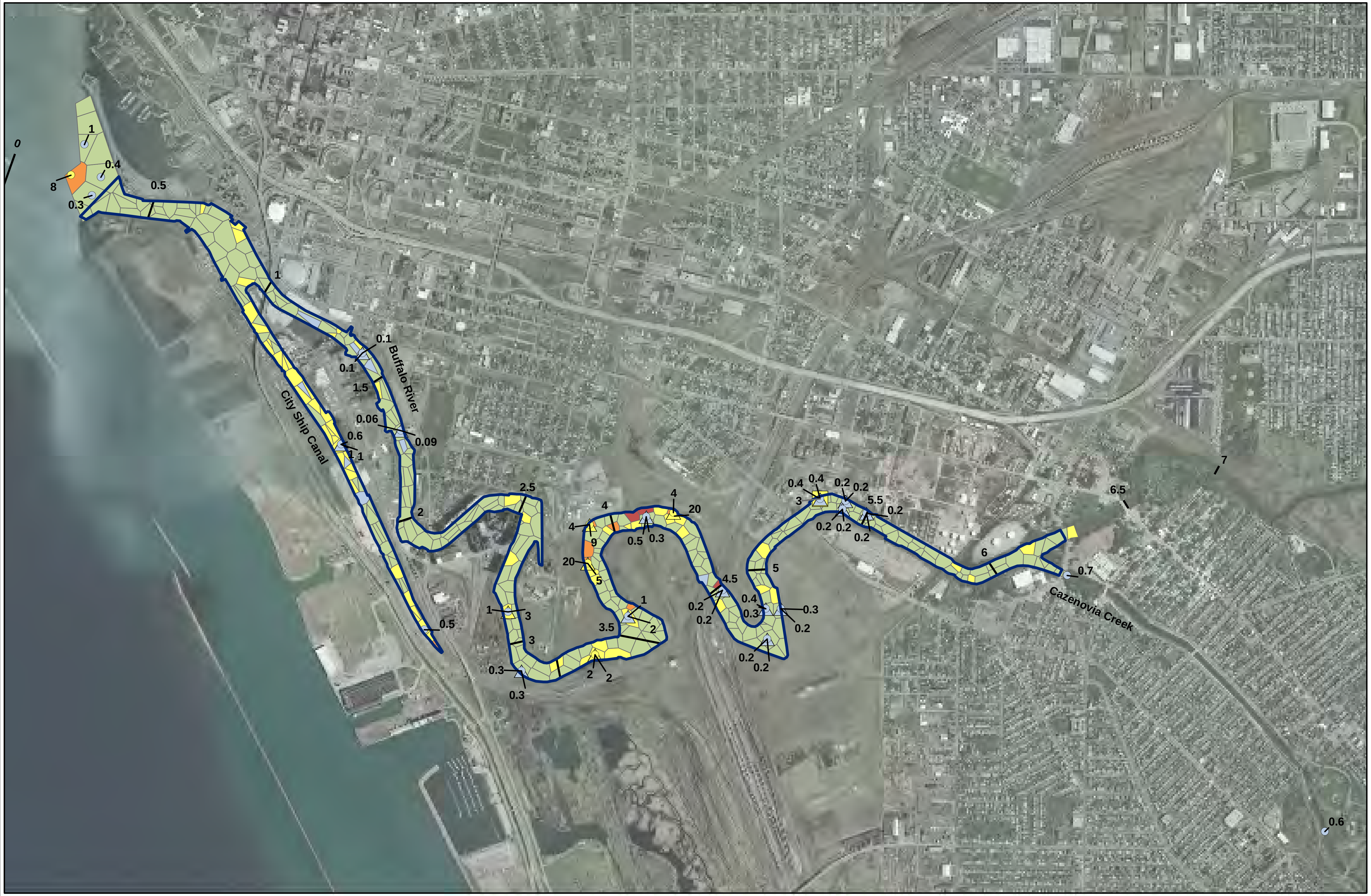
Fish Community Lines of Evidence That Inform the Feasibility Study of the Buffalo River

Figure 5-2b



Legend

Buffalo River Area of Concern

River Mile Segments

Toxic Unit Surface Sample Locations (0 - 0.5')

< = 1

> = 2

Toxic Unit Subsurface Sample Locations (0.5 - 1')

< = 1

> = 2

Toxic Unit Subsurface Sample Locations (2 - 3')

> = 2

Total PAH Surface Concentrations Thiessen Polygons mg/kg

< 1.0

1.0 - 10

10 - 50

50 - 100

> 100

A TU value exceeding 1 indicates the potential for toxicity to benthic organisms.

0 0.2 0.4 0.8

Miles

N

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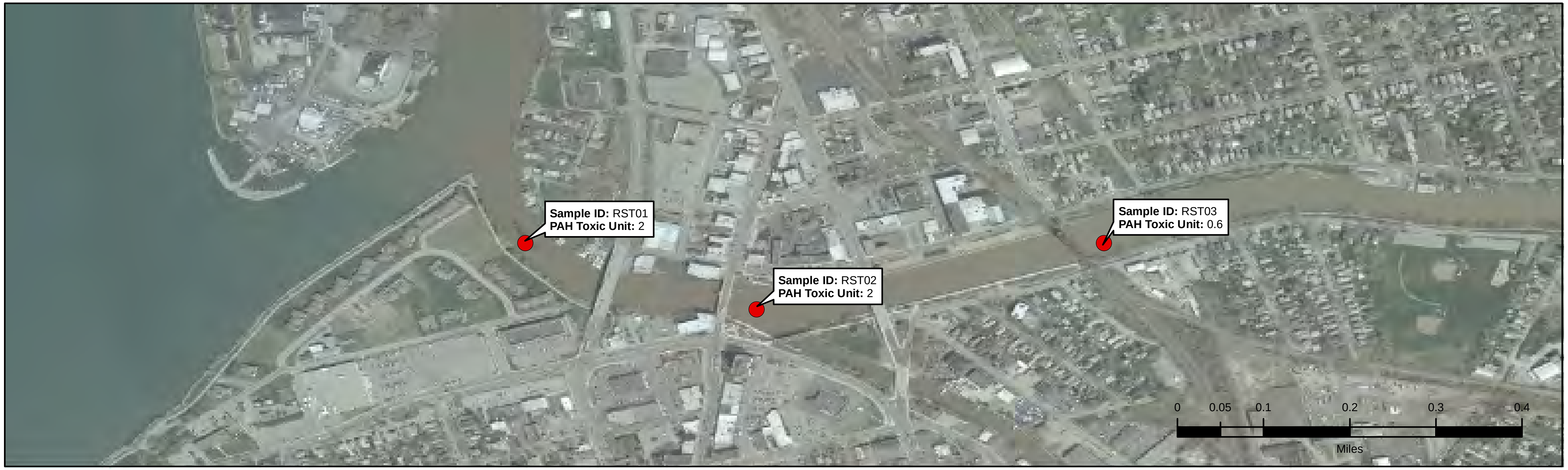
TOTAL PAH CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS, THIESSEN POLYGON ANALYSIS AND EVALUATION OF PAH TOXIC UNITS IN BUFFALO RIVER SEDIMENT BUFFALO RIVER, NY

Figure 5-3a

Drafter: B. Radakovich
Contract Number:
File Name: 20090123_ToxicUnit_PAH_Thiessen.mxd

Tonawanda Creek



Cattaraugus Creek

Legend

● Benthic Community Assessment and Sediment Chemistry Sampling Locations

N

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PAH TOXIC UNITS AT CATTARAUGUS AND TONAWANDA CREEKS

Figure 5-3b

Drafter: B. Radakovich
Date: 01/09/2009
File Name: 20090109_Benthos_Reference_PAHToxic.mxd

Legend

- Buffalo River Area of Concern
- River Mile Segments
- SEM > AVS Surface Sample Locations (0 - 6")
- AVS > SEM Surface Sample Locations (0 - 6")
- SEM > AVS Subsurface Sample Locations (6 - 12")
- AVS > SEM Subsurface Sample Locations (6 - 12")

Lead Surface Concentrations Thiessen Polygons
mg/kg

- < 50
- 50 - 100
- 100 - 500
- 500 - 1,000
- > 1,000

AVS - Acid Volatile Sulfides

SEM - Simultaneously Extracted Metals

∑SEM = Sum of Metals (cadmium, copper, lead, mercury, nickel, and zinc)

Sum of Metals = Divalent metals cadmium, copper, lead, mercury, nickel, and zinc.

µmol/g - micromoles per gram dry sediment

foc - Fraction of organic carbon

In 89% of sediment samples (40 of 45 samples) AVS exceeds SEM indicating that toxicity due to divalent metals is very unlikely.

For sediment samples in which SEM minus AVS results in a negative number than AVS is in excess of SEM and toxicity due to divalent metals is very unlikely.

At locations where SEM minus AVS is positive (SEM > AVS) samples were further analyzed using an evaluation of OC-normalized excess metals (USEPA 2005):

Where [∑SEM-AVS]/foc < 130 µmol per gram – Toxicity unlikely
Where [∑SEM-AVS]/foc > 3,000 µmol per gram - Toxicity likely

0 0.2 0.4 0.8
Miles

N

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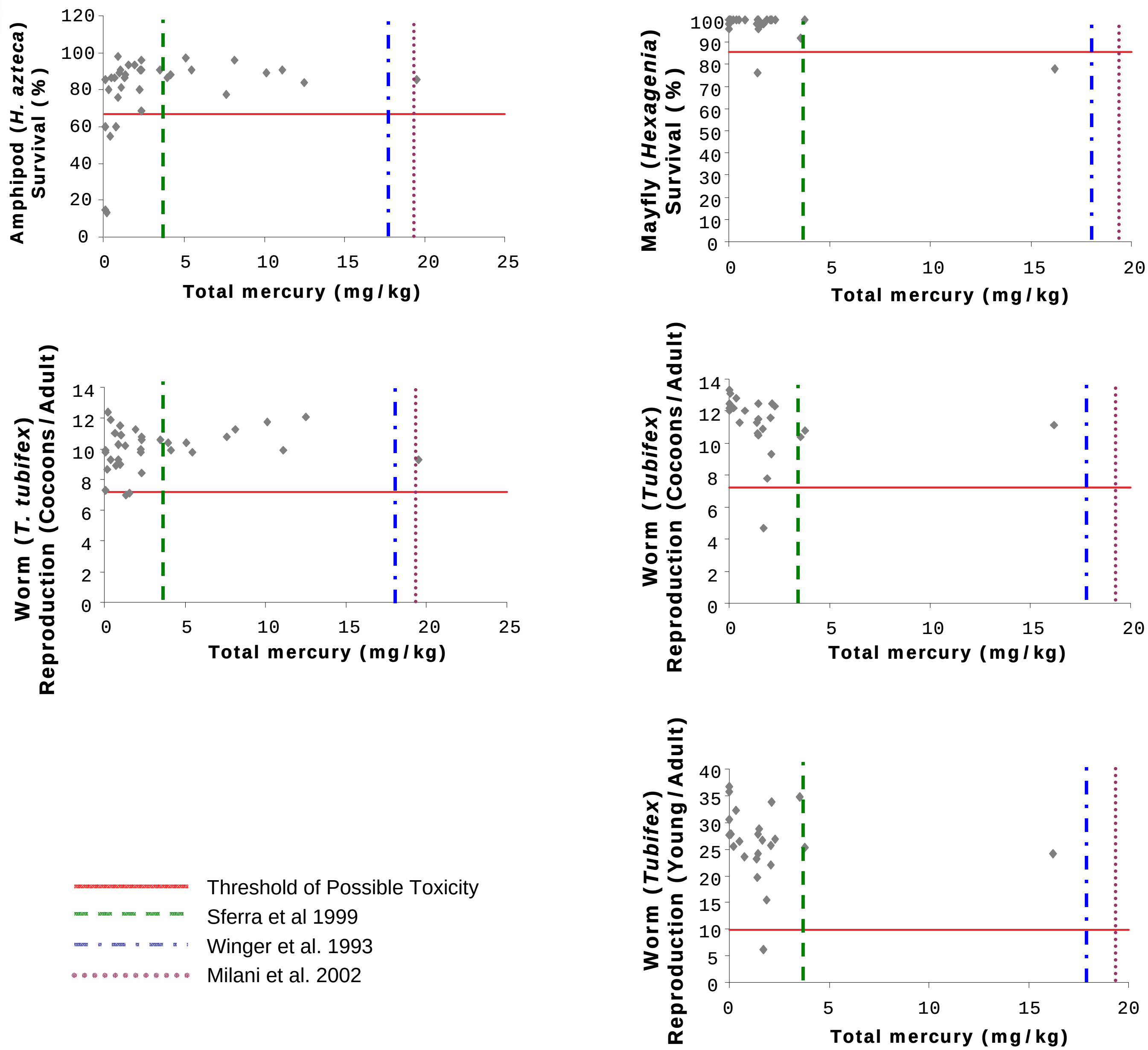
LEAD SURFACE CONCENTRATIONS FROM 2005/2007 AND 2008 SAMPLING EVENTS, THIESSEN POLYGON ANALYSIS AND EVALUATION OF ACID VOLATILE SULFIDES AND SIMULTANEOUSLY EXTRACTED METALS IN BUFFALO RIVER SEDIMENTS FROM 2008 SAMPLING EVENT
BUFFALO RIVER, NY

Figure 5-3c

Drafter: B. Radakovich
Contract Number:
File Name: 20090123_AVS_Gtr_SEM_PB_Thiessen.mxd

Data Source: Milani et al. (2002)

Data Source: Milani et al. (2007)



Mercury No Effect Sediment Concentrations for Benthic Invertebrates

Location	Species	Hg (mg/kg)	Reference
Calcasieu, LA	*Hyalella azteca*	4.1	Sferra et al. 1999
Brunswick, GA	*Hyalella azteca*	17.8 to 24.7	Winger et al. 1993
Peninsular Harbor, ONT	*Hyalella azteca*	19.5 to 22.6	Milani et al. 2002

Notes:

Toxicity threshold is based on regional reference data (Reynoldson and Day 1998).

% Percent mg/kg Milligram per Kilogram

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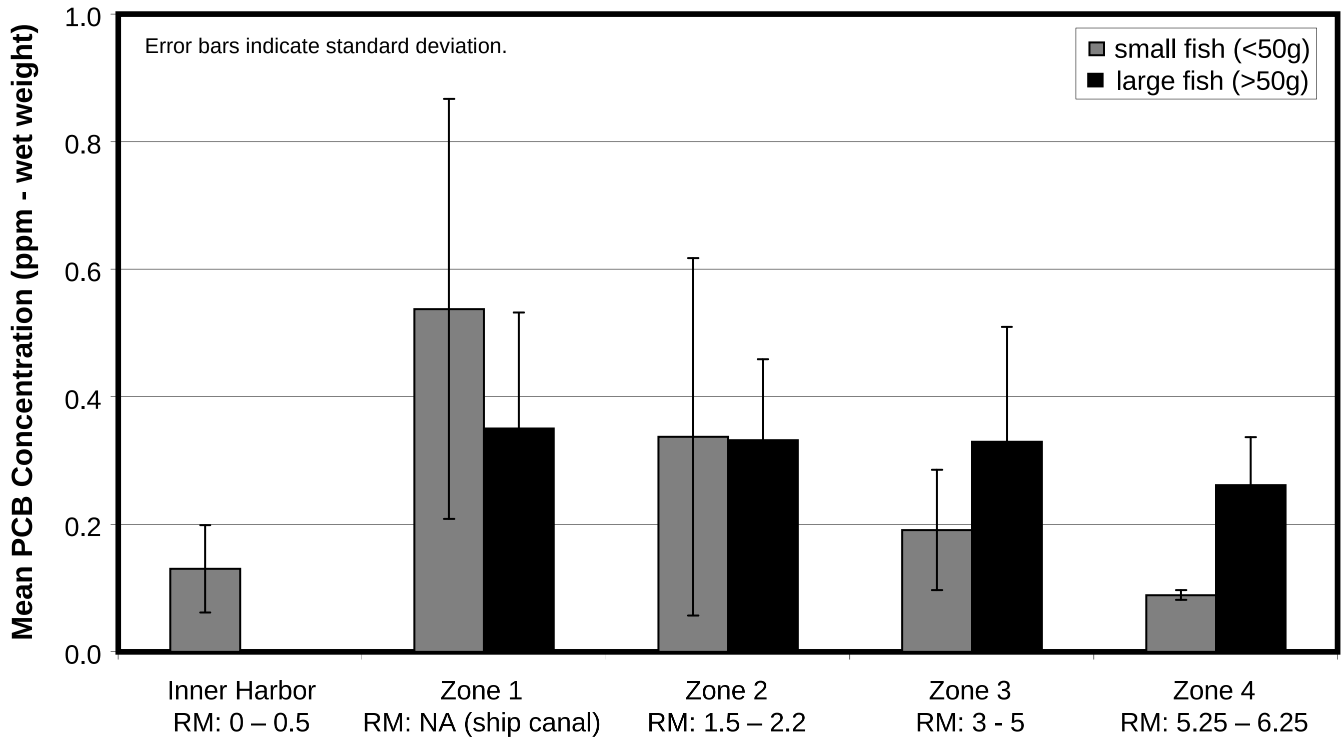
Examples of Mercury Effects in Freshwater Sediment: Peninsula Harbour and St. Clair River Toxicity Test Results

Figure 5-4



PCB No Effect Body Residues in Fish

Species	Exposure Media	PCB Type	No-Effect Concentration[a] (mg/kg wet weight)	Effect Endpoint	Reference
Eurasian minnow (*Phoxinus phoxinus*)	Food	Clophen A50	1.6	Larval survival	Bengtsson 1980
Sheepshead minnow (*Cyprinodon variegatus*)	Water	Aroclor 1254	1.9	Larval survival	Hansen et al. 1974
Mummichog (*Fundulus heteroclitus*)	Food	Aroclor 1268	14 to 15	Fecundity, fertilization success, hatch success, larval survival, juvenile weight,[b] sex ratios; 2 generation study	Matta et al. 2001
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1248	2.8 to 30.6[d]	Larval growth; 2 generation study	DeFoe et al. 1978
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1254	105	Fecundity[e]	Nebeker et al. 1974
Three-spined stickleback (*Gasterosteus aculeatus*)	Food	Clophen A50	289	Fecundity	Holm et al. 1993
Fathead minnow (*Pimephales promelas*)	Water	Aroclor 1260	350 to 567[d]	Larval survival and growth; 2 generation study	DeFoe et al. 1978

Notes:

a. PCB concentration in parental fish; concentration in females used if different than males.
b. Increased weight (growth) observed with PCB exposure; not an adverse effect.
c. Concentration converted from dry weight.
d. Concentrations presented graphically by DeFoe et al. (1978) and reported numerically by Jarvinen and Ankley (1999).
e. Control fish contained 1.1 mg/kg to 2.7 mg/kg Aroclor 1254.

g	Gram	NOEC	No Observable Effects Concentration
kg	Kilogram	PCB	Polychlorinated Biphenyl
mg	Milligram	ppm	Parts per Million
NA	Not Applicable	RM	River Mile

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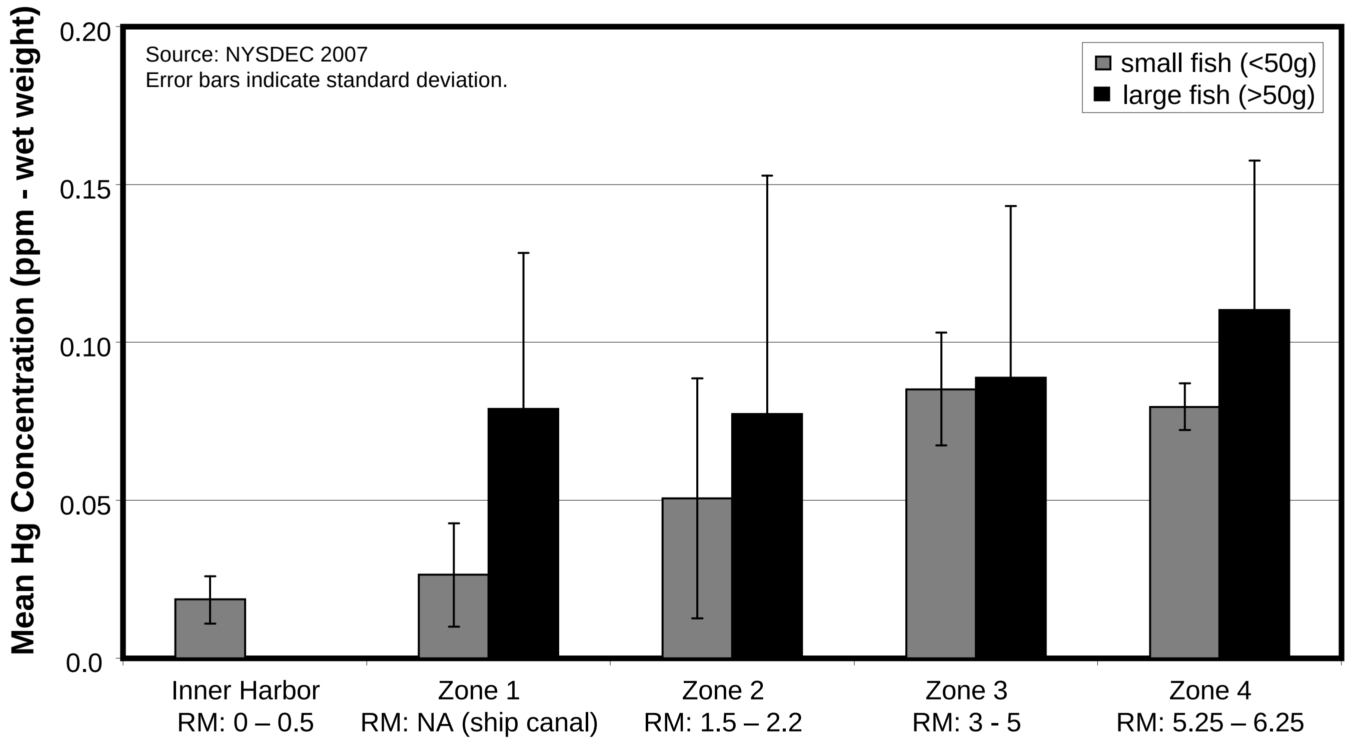
PCB Concentration in Fish Collected from the Buffalo River

Figure 5-5a



Methylmercury No Effect Body Residues in Fish
Buffalo, NY

Location	Species	Hg (mg/kg wet weight)	Reference
Ontario Lake Fish Residues	Walleye	0.75	Weiner and Spry 1996
	Northern pike	0.58	
	Large mouth bass	0.45	
	Small mouth bass	0.53	
	Small mouth bass	0.63	
Bioassay Control Residues	Fathead minnow	0.068	Sanderheinrich and Miller 2006
	Fathead minnow	0.079	Drevnick and Sanderheinrich 2003
Bioassay No Effect Residues	Brook trout	2.7[a]	McKim et al 1976
	Rainbow trout	30[b]	Wobeser 1975
	Killifish	0.2[b]	Matta et al. 2001
	Fathead minnow	12.6[b]	Olson et al. 1975

Notes:
(a) 3-generation reproduction
(b) Survival

g	Gram	NA	Not Applicable
Hg	Mercury	NYSDEC	New York State Department of Environmental Conservation
Kg	Kilogram	NOEC	No Observable Effects Concentration
LMB	Largemouth Bass	ppm	Parts per Million
MeHg/kg	Methylmercury per Kilogram	SMB	Smallmouth Bass
mg	Milligram	RM	River Mile

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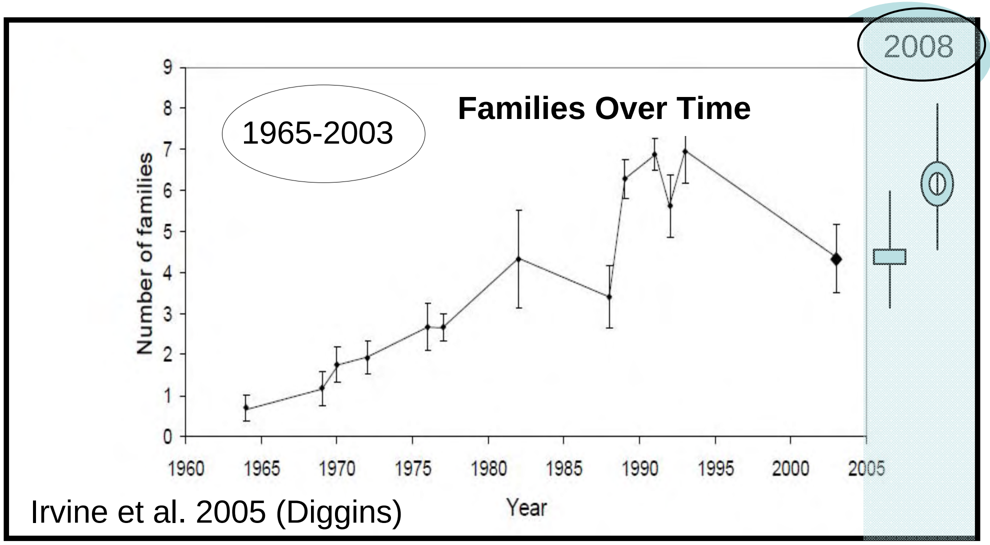
Mercury Concentrations in Fish Collected from the Buffalo River

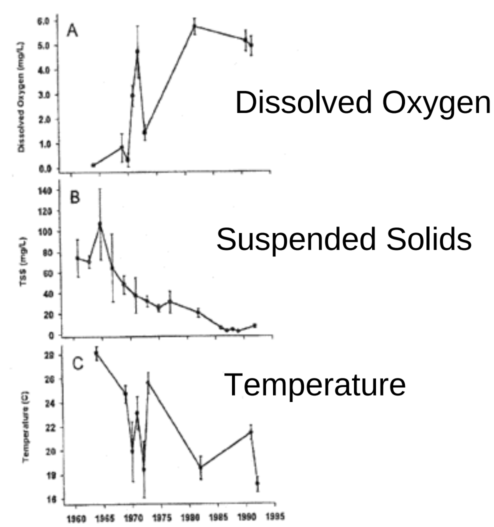
Figure 5-5b



Irvine et al. 2005 (Diggins)

2008 Sediment grab sample results (mean and standard deviation; refer to Figure 4-2e for location specific results). It is noted that the historic data are presented as sediment grab sample families, so this comparison is applicable to historic results. 2008 study findings show that conditions were similar in 2008 compared to the 2003/4 study.

2008 Hester-dendy sampling results (mean and standard deviation; refer to Figure 4-2e for location-specific results). It is noted that these results are not directly comparable to the historic trends. However, this comparison does show a context for potential observations of greater family diversity when other sampling methods are considered.



1965-1995 per Diggins and Snyder 2003

Source: According to Diggins and Snyder (2003), some of the early benthic community improvements were due to increases in water quality metrics, such as DO, temp., and solids.

Comparison of Benthic Invertebrate Families Over Time

Figure 5-6