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General Electric (GE) Housatonic River Project
Pittsfield, Massachusetts

Contract No. DACW33-94-D-0009

FINAL

SUPPLEMENTAL INVESTIGATION WORK PLAN FOR THE LOWER HOUSATONIC RIVER

VOLUME I - TEXT AND FIGURES

Task Order No. 0032

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FINAL

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FOR THE LOWER HOUSATONIC RIVER

GENERAL ELECTRIC (GE) HOUSATONIC RIVER PROJECT
PITTSFIELD, MASSACHUSETTS

Text and Figures

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Prepared for

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22 February 2000

W.O. No. 10971-032-002-0149

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%RSD	percent relative standard deviation
µm	micrometer
µm	microns
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
ACO	Administrative Consent Order
ADCP	Acoustic Doppler Current Profiler
ADDs	average daily doses
AF	adherence factor
AFDW	ash-free dry weight
Ah-R	Ah-receptor
AhR	aryl hydrocarbon receptor
ANCOVA	analysis of covariance
ANOVA	analysis of variance
APHA	American Public Health Association
ARARs	applicable or relevant and appropriate requirements
ARCS	Assessment and Remediation of Contaminated Sediment
ASTM	American Society for Testing and Materials
ASTs	aboveground storage tanks
ATc	carcinogenic averaging time
ATn	noncarcinogenic averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BACT	Best Available Control Technology
BAT	best available technology
BEST	Biomonitoring of Environmental Status and Trends
bgs	below ground surface
BHC	benzene hexachloride
BHHRA	baseline human health risk assessment
BOD	biochemical oxygen demand
BOD_5	five-day biochemical oxygen demand
BROD	benzyloxyresorufin O-deethylase
BSA	bovine serum albumin
BW	body weight
CCC	criteria continuous concentration
CCDF	complementary cumulative distribution function

LIST OF ACRONYMS (Continued)

CDDs	chlorodibenzo-p-dioxins
CDF	Confined Disposal Facility
CDFs	chlorodibenzofurans
CPDFs	cumulative probability density functions
CERC	Columbia Environmental Research Center
cfm	cubic feet per minute
CFR	Code of Federal Regulations
cfs	cubic ft per second
CMC	criterion maximum concentration
CMS	Corrective Measures Study
COD	chemical oxygen demand
COPCs	contaminants of potential concern
CPA	Comprehensive Plan Application
CSF	cancer slope factor
CT	central tendency
CTDEP	Connecticut Department of Environmental Protection
CTE	central tendency exposure
CWA	Clean Water Act
d	day
dbh	diameter at breast height
DELTs	deformities, erosion, lesions, and tumors
DEM	digital elevation model
DGPS	differential GPS
DO	dissolved oxygen
DOJ	Department of Justice
DOM	dissolved organic matter
DOT	U.S. Department of Transportation
DQCR	Data and Quality Control Report
DQOs	data quality objectives
DRE	dioxin responsive elements
ECD	electron capture detector
ECOD	ethoxycoumarin O-deethylase
ED	exposure duration
EDTA	ethylene diamine tetra-acetate
EE/CA	Engineering Evaluation/Cost Analysis

LIST OF ACRONYMS (Continued)

EF	exposure frequency
EFDC	Environmental Fluid Dynamics Code
EO	element occurrence
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
EqP	equilibrium-partitioning approach
ERA	Ecological Risk Assessment
ER-L	effects range - low
ER-M	effects range - median
EROD	ethoxyresorufin O-deethylase
FCV	final chronic value
FSP	Field Sampling Plan
GC/HRMS	gas chromatography/high-resolution mass spectrometry
GE	General Electric Company
g-EQ	gram-equivalents
GERG	Geotechnical and Environmental Research Group
GI	gastrointestinal
GIS	Geographic Information System
GLNPO	Great Lakes National Program Office
GLP	Good Laboratory Practice
gpm	gallons per minute
GPS	global positioning system
HAP	Hazardous Air Pollutant
HASP	Health and Safety Plan
HBI	Hisenhoff Biotic Index
HCB	hexachlorobenzene
HClO4	perchloric acid
HEAST	Health Effects Assessment Summary Tables
HIs	hazard indices
H_O	null hypothesis
HP-GPC	high-pressure gel permeation chromatography
HP-PGC	high-performance porous graphitic carbon chromatography
HQs	hazard quotients
HSDB	Hazardous Substances Data Bank
HSPF	Hydrologic Simulation Program-Fortran

LIST OF ACRONYMS (Continued)

HVWMA	Housatonic River Valley State Wildlife Management Area
IDW	Inverse Distance Weighting
IMPGs	Interim Media Protection Goals
IRIS	Integrated Risk Information System
IRS	soil and sediment ingestion rates
km^2	square kilometers
KS	Kolmogorov-Smirnov
L	liters
LADDs	lifetime average daily doses
LD50	median values for mortality
LEL	lowest-effect level
LGP	low ground pressure
LHRH	luteinizing hormone releasing hormone
LMS	Lawler, Matusky & Skelly
LOAEL	lowest-observed-adverse effect level
LOECs	lowest observable effect concentrations
LOEL	lowest observable effect level
LPA	Limited Plan Application
LPIL	lowest practical identification level
LSD	least-significant difference
m^2	square meters
m^3/d	cubic meters of air per day
mAb	monoclonal antibody
MADEP	Massachusetts Department of Environmental Protection
MADFW	MA Division of Fisheries and Wildlife
MATCs	Maximum Allowable Tissue Concentrations
MCL	maximum contaminant level
MFD	Modeling Framework Design
MFO	mixed-function oxygenase
mg/kg-day	milligrams of chemical per kilogram of body weight per day
mg/m^3	milligrams of chemical per cubic meter of air
MNAP	Maine Natural Areas Program
MNHESP	Massachusetts Natural Heritage and Endangered Species Program
MS/MSD	matrix spike/matrix spike duplicate
MSU	Michigan State University

LIST OF ACRONYMS (Continued)

MWRC	Massachusetts Water Resources Commission
NAAQS	National Ambient Air Quality Standards
NAPLs	nonaqueous phase liquids
NCEA	National Center for Environmental Assessment
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed-adverse-effect level
NPDES	National Pollution Discharge Elimination System
NSPS	New Source Performance Standards
OC	organochlorine
OMEE	Ontario Ministry of Environment and Energy
ORP	oxidation-reduction potential
PAB	palustrine aquatic bed
PACF	Patuxent Analytical Control Facility
PBS	phosphate-buffered saline
PCB	polychlorinated biphenyl
PCDDs	polychlorinated dibenzo-p-dioxins
PCDEs	polychlorinated diphenyl ethers
PCDFs	polychlorinated dibenzofurans
PCNs	polychlorinated naphthalenes
PDFs	probability density functions
PEM	palustrine emergent marsh
PFO1	palustrine forested broad-leafed deciduous
PHHs	planar halogenated hydrocarbons
PM	polyethylene membranes
POC	particulate organic carbon
POTW	publicly owned treatment works
PRG	Preliminary Remediation Goal
PROD	pentoxyresorufin O-deethylase
PSD	Prevention of Significant Deterioration
psi	pounds per square inch
PSS1	broad-leaf deciduous
PUB	palustrine unconsolidated bottom
QA	quality assurance
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan

LIST OF ACRONYMS (Continued)

QC	Quality Control
RAB	riverine aquatic bed
RAGS	Risk Assessment Guidance for Superfund
RAs	risk assessments
RBCs	risk-based concentrations
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfDs	reference doses
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RIA	radioimmunoassay
RME	reasonable maximum exposure
RPD	relative percent difference
rpm	revolutions per minute
RTECS	Registry of Toxic Effects of Chemical Substances
RTVs	reference toxicity values
SA	surface area
SA/SG	Sulfuric Acid/Silica Gel
SD	Standard Deviations
SECs	Sediment Effect Concentrations
SEL	severe-effect level
SI	Supplemental Investigation
SIWP	Supplemental Investigation Work Plan
SMDPs	scientific/management decision points
SOPs	standard operating procedures
SQGs	sediment quality guidelines
SRBCs	screening risk-based concentrations
ST	Soil Technology
START	Superfund Technical Assistance and Response Team
SVL	snout to vent length
SVOCs	semivolatile organic compounds
T&E	threatened or endangered
TBD	To be determined
TDS	total dissolved solids
TdT	terminal deoxynucleotidyl transferase

LIST OF ACRONYMS
(Continued)

TEFs	toxic equivalency factors
TEQ	toxic equivalence
TIE	toxicity identification evaluation
TOC	total organic carbon
TOM	total organic matter
tPCB	total PCB
tpy	tons per year
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UCL	upper confidence limit
UMESC	Upper Midwest Environmental Sciences Center
URF	unit risk factor
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USTs	underground storage tanks
VOA	volatile organic analysis
VOCs	volatile organic compounds
WESTON	Roy F. Weston, Inc.
WHO	World Health Organization
WMA	Wildlife Management Area
WOE	weight-of-evidence
WQC	water quality criteria
WWTP	wastewater treatment plant

1. INTRODUCTION

The General Electric (GE) Pittsfield Housatonic River site consists of the 254-acre GE manufacturing facility; the Housatonic River and associated riverbanks and floodplains from Pittsfield, MA, to Rising Pond Dam (approximately 30 miles); former river oxbows that have been filled; neighboring commercial properties; Allendale School; Silver Lake; and other properties or areas that have become contaminated as a result of GE's facility operations. Figure 1-1 depicts the general GE facility site area in Pittsfield. Figure 1-2 is the site location map, which shows the area from the GE site to the Massachusetts-Connecticut border.

Hazardous substances potentially associated with the site include polychlorinated biphenyls (PCBs), dioxins/furans, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and inorganic constituents.

This Supplemental Investigation Work Plan (SIWP) has been prepared for the Lower Reach of the Housatonic River ("Rest of River"). The "Rest of River" is the portion of the river from the confluence of the East and West Branches of the Housatonic River (the confluence) to the Massachusetts state line, a distance of approximately 50 miles, and beyond into Connecticut. In addition to the river proper, the Rest of River includes its associated riverbanks and floodplains. The Rest of River is further defined in the Consent Decree (00-0388, 00-0389, 00-0390) lodged with the U.S. District Court, Massachusetts, in October 1999. The Rest of River includes areas of the River and its sediments and floodplain (except for Actual/Potential Lawns), at which waste materials originating at the GE Plant Area have come to be located. These reaches may extend through Connecticut to Long Island Sound. The principal initial focus of the Work Plan is the section of the river from the confluence to the Woods Pond Dam, a distance of approximately 10 miles.

Under U.S. Army Corps of Engineers (USACE) Contract No. DACW33-94-D-0009, Roy F. Weston, Inc. (WESTON®) was issued Task Order No. 32 to prepare a SIWP for the Lower River. This document details the Work Plan rationale and tasks performed under this task order and EPA Contract 68-W7-0026, Work Assignment No. 33.

1.1 OBJECTIVES

The main objectives of the Supplemental Investigation (SI) are as follows:

- Provide surface water, hydrology, and sediment data to support the development of a site-specific hydrodynamic model.
- Characterize and sample biological media and ecological communities to support human health and ecological risk assessments.
- Acquire sufficient information to compare soil and sediment concentrations against screening risk-based concentrations.
- Develop site-specific human health and ecological risk assessments (RAs) for the Lower River.
- Define the nature and extent of the soil and sediment contamination in the Lower River and associated floodplain by PCBs and other contaminants and further delineate pathways of contaminant migration to support the above objectives.

An evaluation of the current set of data available for the Lower River is also presented within this SIWP. The evaluation includes a summary of available data from previous reports and a review of data quality and usability. The data evaluation provides the information required to identify potential data gaps due to the distribution of samples, the quality of the analytical data, and the completeness of analytes tested.

An iterative approach to the sampling program will be used whenever possible to improve the efficiency and effectiveness of the investigative programs. A review of available data with preliminary data from the studies will be used to modify ongoing activities to better address data quality objectives.

1.2 REGULATORY FRAMEWORK

The GE Housatonic River site has been subject to regulatory investigations dating back to the late 1970s. These investigations were consolidated under two regulatory mechanisms: an Administrative Consent Order (ACO) with the Massachusetts Department of Environmental Protection (MADEP) and a Corrective Action Permit with the U.S. Environmental Protection Agency (EPA) under the Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA).

In 1991, EPA issued a RCRA Corrective Action Permit to the GE-Pittsfield facility. Following an appeal and subsequent modification, the permit was reissued in 1994. The permit included the 254-acre facility, Silver Lake, the Housatonic River and its floodplains and adjacent wetlands, and all sediments contaminated by PCBs migrating from the GE facility.

In addition to the permit, the ACO between GE and MADEP became effective in 1990 and included those areas defined in the permit as well as three additional study areas: Newell Street Area I, the Former Housatonic River Oxbows, and the Allendale School Property. Under the ACO, GE has performed several investigations and short-term cleanups.

In September 1998, representatives of EPA, MADEP, U.S. Department of Justice (DOJ), Connecticut Department of Environmental Protection (CTDEP), the City of Pittsfield, GE, and others reached a comprehensive agreement relating to GE's Pittsfield facility and the Housatonic River. This agreement provides for the investigation and cleanup of the Housatonic River and associated areas. In addition, the agreement provides for the cleanup and economic redevelopment of the GE facility, environmental restoration of the Housatonic River, compensation for natural resource damages, and government recovery of past and future response costs.

Under the scope of the agreement, EPA will conduct additional characterization sampling to determine the nature and extent of contamination, as well as to support the conduct of human health and ecological risk assessments, and surface water modeling.

The agreement includes the following actions for the Lower River:

- EPA/MADEP to conduct additional sampling, human health and ecological risk assessments, and modeling, and will submit both risk assessments and modeling for peer review.
- GE to compile all data into a RCRA Facility Investigation (RFI) report and a Corrective Measures Study (CMS).
- The governments intend to submit drafts of major technical documents to the Citizens Coordinating Council for review and discussion.
- At the conclusion of the studies, EPA will issue a Statement of Basis and modify the RCRA permit.

- GE agrees to perform cleanup unless it invokes dispute resolution:
  - Review process can include both internal EPA and federal court review.
  - During dispute resolution, all work not subject to the dispute continues, and EPA can proceed with designing disputed aspects of cleanup.
- GE to perform cleanup as determined after dispute resolution.

This agreement was codified in a Consent Decree (00-0388, 00-0389, 00-0390) lodged in U.S. District Court, Massachusetts, Western Division, in October 1999.

This Work Plan describes the activities that EPA will be conducting as its SI to support and complete the human health and ecological risk assessments and modeling. The SI will incorporate information developed from previous investigations and remediation activities under other regulatory programs, as well as other new or pertinent information to fill existing data gaps.

1.3 PLANNING DOCUMENTS

The SI activities will be conducted in accordance with project-wide and site-specific planning documents, which have either been developed or are in the process of being developed. These planning documents include the following:

- Project Field Sampling Plan (FSP) (00-0334).
- Project Quality Assurance Project Plan (QAPP) (00-0458).
- Project Health and Safety Plan (HASP) (00-0313).
- Preliminary Work Plan for OU 2 Housatonic River (02-0161).
- Final Work Plan for Engineering Evaluation/Cost Analysis (EE/CA) (07-0001).
- Site-Specific Addenda.

Addenda specific to the project planning documents will be prepared as needed to address specific activities proposed for the Lower River. The Site-Specific Health and Safety Plan is being submitted as a separate deliverable. The scope and methodology of the SI are prepared in accordance with CERCLA and RCRA requirements and related guidance.

1.4 REPORT OVERVIEW

The Lower River is a complex hydrological system with many different adjoining land uses and numerous ecological habitats and receptors. This SI is designed to provide a logical approach to characterizing this large area and evaluating potential human health and ecological risk from site contaminants that have been transported to the area from the GE site. The following section descriptions are provided to assist the reader in understanding the overall SI approach and in locating specific topics of interest.

Section 2 – Background and Environmental Setting

This section provides:

- An overview of the site history of the GE Pittsfield facility, its operations, and the surrounding area (Subsection 2.1).
- A brief description of the hydrogeologic setting (Subsection 2.2).
- A description of the physical and ecological characteristics of the Housatonic River between Dalton, MA, and the Massachusetts-Connecticut state line (Subsection 2.3).

Section 3 – Initial Evaluation of Existing Information

This section provides:

- A description of the contaminant source areas and the contaminants of potential concern (Subsection 3.1).
- A discussion of contaminant migration pathways (Subsection 3.2).
- A detailed summary of previous investigations and contaminant concentrations in sediments, riverbanks, floodplain soils, and water (Subsection 3.3).
- A list of chemical-specific, location-specific, and action-specific applicable or relevant and appropriate requirements (ARARs) (Subsection 3.4).
- A brief overview of potential remedial technologies (Subsection 3.5).

Section 4 – Work Plan Rationale

This section provides:

- A reiteration of the objectives of the SI (Subsection 4.1).
- An overview of data requirements (Subsection 4.2).
- A discussion of the Data Quality Objectives (Subsection 4.3).
- A discussion of the data management system (Subsection 4.4).

Section 5 – Field Investigation Tasks

This section provides a description of the planned field investigations intended to support the overall objectives of the SI. It provides:

- A brief description of the source area (Subsection 5.1).
- A detailed description of the proposed sediment and soil sampling program (Subsection 5.2).
- A detailed description of the proposed water quality sampling program (Subsection 5.3).
- An overview of the air sampling program (Subsection 5.4).
- A discussion of each of the proposed biological investigations (Subsection 5.5).

Section 6 – Human Health Risk Assessment

This section describes the approach for evaluating potential human health risks from various exposure scenarios through all impacted media. It provides:

- An introduction to the risk assessment process as well as a summary of recent risk assessment activities in the Upper Reach area (defined as the portion of the river from the GE facility to the confluence) (Subsection 6.1).
- A description of the site screening approach (Subsection 6.2).
- A description of the hazard identification process (Subsection 6.3.2).
- A review of the approach to establishing toxicity criteria (Subsection 6.3.3).
- A discussion of the approach to the exposure assessment including the conceptual site model, development of potential current and future scenarios of human exposure, and the methodology for the calculation of exposure point concentrations (Subsection 6.3.4).
- An overview of the risk characterization (Subsection 6.3.5).

- A brief discussion of the approach to evaluating and dealing with uncertainties in the process (Subsection 6.3.6).

Section 7 – Ecological Risk Assessment

This section describes the approach for evaluating potential risk to ecological receptors in the Lower River. It provides:

- An introduction to the approach of the ecological risk assessment (Subsection 7.1).
- A detailed discussion of the problem formulation stage in which the objectives of the ecological risk assessment are presented (Subsection 7.2).
- A description of the approach to the technical evaluation of the data in the analysis phase (Subsection 7.3).
- An overview of the risk characterization phase of the ecological risk assessment (Subsection 7.4).

Section 8 – Supplemental Investigation Report

This section provides the general report outline for the SI and human health and ecological risk assessments.

Section 9 – Schedule

This section presents the proposed project schedule.

Section 10 – References

This section contains references from all sections of the report.

Figures are provided in this volume, and the appendices are provided in a separate volume.

Maps showing historical sample locations and posted analytical results are also provided with this Work Plan in Appendix D.

1.5 ROLES AND RESPONSIBILITIES

The project team for the SI is composed of an interdisciplinary team of several government agencies, WESTON, other contractors, and subcontractors. Table 1-1 summarizes the entity and its respective role/responsibility as currently identified. Subcontractors to WESTON are noted.

Table 1-1

Roles and Responsibilities

Entity	Role/Responsibility
Avatar Environmental LLC*	Human Health and Ecological Risk Assessment leads.
Massachusetts Division of Fisheries and Wildlife	Waterfowl collection.
U.S. Geological Survey (Biological Services Division)	Ecological studies including tree swallow study (Custer) and fish health and toxicity studies (Tillitt).
U.S. Fish and Wildlife Service	Fish sampling and all tissue analysis.
U.S. Army Corps of Engineers Waterways Experiment Station	Peer review of hydrodynamic model.
WESTON	Supplemental Investigation lead, overall project coordination, technical input to hydrodynamic model input parameters, provide review of model output.
Woodlot Alternatives, Inc.*	Ecological studies including herpetological studies, vegetative studies, habitat assessments, wading and forest bird surveys, mussel study, waterfowl study, mammal surveys, vernal pool study.
ZZ Consulting LLC*	Technical direction and coordination of hydrodynamic model.
Dr. Richard Neves/Matthew Patterson* Virginia Cooperative Fish & Wildlife Research Unit	Technical direction of freshwater mussel study.
Dr. Doug Smith* University of Massachusetts	Provide historical information on mussel community.
Dr. Allen Burton* Wright State University	Sediment toxicity study.
Dr. Doug Fort* The Stover Group	Frog reproduction toxicity study.
Dr. Steven Bursian Dr. Richard Aulerich Michigan State University*	Mink toxicity study.

*Subcontracted to WESTON

2. BACKGROUND AND ENVIRONMENTAL SETTING

A brief summary of the background and physical characteristics of the site and Lower River is provided in the following subsections. Figure 1-2 presents the overall Lower River study area.

2.1 SITE HISTORY

The Housatonic River is located in the center of a rural area of western Massachusetts where farming was the main occupation from colonial settlement through the late 1800s. As with most rivers, the onset of the industrial revolution in the late 1800s brought manufacturing to the banks of the Housatonic River. The manufacture of paper and textiles began in Pittsfield and the area to the south during the late 19th century. The city's manufacturing base grew to include machinery and electrical transformers during the early 20th century (ChemRisk, 02-0166), when industries such as the Stanley Electric Company and the Berkshire Gas Company and its predecessors occupied portions of the property near the intersection of East Street and Merrill Road (Blasland, Bouck & Lee, Inc. [BBL] 01-0024). GE began its operations in its present location in 1903. Three manufacturing divisions have operated at the GE facility (Transformer, Ordnance, and Plastics) (01-0024).

The GE plant in Pittsfield has historically been the major handler of PCBs in western Massachusetts, and is the only known source of PCB wastes discovered in the Housatonic River sediments and floodplain between Pittsfield and Lenox. Although GE performed many functions at the Pittsfield facility throughout the years, the activities of the Transformer Division were the likely primary source of PCB contamination. Briefly, GE's Transformer Division's activities included the construction and repair of electrical transformers using dielectric fluids, some of which contained PCBs (primarily Aroclors 1254 and 1260). GE manufactured and serviced electrical transformers containing PCBs at this facility from approximately 1932 through 1977.

According to GE's reports, from 1932 through 1977 releases of PCBs reached the wastewater and storm systems associated with the facility and were subsequently conveyed to the East Branch of the Housatonic River and to Silver Lake (*Supplemental Phase II/RCRA Facility*

Investigation Report for Housatonic River and Silver Lake, Volume I, by BBL, January 1996; 04-0004).

During the 1940s, efforts to straighten the Pittsfield reach of the Housatonic River by the City of Pittsfield and the U.S. Army Corps of Engineers (USACE) resulted in 11 former oxbows being isolated from the river channel. These areas were filled with materials that were later discovered to contain PCBs and other hazardous substances. In 1968, a 1,000-gallon PCB storage tank located in Building 68 of the Pittsfield GE facility collapsed, releasing liquid Aroclor 1260 onto the riverbank soil and into the Housatonic River. Aroclor-contaminated soils and sediments were excavated by GE and eventually landfilled; however, significant contamination remains as a result of this release.

Areas of the 254-acre GE manufacturing facility; the Housatonic River, riverbanks, and associated floodplains from Pittsfield, MA, to Rising Pond Dam (approximately 30 miles); former river oxbows that have been filled; neighboring commercial properties; Allendale School; Silver Lake; and other properties or areas have become contaminated as a result of GE's facility operations.

Numerous studies conducted since 1988 have documented PCB contamination of soils within the floodplain of the Housatonic River downstream of the GE plant and former oxbows. Most of the floodplain soil PCB contamination (exceeding 1 ppm total PCBs) detected historically falls within the approximate extent of the river's 5-year floodplain (BBL, 04-0004). PCBs have also been detected in sediments as far as the Connecticut state line (BBL, 04-0007). PCB contamination downstream is believed to result from the redistribution by flooding of PCB wastes released from wastewater discharge, flooding of source areas by the Housatonic River, migration of nonaqueous phase liquids, direct discharge of PCB fluids from the Building 68 tank implosion, and groundwater discharge from the sources to the Housatonic River (BBL, 01-0147, 04-0007, 06-0001). In some cases, the contaminated soil is located on residential properties and within 200 ft of the residences on these properties. Other contaminated areas include parts of the Audubon Society's Canoe Meadows Wildlife Sanctuary and the Housatonic River Valley State Wildlife Management Area (HVWMA). The Housatonic River was closed to all but catch and release fishing from Dalton, MA, to the Connecticut border by MADEP in 1982 as a result of

PCB contamination in the river sediments and fish tissues. Concerns expressed by local residents regarding possible health effects resulting from exposure to PCB contamination are being investigated by the Massachusetts Department of Public Health.

Analyses of sediment samples collected upstream of the GE site reveal trace or non-detectable concentrations of Aroclor 1254 or 1260 (04-0007). Beginning at the confluence of Unkamet Brook and the Housatonic River, either Aroclor 1254, or 1260, or both, as well as other hazardous substances, have been detected in samples collected at the GE facility, and from within the sediments, banks, and floodplain of the Housatonic River (BBL, 01-0024, 01-0027, 05-0005, 06-0001; Geraghty & Miller, 05-0003). The highest concentrations of Aroclor 1254 and 1260 have been detected near the GE facility in the vicinity of the site, downstream of the former Building 68 PCB spill (01-0020, 01-0022, 01-0024).

The Housatonic River flowed through the City of Pittsfield in its natural state until the 1940s when the U.S. Army Corps of Engineers (USACE) channelized the river within the City of Pittsfield, isolating several oxbows (06-0001). From the 1940s until approximately the 1980s, these oxbows were backfilled with various materials (06-0001, 05-0005, 01-0027). In addition, the Massachusetts Department of Public Works undertook flood control work based on reports by USACE. Work within the site area included the East Branch within the City of Pittsfield, and the riverbanks above and below Woods Pond. The river's course is relatively unaffected (with the exception of the dams discussed below) in areas south of the city.

The many dams that are part of the historical development of the Housatonic River may have affected the downstream distribution of PCBs and other contaminants from the GE facility. Multiple dams were constructed on the Housatonic River as industrial development created a demand for water power, water supplies, and hydroelectric power. There are a total of 13 dams on the river in Massachusetts and 5 dams on the river in Connecticut (Connecticut Agricultural Experimentation Station, 02-0016). Between the confluence of the East and West Branches of the Housatonic River and the Connecticut state line, there are six dams as described below:

- One dam at Woods Pond in Lee, MA (known as the Valley Mill Dam) forms a 122-acre impoundment (including backwaters) and a wetland floodplain of bays, coves, and seasonal ponds several miles upstream of Woods Pond. This dam includes a head race canal with two water returns to the river, a gated outlet return, and a mill pond located between the head race canal and the second water return. The dam was used to generate hydroelectric power from approximately the mid 1800s through approximately 1920. Since 1920 the dam has been used to maintain a fire protection supply of water. The dam was recently rebuilt approximately 180 ft downstream from the old dam to ensure that PCB-contaminated sediments would not be released during a possible dam failure. Approximately a quarter-mile downstream of the Woods Pond Dam is the breached Niagra Mills Dam owned by Schweitzer Maduit.

- Two other small dams in Lee, the Columbia Mill Dam above the business district, and the Willow Mill Dam of the Mead Paper Company at the southern end of town. Also, the remains of two former dams, Eagle Mills (owned by Schweitzer Maduit) and Eaton Bikeman, were located between these two existing dams. These remnants were reported in 1975 (Massachusetts Water Resources Commission, 02-0007) but have not been observed during more recent investigations.

- One small dam in Stockbridge, the Glendale Dam (formerly the Monument Mills Dam No. 1), is being used to generate hydroelectric power. The gates for this dam were open for much of the 1970s, but the reservoir was refilled in 1981 and used during some periods since then for power generation. Downstream of the Glendale Dam is the breached Monument Mills Dam No. 2.

- One small dam at the northern end of Great Barrington at the Village of Housatonic. This dam is the former Monument Mills Dam No. 3.

- One dam at Rising Pond in the southern end of Great Barrington. The dam was built in 1900 and formed a 45-acre impoundment. The dam originally was used by the Rising Paper Company and contained a diversion that flowed under the paper mill and reentered the river below the dam (02-0016; 02-0007). Downstream of the Rising Pond Dam is the former Southern Berkshire Power and Electric Dam.

In response to population growth in Pittsfield, residential housing units were constructed on many river floodplain areas, which were formerly in use for agricultural production (02-0166).

2.2 HYDROGEOLOGIC SETTING

The current understanding of hydrogeologic conditions at the Lower River and the GE Housatonic River site in general has been derived from a review of regional geologic and hydrologic reports produced by the U.S. Geological Survey (USGS) and Massachusetts Water Resources Commission (MWRC) (02-0007 and Norvitch and Lamb, 99-0314), as well as from numerous engineering reports prepared by consulting firms for various portions of the GE facility and neighboring areas.

2.2.1 Overburden

Based on available information, groundwater in the overburden adjacent to the river is typically found in the alluvium within 5 to 10 ft of the ground surface under unconfined conditions. Overburden groundwater is not used for economic purposes in the vicinity of the site.

In general, groundwater flow in the overburden is toward the Housatonic River, which acts as the predominant groundwater discharge point for the region. Horizontal hydraulic gradients vary widely across the area adjacent to the river, within a range of two orders of magnitude, from approximately 0.1 to 0.001 ft. Groundwater flow direction and gradient in the overburden are impacted significantly on a local basis by the various groundwater remediation activities currently ongoing.

Numerous slug tests have been performed on monitoring wells, and several long-term pumping tests have been conducted at various locations near the site. The results of these tests indicate that the hydraulic conductivity of the overburden varies widely, ranging from approximately 1 x 10^{-6} cm/sec (0.003 ft/day) in the till to 2 x 10^{-2} cm/sec (57 ft/day) in the alluvium. In general, the hydraulic conductivity of the alluvium is two to three orders of magnitude greater than that of the till.

Vertical gradients in the overburden are typically upward in the area of the river and increase in magnitude close to the Housatonic River. This finding is consistent with the observation that the Housatonic River is the regional groundwater discharge point. A year-long vertical gradient assessment was conducted by GE and its contractors in the Unkamet Brook area (*MCP Interim Phase II Report and Current Assessment Summary for Unkamet Brook Area/U.S. EPA Area I;* 01-0021). The vertical gradients remained upward throughout the year, but small, local downward gradients can occur immediately adjacent to the Housatonic River in the shallow zone during flooding events. This temporary reversal was attributed to bank storage of surface water during floods.

2.2.2 Bedrock

Groundwater in the bedrock exists predominantly in fractures. Regional tectonic events have left the bedrock in the vicinity of the site somewhat fractured and faulted, providing an extensive network of pathways for groundwater movement and storage (fracture porosity). In addition, groundwater flow though the carbonate rocks of the Stockbridge Formation has enhanced the permeability and porosity of these rocks by dissolving the fracture faces (solution porosity).

Bedrock groundwater in the vicinity of the site is used for economic purposes. The Altresco facility, located adjacent to the GE site, uses four bedrock wells screened in the Stockbridge Formation to provide cooling water for its manufacturing process. Pumping rates for the four wells range from 150 gallons per minute (gpm) to 600 gpm, indicating the Stockbridge Formation can provide significant amounts of water. Although the Town of Pittsfield uses surface water reservoirs to supply the city with potable water, residents in outlying rural areas use the bedrock as a water source. The residential wells are typically several hundred feet deep, and tap the gneisses and schists underlying the upland areas. Yields for the residential wells are typically in the range of 5 to 10 gpm.

Because of the limited number of wells screened in the bedrock, little is known about groundwater flow directions or gradients in that zone. The overlying low-permeability till unit may act as a confining or semiconfining unit for the bedrock. No information is available regarding the transmissivity of the bedrock, although, from the well yield information discussed above, it is apparent that the Stockbridge Formation is significantly more transmissive than the surrounding schists and gneisses of the upland areas.

2.2.3 Groundwater-Surface Water Interaction

As indicated above, the Housatonic River is the predominant groundwater discharge point for the region. This means that most groundwater in the Housatonic River basin (which includes the GE facility) eventually discharges to the Housatonic River, either by direct subsurface flow through the river bottom sediments, or by discharging into smaller tributaries, such as Unkamet Brook, which then flow to the Housatonic River. The only groundwater in the Housatonic River basin that does not eventually reach the Housatonic River is groundwater that is lost to evapotranspiration, is removed by pumping, or leaves the drainage basin via underflow.

The main tributaries to the Housatonic River in the vicinity of the GE facility include Barton Brook, Brattle Brook, and Unkamet Brook. Other tributaries within Massachusetts include the East and West Branches of the Housatonic River, Hop Brook, Roaring Brook, Yokum Brook, Williams River, Sackett Brook, and Schenob Brook.

In addition to groundwater discharges to the Housatonic River, there are also industrial and municipal treatment plant discharges directly to the river (BBL, 04-0004). Several stormwater drain lines discharge from the GE facility, Silver Lake, and stormwater swales at former oxbows that discharge directly into the river. Municipal treatment plant discharges include the City of Pittsfield wastewater treatment plant (WWTP), which is located off Holmes Road. In the past, domestic sewage was discharged directly into the river (Massachusetts Water Resources Commission, 02-0007).

Although a gaining stream (one that receives groundwater inflow) over most of it length, the Housatonic River loses water locally in areas where it is dammed. The Woods Pond area of the river, located approximately 12 miles downstream of the GE facility, is such a location. The Woods Pond Dam tends to back up flow in the river, resulting in an artificially high water level, which causes a locally downward hydraulic gradient. This condition is enhanced by the pumping of three industrial supply wells near the dam. It is likely that the Rising Pond Dam also may tend to back up flow in the river, resulting in an artificially high water level, which would cause a locally downward hydraulic gradient. In addition, there are four drilled wells at the Columbia Mill Dam in Lee and three drilled wells at the Hurlbut Paper Company at the Willow Mill Dam in Lee (02-0007). The current status of these wells is unknown, as is their impact (if any) on local hydraulic gradients.

2.3 PHYSICAL AND ECOLOGICAL RIVER CHARACTERIZATION

The following description summarizes the physical characteristics of the Housatonic River, with emphasis on the approximately 62-mile stretch in Berkshire County, MA, between Dalton and the Massachusetts/Connecticut state line. To date, the ecological characterization of the river has focused on the approximately 10-mile section from the confluence of the East and West Branches to Woods Pond.

The Housatonic River flows approximately 150 miles from near Pittsfield, MA, to Long Island Sound and drains an area of approximately 1,950 square miles in Massachusetts, New York, and Connecticut. Within Massachusetts, the river elevation decreases approximately 600 ft (02-0016). The average annual rainfall in the river valley is 43.5 inches, of which 47% is lost to evaporation or transpiration (02-0007). An estimated 24 inches per year leaves the basin as runoff in the river (04-0004). Major floods on the Housatonic River occurred with a hurricane in September 1938, and in 1948, 1955 (02-0007) and 1990. The section of the Housatonic River found in Massachusetts is located in the Humid Temperate Domain, Warm Continental Mountains, Adirondack-New England Mixed Forest-Coniferous Forest Tundra ecoregion. This province is composed of subdued glaciated mountains and maturely dissected plateaus of mountainous topography. Many glacially broadened valleys have glacial outwash deposits and contain numerous swamps and lakes (Bailey, 99-0030). The forests within this ecoregion are characterized by sugar maple, yellow birch, beech, and a mixture of hemlock within valleys. Low mountain slopes contain spruce, fir, maple, beech, and birch.

Table 2.3-1 describes nine reaches of the Housatonic River from the lower portion of Reach 1 in Dalton, MA, to the Connecticut border and their physical characteristics, including average water depth, bank description, sediment depth, flow, and depositional environment. Figures 2.3-1 and 2.3-2 show the extent of these reaches, and Table 2.3-2 describes their estimated length and slopes. The discussion below provides further description of the physical and ecological characteristics for these reaches.

2.3.1 Description by River Reach

2.3.1.1 Upstream of Unkamet Brook Confluence (Reach 1)

Reach 1 consists of the section of the East Branch of the Housatonic River from its origin in Hinsdale, MA, extending southward to the confluence of Unkamet Brook and the Housatonic River. This reach of the river has been significantly altered by human activities, including the presence of three dams and associated impoundments in the northern portion of this reach. The

Table 2.3-1

Physical Characteristics of Housatonic River Reaches
Housatonic River – Supplemental Investigation

Reach Number	Reach Description	Average Water Depth (ft)	Bank Description	Average Sediment Depth (ft)	Flow	Depositional Environment
1	Dalton to Unkamet Brook Confluence	1 – 2	Banks range from natural to channelized; moderate to steep	1 – 6	Moderate	Depositional areas towards Unkamet Brook; primarily cobble, gravel, and boulder in upstream areas
2	Unkamet Brook Confluence to Newell Street Bridge	0.2 – 5	Both banks moderate to steep except for some minor exceptions	0.4 – 10	Slow - Moderate	Terrace, channel and aggrading bar deposits
3	Newell Street Bridge to Lyman Street Bridge	1 – 3.5	Both banks steep with some minor exceptions	1.6 – 7	Slow - Moderate	Terrace, channel and aggrading bar deposits
4	Lyman Street Bridge to West Branch Confluence	0.2 – 4	Both banks low to steep slopes	2 – 8	Slow-Fast	Terrace, channel and aggrading bar deposits
5	West Branch Confluence to Woods Pond Confluence	0.5 – 11	Banks moderate to low lying with backwater areas	0.5 – 15.5	Moderate to Minimal	Channel, terrace and backwater deposits
6	Woods Pond	1 – 3 (16 max)	Low or no banks	2 (14 max)	Minimal	Major depositional area
7	Woods Pond to Confluence with Rising Pond	1 (average)	Both banks low to steep slopes	-	Slow - Fast	Terrace, channel and aggrading bar deposits
8	Rising Pond	-	Low or no banks	2 – 4 (9 max)	Minimal	Major depositional area
9	Rising Pond to Connecticut Border	-	Both banks low to steep slopes	-	Slow-Fast	Terrace, channel and aggrading bar deposits

NOTES:

- information unavailable

Sources: Stewart Laboratories, 02-0030. HEC, 02-0098; BBL, 04-0004.

Table 2.3-2

Estimated Slopes Per River Reach
Housatonic River – Supplemental Investigation

Reach	Description	Length (miles)	Elevation Change (ft)	Slope (ft/mile)
1	Dalton to Unkamet Brook	2.8	82	29.4
1a (subreach)	Higher Gradient Subreach	0.8	39	48.8
2	Unkamet Brook to Newell St	2.0	10	4.8
3	Newell St to Lyman St	0.5	3	6.9
4	Lyman St to Confluence of East and West Branches	1.4	7	4.7
5	Confluence to Woods Pond	10	13	1.3
6	Woods Pond	NA	NA	0
7	Woods Pond to Rising Pond	17.2	249	14.5
7a (subreach)	Higher Gradient Subreach of 7	1.4	39	28
7b (subreach)	Lower Gradient Subreach of 7	3.6	10	2.6
7c (subreach)	Higher Gradient Subreach of 7	2.9	89	30.1
8	Rising Pond	NA	NA	0
9	Rising Pond to the Connecticut Border	23.3	59	2.9
9a (subreach)	Higher Gradient Subreach of 9	0.6	10	16.7

portion of the reach running parallel to Routes 8 and 9 has been channelized and banks lined with riprap. Farther south the river meanders shortly before it reaches its confluence with Unkamet Brook. The Pittsfield Municipal Landfill straddles the boundary of Reaches 1 and 2 along the eastern side of the river.

2.3.1.2 Unkamet Brook Confluence to Newell Street Bridge (Reach 2)

Reach 2 extends from Unkamet Brook southward approximately 2 miles to the Newell Street Bridge in Pittsfield. This reach starts with a meandering section of the river, but is channelized shortly after the river enters the City of Pittsfield. Banks are moderate to steep throughout this reach, and water depths range from 0.2 to 5 ft deep. The surrounding land use is primarily industrial, commercial, and residential.

2.3.1.3 Newell Street to Lyman Street (Reach 3) and Lyman Street to the Confluence of the West Branch of the Housatonic River (Reach 4)

Reach 3 extends from the Newell Street Bridge in Pittsfield to the Lyman Street Bridge, (approximately 0.5 miles) and contains most of the potential source areas for PCB contamination to sediments, banks, and floodplain soils. Reach 4 extends approximately 1.4 miles from Lyman Street to the confluence of the East and West Branches of the Housatonic River. The West Branch of the Housatonic River is expected to be relatively uncontaminated by PCBs, and is not considered to be a subject of investigation.

Reach 3 and Reach 4 have both been significantly altered by human activities. Extensive development and alteration of the East Branch Housatonic River and Housatonic River floodplain and river channel have occurred within these reaches. The river has been straightened/channelized for flood control purposes and oxbows filled. The result has been an alteration and loss of significant areas of aquatic habitat.

The Housatonic River was channelized in the early 1940s in these portions of the river. The river characteristics, a straight channel, well-defined banks, an average flow velocity of 100 cubic ft per second (cfs), and a width consistently between 40 to 60 ft reflect this realignment project (02-0098). The river is generally less than 2 ft deep in this area and the riverbed material is composed of cobbles, gravel, coarse sand, and some areas of fine sand (02-0098 and 02-0030).

Grain size analysis indicates that sediments are primarily composed of gravel and coarse sand (04-0004). Very little silt and clay are present (02-0098 and 02-0030).

Aquatic habitat in Reaches 3 and 4 is considered somewhat poorer habitat than that in upstream areas. The predominant aquatic habitat cover type is snags (larger woody debris), with some bank, rock, and undercuts providing additional cover.

The land use surrounding this stretch of river includes industrial, commercial, and residential activities. There has been extensive development and alteration of the Housatonic River floodplain and adjacent areas within these reaches, and in many areas native vegetation has been replaced with ornamental species (trees, shrubs, and grasses for lawns). Riverbanks, however, are lined with eastern cottonwood, boxelder, and silver maple trees averaging 56 ft tall. The native species provide some riparian habitat. The result has been a loss of significant areas of ecological habitat and the fragmentation of undeveloped areas.

2.3.1.4 Confluence to Woods Pond (Reach 5)

The stretch of river from the confluence of the East and West Branches of the Housatonic River to Woods Pond is best described in two parts: the first section from the confluence to the New Lenox Road Bridge; and the second section from the New Lenox Road Bridge to the headwaters of Woods Pond. Both sections include the HVWMA. Reach 5 extends approximately 10 miles.

The first section of the river is approximately 50 to 120 ft wide (02-0098), and up to 11 ft deep. The water velocity is generally slower as compared to upstream reaches. The river meanders and has a few oxbows. The banks are generally scoured and eroded. Sediment deposition is moderate and consists of coarse to fine sand (TechLaw, Inc., 00-0309) with approximately 10% silt and clay. The predominant aquatic habitat cover is snags (larger woody debris), with undercuts, bank, and rock providing additional cover. The land use in this area is primarily residential, with some open space and some forested areas.

The second section of the river ranges from 60 ft to 160 ft wide and varies in depth from 4 ft to 8 ft. This section of river is dominated by a broad wetland floodplain, which ranges from 800 ft to 3,000 ft wide (00-0309), and includes numerous backwater areas, side channels, and poorly defined streambanks and meanders (02-0098 and 02-0030). The river is slow mixing with little gradient. Sediments in this area are mostly fine sand and some silt and sediment deposition rates are estimated at 0.5 to 0.6 inches per year (04-0004).

Closer to Woods Pond, the river has low water velocities and deep pool habitat (up to 7-ft depths or greater). The cover habitat is almost entirely dense vegetation overhanging the banks of the river, although aquatic vegetation is extensive in certain areas. Numerous snags of large-diameter (10- to 12-inch) logs also provide cover. These snags are large enough to divert stream flow and create deep pools through scouring of the stream bed. Additional cover includes banks, undercuts, and aquatic macrophytes.

The land surrounding this area is agricultural and forested near New Lenox Road, and includes the publicly owned, undeveloped HVWMA. A railroad track is located on the western side of the river valley, but is separated from the river by a wetland. Widespread physical access to the river is limited due to the wetlands and the lack of improved roads near the river (02-0098). An unimproved road that travels along the eastern side of the river (October Mountain Road) can be accessed from New Lenox Road and provides numerous points of access to the river. Woods Pond is located within the HVWMA, which is actively managed for hunting.

The floodplain from New Lenox Road to Woods Pond is relatively wide and provides the largest intact wildlife habitat in the river above Woods Pond Dam.

2.3.1.5 Woods Pond (Reach 6)

Woods Pond is a 60-acre manmade pond. Several upstream backwater areas are associated with the pond and form an area of more than 120 acres. The former dam was built around 1900, and the second replacement dam is a concrete overflow weir dam constructed in 1989 approximately 180 ft downstream of the original dam. The pond is approximately 12 miles downstream of the GE facility in Pittsfield and is the first impoundment downstream of the GE facility (02-0098). Shallow areas of the pond contain extensive stands of macrophytes and large algal mats during the summer months (02-0030). The pond has aquatic habitat characteristic of a standing water environment. Cover along banks is abundant, with overhanging vegetation, woody debris, rock piles, and submerged macrophytes.

Woods Pond has a maximum depth of 16 ft; however, most areas of the pond are 1 to 3 ft deep (02-0098 and 02-0030). Water in the pond is relatively calm, and the pond functions as a sedimentation basin. Sediment thickness ranges from 0.5 to 10 ft, with an average thickness of 2 ft (02-0098). Sediment deposition rates within Woods Pond are estimated at 0.03 ft to 0.08 ft per year (04-0004). The sediment has a high organic content (02-0030), and grain size analysis indicates that it is predominantly silt (04-0004). Sedimentation has occurred primarily in the low-flow areas of the pond; the lakebed sediment near the dam is cobble overlain with sand and gravel (02-0098).

2.3.1.6 Woods Pond to Rising Pond (Reach 7)

In the 17.2 miles between Woods Pond and Rising Pond, the Housatonic River has an average gradient of 14.5 ft per mile and five small dams are located in this area (02-0030). Most of the broad floodplain land use is dominated by agriculture. The riverbanks in southern Lee are lightly wooded with minimal development (02-0007).

2.3.1.7 Rising Pond (Reach 8)

Rising Pond is another impoundment where deposition of transported suspended solids is significant. The pond, approximately 45 acres in size, is formed by a dam adjacent to the Rising Paper Company.

2.3.1.8 Downstream of Rising Pond (Reach 9)

Below Rising Pond, the Housatonic River flows along a widened, relatively flat floodplain that includes many meanders and oxbows (04-0004). Within this 20-mile reach, one section near Great Barrington has a steeper gradient (16.7 ft/mile) as compared to the rest of the reach (2.9 ft/mile).

2.3.2 Floodplain Vegetation

This discussion of the Lower Housatonic River floodplain vegetation is to provide an overview of the major vegetative communities present within the study area that have been or are potentially subject to PCB contamination originating at the GE facility in Pittsfield. The primary sources of information contained in this section include the *Final Preliminary Ecological Characterization, Newell Street to Woods Pond* (05-0062) and the *Preliminary Wetland Characterization and Functional-Value Assessment, Housatonic River from Newell Street to Woods Pond* (00-0309). Additional studies proposed in this Work Plan will provide a more comprehensive characterization of the natural communities present within the study area (see Subsection 5.1.5 and Appendices A.6 and A.7).

Historic and active land use and management practices have fragmented some of the Housatonic River floodplain and vegetative communities. While there are few large expanses of undisturbed forest in Pittsfield, downstream floodplain habitat in Lenox and Lee is more expansive. Moreover, many areas are maintained as scrub/shrub communities and fields to promote the goals of the HVWMA. Vegetative communities are primarily a mosaic of floodplain forests, shrub swamps, and emergent wetlands.

In the upper reaches of the study area, between Newell Street and the confluence of the East and West Branches of the Housatonic River (hereafter referred to as the confluence), early successional trees and shrubs or exotic shrubs line most of the riverbanks. In the vicinity of the confluence, floodplain wetlands with a mosaic of forested wetlands occur on somewhat more established and higher ground; shrub and emergent wetlands occur on lower areas that are more regularly flooded. Floodplain wetlands become more abundant farther south in the study area, where they are interspersed with farmland near the central portion of the study area. South of New Lenox Road, floodplain wetlands fill the base of the stream valley. These wetlands are interspersed with backwater ponds, channels, and abandoned oxbows (00-0309).

Wetland types classified in the study area include the following: riverine, upper perennial, stream bed cobble-gravel; palustrine unconsolidated bottom (PUB); palustrine; emergent marsh, persistent and non-persistent marsh (PEM); palustrine, scrub/shrub, broad-leaf deciduous (PSS1); palustrine, forested, broad-leafed deciduous (PFO1); palustrine aquatic bed (PAB); and combination types. Detailed wetland community maps are provided in the wetland functional assessment report (00-0309).

The following discussion presents a description of the dominant species for the riverbanks and major wetland communities present.

2.3.2.1 Riverbanks

Along the upper reaches of the study area, there is a narrow buffer of vegetation between residential, commercial, and industrial lots and the river. The mature trees are eastern cottonwood (*Populus deltoides*), boxelder (*Acer negundo*), and silver maple (*Acer saccharinum*). Overstory trees are on average 56 ft tall and 9 to 26 inches in diameter at breast height (dbh). The shrub layer beneath this sparse overstory contains young overstory trees, mostly boxelder, with Japanese barberry *(Berberis thunbergii*), red-osier dogwood (*Cornus sericea*), Morrow's honeysuckle (*Lonicera morrowi*), red raspberry (*Rubus idaeus*), and often a dominant vine/liana (either river grape [*Vitus riparia*], oriental bittersweet [*Celastrus orbiculata*], or virgin's bower [*Clematis virginiana*]). The herb stratum, which is generally overshadowed by the shrub stratum, contains patches of smooth goldenrod (*Solidago gigantea*), zig-zag goldenrod (*Solidago flexicaulis*), garlic mustard (*Alliaria petiolata*), lady fern (*Athyrium filix-femina*), wood blue-grass (*Poa nemaralis*), white snakeroot (*Ageratina altissima*), and sensitive fern (*Onoclea sensibilis*).

2.3.2.2 Wet Meadows

These areas contain a mix of grasses, sedges, and rushes that tolerate mowing or grazing. Although wet meadows can be classified as palustrine emergent marsh (PEM) according to Cowardin et al. (99-0104), they typically contain different dominant species than PEMs occurring in an area, and for that reason, are classified separately. Grasses identified in this community type include blue joint grass (*Calamagrostis canadensis*), reed canary-grass (*Phalaris arundinacea*), redtop (*Agrostis gigantea*), quackgrass (*Elymus repens*), and wild rye (*Elymus virginicus*).

Pockets of emergent vegetation are often found in portions of wet meadows that are wet enough to exclude more agrarian species. In the study area, these pockets contained primarily sensitive fern, with lesser amounts of sedges (unidentified), soft rush (*Juncus effusus*), a bulrush (*Scirpus hattarianus*), and goldenrod (*Solidago spp*.).

2.3.2.3 Emergent Wetlands (PEM)

Much of the area mapped as emergent wetland is vegetated, in part, by purple-loosestrife (*Lythrum salicaria*). This invasive Eurasian species has become established in nearly all of the emergent habitats and many of the scrub/shrub wetlands, and is sometimes the dominant herb. Common emergent plants are: common arrowhead (*Sagittaria latifolia*), pickerel weed (*Pontederia cordata*), tuckahoe (*Peltandra virginica*), false water-pepper (*Persicaria hydropiperoides*), and broadleaf cattail (*Typha latifolia)*.

2.3.2.4 Scrub/Shrub Wetlands (PSS1)

There are four dominant scrub/shrub wetland types that are sometimes distinct, but more often intermixed. These include areas dominated primarily by dogwood: both red osier dogwood (*Cornus sericea*) and silky dogwood (*Cornus amomum*); areas dominated by willow (mostly silky willow-*Salix sericea*) and speckled alder (*Alnus incana*); areas with a tall shrub overstory of dotted hawthorn (*Crataegus punctata*); and areas that are regularly flooded containing buttonbush (*Cephalanthus occidentalis*). Silky dogwood is the most dominant shrub in the study area; it lines the edges of much of the open water as well as upland banks along the edge of the floodplain. The dominant willows include pussy-willow (*Salix discolor*), shining-willow (*S. lucida*), silky willow (*S. sericea*), and black willow (*S. nigra*). White willow (*S. alba*) is also common in the study area, but usually in marginally wet areas, rather than as a dominant in shrub swamps. Other frequently occurring shrub species include winterberry (*Ilex verticillata*) in more shaded habitats, meadowsweet (*Spiraea alba*) in abandoned farmland, arrowwood (*Viburnum dentatum*) in mixed shrub and forest areas, and high-bush blueberry (*Vaccinium corymbosum*), which is more common in forested areas. There are nearly as many areas with mixed forest/shrub wetlands as there are shrub wetlands. These areas are often dominated by dogwood and willows, with young red maple (*Acer rubrum*) creating a low, disperse forest canopy.

2.3.2.5 Forested Wetlands (PFO1)

Forested wetlands include high- and low-floodplain forests in areas with regular flooding, and forested swamps in groundwater discharge wetlands beyond the reach of regular flooding. Floodplain forests are found on low terraces on the inside bend of river meanders, along natural levees between the river and backwater shrub or emergent wetlands, and in narrow bands along riverbanks.

Low-floodplain forests grow closest to the elevation of the river, but high enough such that tree roots remain aerobic most of the year. These forests generally have temporary pools (i.e., floodplain vernal pools) and both natural and artificial drainages. Alluvial sediments are deposited in these forests regularly, creating a difficult environment for many herb species. Ostrich fern (*Mattcuccta struthiopteris*), sensitive fern, garlic mustard, and white avens (*Geum canadense)* are common in the herb stratum of these forests. In many places, large areas are dominated by just one or two of these species, most commonly, ostrich fern. Strong floodwater currents appear to affect small-diameter woody plants. This could explain the wide spacing of larger trees and the paucity of young trees and shrubs. Understory vegetation in these forests generally consists of arrowwood, boxelder, young silver maple, and Morrow's honeysuckle. The overstory trees are almost exclusively silver maple with occasional boxelder, green ash (*Fraxinus pennsylvanica*), and sycamore (*Platanus occidentalis*). The forest canopy in these areas is commonly 55 to 65 ft tall with a canopy closure of approximately 75%. Dominant overstory trees in low-floodplain forests generally range from 18 inches dbh to more than 36 inches dbh. Most of the silver maple in the low-floodplain forests have multiple stems.

High-floodplain forests, which are generally associated with low-floodplain forests, occur on fluvial berms within low floodplain, or on natural levees that form along the banks of the main river channel. These forests are typically more diverse and more densely vegetated in all strata than the low-floodplain forests. They often contain pockets of upland vegetation and drier-end wetlands. Silver maple, boxelder, and ostrich fern are also found in the high floodplain. Some of the other common herbaceous species include sensitive fern, lady fern, cinnamon fern (*Osmunda cinnamomea*), orange jewelweed (*Impatiens capensis*), spring beauty (*Claytonia virginica*), wild leek (*Allium tricoccum*), wood nettle (*Laportea canadensis*), and sedges in the rich areas: long beaked sedge (*Carex sprengelii*); pubescent sedge (*Carex hirtifolia*); a sedge, no common name (*Carex radiata*). The shrub layer often contained dense thickets (40 to 80% of the shrub stratum) of Morrow's honeysuckle, mixed with northern arrowwood, red-osier dogwood, winterberry, Japanese barberry, and occasionally bladdernut (*Staphylea trifolia*). There is diversity in both the size classes and species composition of the subcanopy and canopy. Boxelder and basswood

(*Tilia americana*) are common tree components, in addition to black cherry (*Prunus serotina*), musclewood (*Carpinus caroliniana*), green ash, black willow, white willow, red maple, occasionally sugar maple, and rarely black maple (*Acer nigrum*).

Forested swamps in groundwater discharge areas have slightly different flora than high-floodplain forests, likely because they are less influenced by floodwaters and upstream seed sources. Forested swamps in the study area tend to occur on broad, gently sloped plains where water pools and organic matter accumulate. Soils may be less enriched because of the accumulation of organic matter and the lack of sand and silt input from flooding. These communities are more spatially homogeneous than either of the floodplain types because they lack the topographic variability and the effects from flooding.

Unlike most of the floodplain forest, these areas tend to have a well-developed bryophyte layer growing on root crowns, hummocks, and shallow tree roots. Common mosses include *Bazzania trilobata, Polystichum c.f. ohioense, Climacium dendroides, Thuidium c.f. delecatulum, Racomitrium sp., Dicranum polysetum, and Mnium c.f. cuspidatum*. These forests contain an herb layer dominated by ferns, including royal fern (*Osmunda regalis*), cinnamon fern, interrupted fern (*Osmunda claytoniana*), fancy fern (*Dryopteris intermedia*), and marsh fern (*Thelypteris palustris*). Other herb species include large patches of tussock-sedge (*Carex stricta*), other sedges (*Carex intumescens, C. trisperma, C. bromoides*), blue joint grass, northern bugleweed (*Lycopus uniflorus*), skunk cabbage (*Symplocarpus foetidus*), swamp-candle (*Lysimachia terrestris*), flat-topped aster (*Doellingeria umbellata*), blue flag iris (*Iris versicolor*), foam-flower (*Tiarella cordifolia*), and crowfoot (*Ranunculus hispidus*). Shrubs occur in small thickets, often on hummocks. Common species include high-bush blueberry, mountain holly (*Nemopanthus mucronatus*), maleberry (*Lyonia ligustrina*), fly-honeysuckle (*Lonicera canadensis*), spicebush (*Lindera benzoin*), and winterberry (Ilex verticillata).

These forests have a multi-layer canopy, with a distinct understory consisting of musclewood, gray birch (*Betula populifolia*), hemlock (*Tsuga canadensis*), and black ash (*Fraxinus nigra*), and a supra-canopy of red maple, green ash, bur oak (*Quercus macrocarpa*), and occasional silver maple, white pine (*Pinus strobus*), and swamp white oak (*Quercus bicolor*). One tamarack (*Larix laricina*) forest occurs in a discharge wetland near Woods Pond.

2.3.2.6 Aquatic Beds (PAB)

Aquatic beds have developed in areas where low-energy hydrology and bottom substrate provide aquatic plants suitable habitat. These areas are most apparent in the southernmost part of the study area near Woods Pond Dam. In this area, at least five major backwaters and over a dozen smaller ones fill in at least partially each summer with aquatic bed vegetation including curly pondweed (*Potamogeton crispus*), common waterweed (*Elodea canadensis*), European water milfoil (*Myriophyllum spicatum*), lesser duckweed (*Lemna minor*), greater duckweed (*Spirodela polyrhiza*), hornwort (*Ceratophyllum demersum*), and yellow water-lily (*Nuphar variegata*).

2.3.3 Floodplain Fauna

The study area floodplain communities provide a broad range of wildlife habitats. While some habitats have been changed by fragmentation, development activities, and the invasion of exotic plant species (e.g., purple loosestrife and phragmites), much of the vegetative communities continue to support a diverse fauna.

The following subsections provide an overview of fauna known or expected to inhabit various portions of the study area. The following information is summarized from the *Final Preliminary Ecological Characterization, Newell Street to Woods Pond* (Tech Law, 1999), where a detailed account of faunal use of the study area can be found.

2.3.3.1 Amphibians and Reptiles

Thirty-nine amphibian and reptile species were identified as potentially occurring within the study area including 7 turtles, 13 snakes, 10 salamanders, and 9 frogs or toads. Fifteen of the species were documented in the study area including three turtles, one snake, three salamanders, and eight frogs or toads. Frogs are the most common group of species. Eight of the nine expected species are known to occur in the study area. Wood frogs (*Rana sylvatica*) are common in small pools isolated from the river. Northern leopard (*R. pipiens*) and green frogs (*R. clamitans*) are also common in isolated pools, as well as permanent pools and backwaters connected to the river. Spring peepers (*Pseudacris "Hyla" crucifer*) and gray treefrogs (*Hyla versicolor*) use a variety of wetland habitats. Bullfrogs (*Rana catesbeiana*) are common in large, open wetlands, particularly the backwaters near Woods Pond. The distribution of American toad (*Bufo americanus*) and pickerel frog (*Rana palustris*) is somewhat limited.

Of the salamanders from the study area, red-spotted newts (*Notophthalmus viridescens*) are the most common. Adult newts use the backwaters near Woods Pond, oxbows, backwater channels, and permanent pools associated with the river throughout the study area, as well as in the river itself. Spotted salamander (*Ambystoma maculatum*) egg masses have been observed in a number of vernal pools throughout the floodplain.

Painted turtles (*Chrysemys picta*) are the most commonly observed turtles and occur throughout the study area in the large backwaters near Woods Pond, in the wetland complexes of Yokum Brook and Spring Creek, and also in permanent and temporary pools in the floodplain. Like the painted turtles, snapping turtles (*Chelydra serpentina*) are common and widespread. Wood turtles (*Clemmys insculpta*) are known from only a few locations in the study area near the confluence of the East and West Branches. Garter snakes (*Thamnophis sirtalis*) are found in a variety of floodplain habitats.

2.3.3.2 Birds

A diverse bird community occurs within the study area—up to 165 species are expected to use the habitat at some time of the year and nearly 70% of the expected species were observed in 1998. Bird community diversity is a reflection of the diverse nature of the habitats available. An abundance of large, open wetlands surrounded by forested and scrub-shrub habitats in the lower part of the study area provides suitable habitat for many species of waterbirds and landbirds. Mallards (*Anas platyrhynchos*), wood ducks (*Aix sponsa*), and Canada geese are common, as are green-backed (*Butorides striatus*) and great blue herons (*Ardea herodias*). The emergent and scrub-shrub borders of floodplain wetlands provide nesting habitat for a number of wetland-dependent species such as red-winged blackbirds (*Agelaius phoeniceus*) and swamp sparrows (*Melospiza georgiana*). Several species of swallows, cedar waxwings (*Bombycilla cedrorum*), and common nighthawks (*Chordeiles minor*) feed over these habitats. Belted kingfishers (*Ceryle alcyon*) are common on the river and likely nest in the banks. Floodplains in the middle section of the study area are more dominated by forested habitats, and provide nesting and feeding sites for several thrushes and wood warblers, as well as American robin (*Turdus migratorius*), black-capped chickadee (*Parus atricapillus*), and blue jay (*Cyanocitta cristata*).

2.3.3.3 Mammals

Twenty-one of the 52 potential mammal species expected in the study area have been recently observed. Many mammals in the study area are common and occur in a variety of the floodplain habitats. These species generally have more cosmopolitan habitat requirements, such as red fox (*Vulpes vulpes*), coyotes (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), and gray squirrels (*Sciurus carolinensis*), which use both forested and non-forested habitats as well as riverine, shoreline, wetland, and upland habitats. Other species with narrower habitat requirements, such as muskrat (*Ondatra zibethicus*) and beaver (*Castor canadensis*), are common in and along the river. Two other semiaquatic mammals, the mink (*Mustela vison*) and river otter (*Lutra canadensis*), are either very uncommon or not present in the study area. Other species, like the black bear, are less frequently observed. Several species of small mammals have been recently observed including southern flying squirrel (*Glaucomys volans*), white-footed mice (*Peromyscus leucopus*), meadow voles (*Microtus pensylvanicus*), and short-tailed shrews (*Blarina brevicuadata*). Several mammal studies, which are ongoing, are expected to provide additional information on species occurrence and abundance.

2.3.3.4 Fish Communities

A total of 20 species of fish were collected from the study area in 1992 and 1993 by Chadwick & Associates (02-0102 and 02-0101) (Attachment 2-1, Figure 1 and Table 11). Previous studies have identified as many as 40 fish species within the Housatonic River system (Attachment 2-1, Table 5). A more complete list of fish species found within the study areas will be available when data collected as part of the fish health and toxicity study are presented.

2.3.3.4.1 Shallow Water Sites

Eight families, representing game fish (sunfish, bass, trout, perch, pike, pickerel, bullhead, and fallfish), rough fish (suckers, carp, goldfish), and forage fish (minnows, dace, shiners, killifish, and darters) were present (Attachment 2-1, Tables 11 and 12). The minnow and sunfish families contained the most species. The white sucker, common shiner, and bluntnose minnow were the numerically dominant species.

2.3.3.4.2 Deep Water Sites

Species representing game fish, rough fish, and forage fish were present (Attachment 2-1, Tables 11 and 12). Most of the fish collected in surveys of these areas were taken from deep pools. The sunfish family, which prefers the deeper, more pond-like conditions found in this portion of the river, was the dominant family. The white sucker and yellow perch were the numerically dominant species.

2.3.3.4.3 Woods Pond

The results of the 1992 and 1993 sampling by Chadwick (02-0101) are attached (Attachment 2-1, Tables 11 and 12). Game fish, rough fish, and forage fish were found. Sunfish and white suckers were the most abundant fish groups. The fish were mostly associated with the deep, open water areas near the middle of the channel.

2.3.3.5 Benthic Invertebrate Communities

Three distinct benthic invertebrate habitats can be characterized for the study area. First, shallow water habitats can be found from Newell Street to north of the New Lenox Road Bridge. Deep water stream habitats that are similar to ponds in their bottom substrate and depth can be found from just north of the New Lenox Road Bridge to Woods Pond. Pond habitat found in Woods Pond can be considered a separate benthic invertebrate community due to its depth and limited water movement.

The benthic invertebrate community assessment by ChemRisk (02-0048) of shallow water habitats in the study area (i.e., location EB2 and HR1) found *Diptera* (true flies) to be the most dominant Order. Other Orders present with more than 200 individuals at one or both of the sample stations include *Trichoptera* (caddisflies), *Ephemeroptera* (mayflies), and *Hydracarina* (water mites).

The deeper water areas are similar to ponds in both bottom substrate and depth, with slower movement of water. The invertebrate community at location HR2 was dominated by members of the dipterans and by oligochaete worms (Attachment 2-1, Figures 1 and 2). These habitats are less productive and less diverse than the shallow water habitats due to the predominantly uniform silt substrate. Many of the less numerous invertebrate groups identified were collected from rare habitat types sampled outside of the deeper water areas.

Woods Pond, location WP1, has a typical lentic species assemblage of benthic invertebrates (Attachment 2-1, Figures 1 and 2). The dipterans are dominant with oligochaetes common. Other taxa present in the area were mostly found in habitats located around the edge of Woods Pond.

ATTACHMENT 2-1

TERRESTRIAL AND AQUATIC BIOTA (FROM CHADWICK & ASSOCIATES, INC., 1994 AND CHEMRISK, 1994)

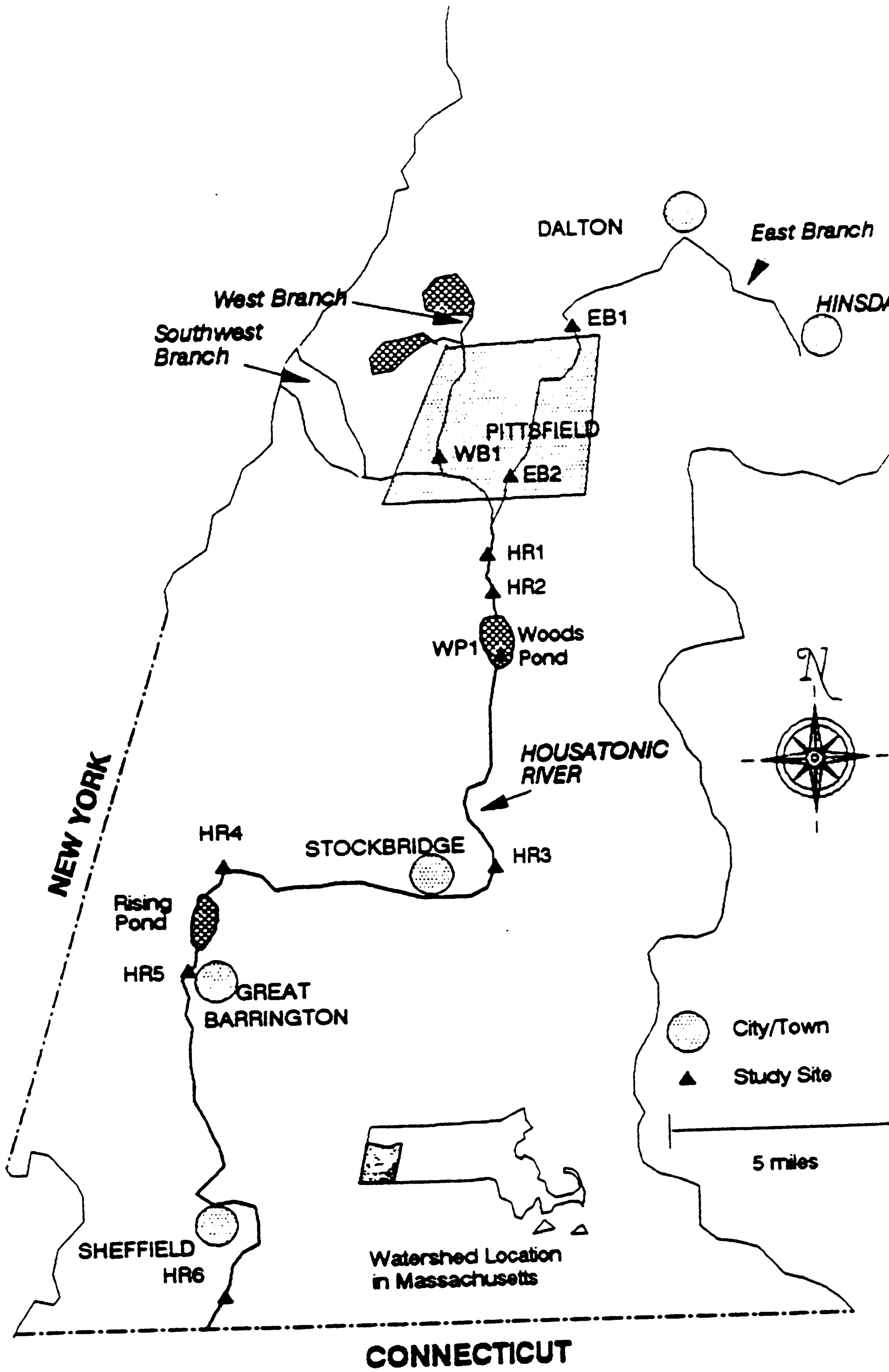


FIGURE 1: Site locations in the Housatonic River Drainage Basin from Hinsdale, Massachusetts, downstream to the Connecticut border.

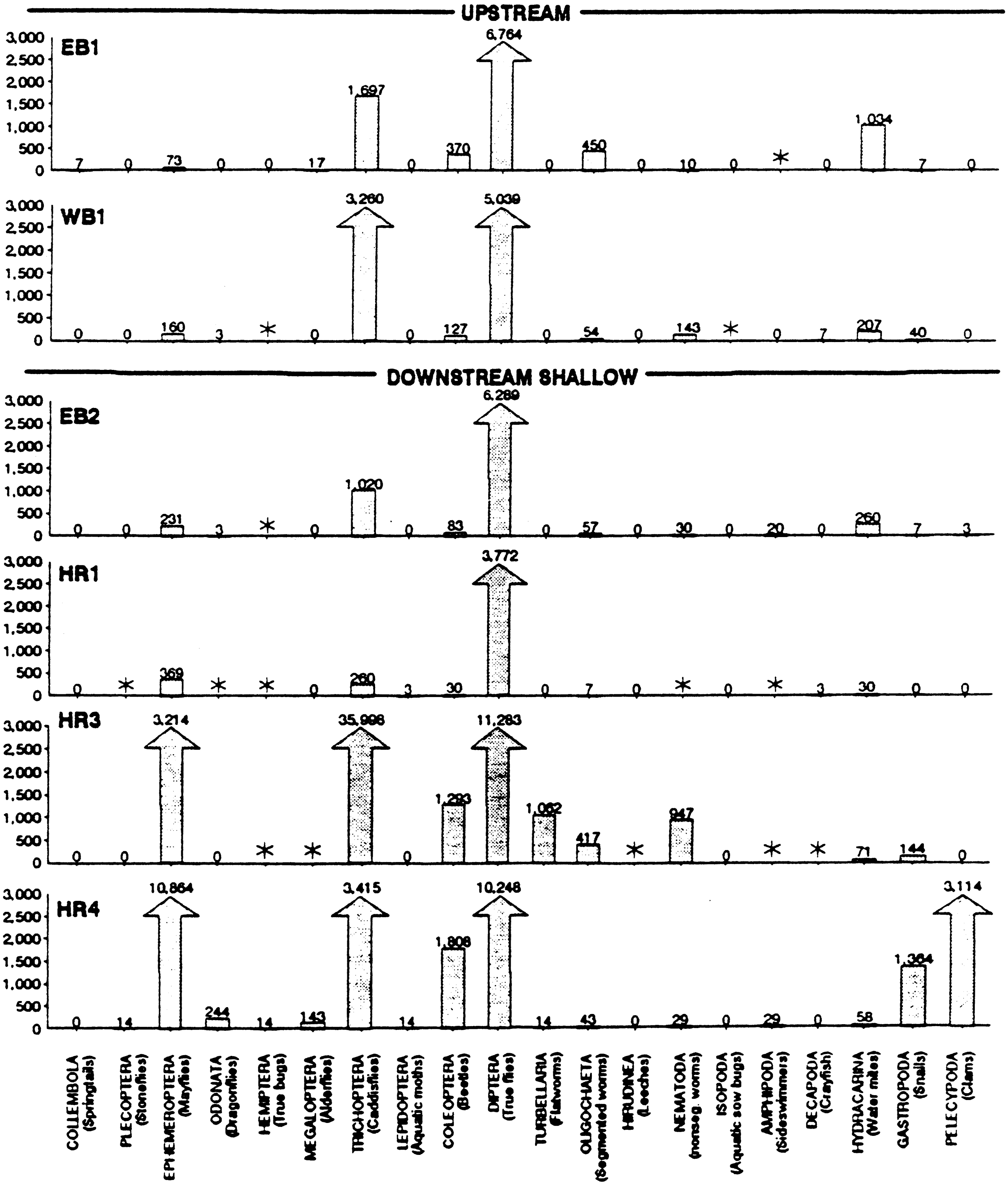


FIGURE 2: Mean densities (#/m²) of orders of benthic invertebrates collected from study sites on the Housatonic River system, September, 1993. Asterisks denote that individuals were collected only in the qualitative kick sample.

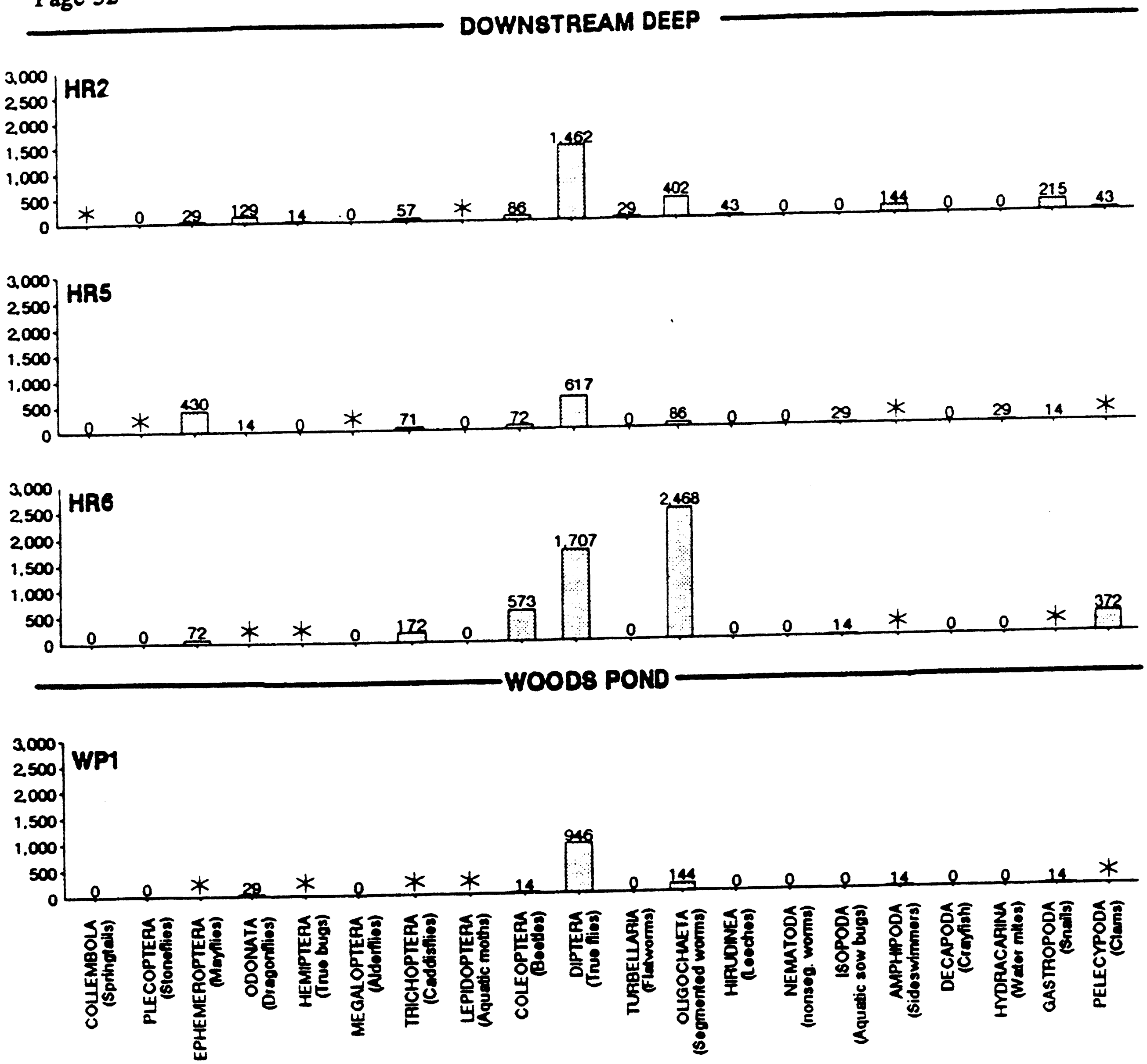


FIGURE 2: Continued.

TABLE 5: List of fish species collected from Housatonic River system, Massachusetts. (Mc=McCabe 1943; M=Bergin 1971; S = Stewart Laboratories 1982; B = Blasland & Bouck Engineers 1991; C = Chadwick & Associates 1992 and 1993).

Family Common Name	Scientific Name	Housatonic River
Salmonidae		
Brook trout	*Salvelinus fontinalis*	Mc,S
Brown trout	*Salmo trutta*	Mc,B,C,M,S
Rainbow trout	*Oncorhynchus mykiss*	Mc,M,S
Centrarchidae		
Bluegill	*Lepomis macrochirus*	Mc,C,M,S
Black crappie	*Pomoxis nigromaculatus*	C,S
White crappie	*Pomoxis annularis*	C
Green sunfish	*Lepomis cyanellus*	S
Largemouth bass	*Micropterus salmoides*	Mc,B,C,M,S
Pumpkinseed	*Lepomis gibbosus*	Mc,C,M,S
Redbreasted sunfish	*Lepomis auritus*	Mc
Redear sunfish	*Lepomis microlophus*	S
Rock bass	*Ambloplites rupestris*	Mc,C,M,S
Smallmouth bass	*Micropterus dolomieu*	Mc,C
Esocidae		
Chain pickerel	*Esox niger*	Mc,C,M,S
Grass pickerel	*Esox americanus*	Mc
Northern pike	*Esox lucius*	C
Muskellunge	*Esox masquinongy*	S
Percidae		
Tessellated darter	*Etheostoma olmstedi*	C
Yellow Perch	*Perca flavescens*	Mc,B,C,M,S
Percopsidae		
Trout perch	*Percopsis omiscomaycus*	Mc
Ictaluridae		
Brown bullhead	*Ameiurus nebulosus*	Mc,C,M,S
Yellow bullhead	*Ameiurus natalis*	C
Catostomidae		
Longnose sucker	*Catostomus catostomus*	Mc,C,M
White sucker	*Catostomus commersoni*	Mc,C,M
Creek chubsucker	*Erimyzon oblongus*	Mc
Cyprinidae		
Blacknose dace	*Rhinichthys atratulus*	Mc,C,M
Bluntnose minnow	*Pimephales notatus*	C
Bridle shiner	*Notropis bifrenatus*	Mc
Common carp	*Cyprinus carpio*	C
Common shiner	*Luxilus cornutus*	Mc,C,M
Creek chub	*Semotilus atromaculatus*	Mc,C,M
Fallfish	*Semotilus corporalis*	Mc,C,M
Fathead minnow	*Pimephales promelas*	C
Golden shiner	*Notemigonus crysoleucas*	Mc,C,M
Goldfish	*Carassius auratus*	C,M
Longnose dace	*Rhinichthys cataractae*	Mc,C,M
Spottail shiner	*Notropis hudsonius*	C,M
Cyprinodontidae		
Killifish	probably *Fundulus diaphanus*	M
Banded killifish	*Fundulus diaphanus*	C
Cottidae		
Slimy sculpin	*Cottus cognatus*	Mc
Total Species Richness		40
Species Richness, Chadwick & Associates		28

TABLE 11: List of fish species collected by Chadwick & Associates, Inc. from the Housatonic River system, September 1992, 1993. X = collected in 1992 and 1993, 92 = collected only in 1992, 93 = collected only in 1993. Site HR5 not sampled in 1992.

Family / Common Name	Upstream		Shallow Downstream				Deep Downstream			Pond
	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6	WP1
Salmonidae										
Brown trout	93				93	X				
Centrarchidae										
Rock bass	X	X	X	X	X	X	92	93	X	X
Black crappie						93	X	93	X	X
White crappie		93								
Bluegill	X	X		X	92	93	X	93	X	X
Largemouth bass	X	X	X	X	93	93	X	93	X	X
Pumpkinseed	X	X	X	X			X	93	X	X
Smallmouth bass								93	X	
Esocidae										
Northern pike										X
Chain pickerel	X						92	93		92
Percidae										
Tessellated darter					X			93	92	
Yellow perch	X	X	X	X			X	93	X	X
Ictaluridae										
Brown bullhead		92			X		X	93		X
Yellow bullhead		93								
Catostomidae										
Longnose sucker					X			93		
White sucker	X	X	X	X	X	X	X	93	X	X
Cyprinidae										
Goldfish							92			X
Common shiner	92	92	93		X					X
Creek chub	92	93	X	93	93					
Common carp							X	93	92	X
Fallfish	X	X	X	X	X	93			X	
Fathead minnow		93								
Golden shiner					93				93	92
Longnose dace	X	X	X	X	X	X				
Bluntnose minnow	93	X	X	X	X	X		93	93	X
Blacknose dace	X	X	X	93	X	93				
Spottail shiner	93			93		93			93	X
Cyprinodontidae										
Banded killifish					93					
Total Species Richness	15	16	11	12	16	11	11	14	14	16

TABLE 12: Number of fish collected by Chadwick & Associates, Inc. from the Housatonic River system, September 1993.

Family / Common Name	Upstream		Shallow Downstream				Deep Downstream			Pond	TOTAL
	EB1	WB1	EB2	HR1	HR3	HR4	HR2	HR5	HR6	WP1	
Salmonidae											
Brown trout	1	–	–	–	1	11	–	–	–	–	13
Centrarchidae											
Rock bass	40	18	31	29	58	23	–	43	7	3	252
Black crappie	–	–	–	–	–	1	1	4	4	10	20
White crappie	–	1	–	–	–	–	–	–	–	–	1
Bluegill	6	1	–	2	–	1	3	32	44	75	164
Largemouth bass	2	2	1	18	2	32	4	22	15	26	124
Pumpkinseed	9	9	1	2	–	–	4	16	6	31	78
Smallmouth bass	–	–	–	–	–	–	–	8	11	–	19
Esocidae											
Northern pike	–	–	–	–	–	–	–	–	–	1	1
Chain pickerel	1	–	–	–	–	–	–	4	–	–	5
Percidae											
Tessellated darter	–	–	–	–	40	–	–	1	–	–	41
Yellow perch	5	21	9	94	–	–	13	18	2	50	212
Ictaluridae											
Brown bullhead	–	–	–	–	2	–	1	4	–	32	39
Yellow bullhead	–	1	–	–	–	–	–	–	–	–	1
Catostomidae											
Longnose sucker	–	–	–	–	47	–	–	1	–	–	48
White sucker	5	174	137	119	405	31	20	80	6	75	1,052
Cyprinidae											
Goldfish	–	–	–	–	–	–	–	–	–	21	21
Common shiner	–	–	153	–	3	–	–	–	–	–	156
Creek chub	–	5	3	14	27	–	–	–	–	–	49
Common carp	–	–	–	–	–	–	2	34	1	1	38
Fallfish	21	131	67	5	7	7	–	–	–	–	238
Fathead minnow	–	2	–	–	–	–	–	–	–	–	2
Golden shiner	–	–	–	–	4	–	–	–	3	11	18
Longnose dace	40	136	46	2	300	662	–	–	–	–	1,186
Bluntnose minnow	1	1,191	427	498	32	10	–	3	1	1	2,164
Blacknose dace	204	289	66	9	6	521	–	–	–	–	1,095
Spottail shiner	4	–	–	119	–	1	–	–	3	7	134
Cyprinodontidae											
Banded killifish	–	–	–	–	3	–	–	–	–	–	3
Number Collected	339	1,981	941	911	937	1,300	48	270	103	344	7,174

3. INITIAL EVALUATION OF EXISTING INFORMATION

3.1 CONTAMINANT SOURCE AREAS AND CONTAMINANTS OF POTENTIAL CONCERN

Potential historical and ongoing sources of PCB contamination to the Housatonic River are located on or near property currently or formerly operated by GE. These potential contaminant sources include the following:

- Former oxbows of the Housatonic River that have been filled with hazardous materials.
- Nonaqueous phase liquids (NAPLs) and soil contaminated with hazardous substances, including PCBs, VOCs, metals, and SVOCs as a result of spills from a number of aboveground storage tanks (ASTs), underground storage tanks (USTs), and process pipelines currently or formerly located on GE property.
- Unkamet Brook landfill and contaminated soils and sediments on the banks or in Unkamet Brook.
- PCB-contaminated soils used as fill material.
- Former waste stabilization basin.
- Silver Lake.
- Stormwater and wastewater discharges.
- Contaminated groundwater discharge to the river.
- Contaminated soils and sediments on the banks or in the river itself.

Surface water runoff from sources, direct discharge, flooding, migration of nonaqueous-phase liquids, the Building 68 tank implosion and release to the river, and groundwater discharge to the Housatonic River have contributed to the sediment contamination in the Housatonic River. Migration and redistribution of contaminated sediments within the Housatonic River has further resulted in contamination detected in the river floodplain downstream from the site.

There are five main potential source areas in the vicinity of the facility, including East Street Area 1, East Street Area 2, Unkamet Brook, Newell Street Parking Lot, and Lyman Street Parking Lot (Figure 1-1) that may have impacted the river. These areas include various underground pipes, outfalls, and tunnels that could act as potential sources/pathways of migration for contaminants. There are also many sanitary sewer pipelines, stormwater drainage lines, and french drains entering the river. Other sources/migration pathways in these areas include surface, subsurface, and riverbank soils through which erosion, surface water flow, or groundwater discharge could impact the Housatonic River. Fill areas such as Oxbow H have been filled with contaminated soils and could impact the river. Groundwater plumes (light nonaqueous phase liquid [LNAPL], dense nonaqueous phase liquid [DNAPL], and other dissolved contaminants) may also impact the river. Unkamet Brook contains PCB-contaminated sediments that could migrate downstream to the Housatonic River.

The focus of this investigation is the Lower Housatonic River downstream of the facility, beginning at the confluence of the East and West Branches. Sources of contamination to the study area, in addition to those previously described upstream, include contaminated soils in the floodplain and along the banks, as well as sediment within the river itself.

The primary contaminants of concern in the Lower River are PCBs, but there may be other contaminants present in the groundwater, surface water, soil, or sediments throughout the facility and other areas of concern. Table 3.1-1 presents a preliminary list of contaminants for analysis in the soils and sediments based upon review of the historical data. Contaminants that will be analyzed as part of this SI consist of the modified Appendix IX list of compounds.

3.2 CONTAMINANT MIGRATION PATHWAYS

Sediment is a critical component in the fate and effects of PCBs in this river system. It is one of the primary elements in the transport and bioavailability of PCBs, and contaminated sediments act as a continuing source of PCBs to the overlying water column and to downstream areas through transport.

Figure 3.2-1 provides a simplified overview of the various potential contaminant transport pathways for PCBs and other contaminants within the Housatonic River system. Review of data collected to date indicates the primary potential sources of PCB and other contamination within the river system are:

Table 3.1-1

Modified Appendix IX List

Metals		
Antimony	Cobalt	Silver
Arsenic	Copper	Thallium
Barium	Lead	Tin
Beryllium	Mercury	Vanadium
Cadmium	Nickel	Zinc
Chromium	Selenium	
Pesticides		
4,4’-DDD	Delta-BHC	Heptachlor
4,4’-DDE	Dieldrin	Heptachlor epoxide
4,4’-DDT	Endosulfan I	Isodrin
Aldrin	Endosulfan II	Kepone
Alpha-BHC	Endosulfan sulfate	Methoxychlor
Beta-BHC	Endrin	Tetra-chloro-m-xylene
Chlordane	Endrin aldehyde	Toxaphene
Decachlorobiphenyl	Gamma BHC (Lindane)	
Semivolatiles		
1,2,4,5-Tetrachlorobenzene	3-Methylcholanthrene	Benzo(k)fluoranthene
1,2,4-Trichlorobenzene	3-Nitroaniline	Benzyl alcohol
1,2-Dichlorobenzene	4,6-Dinitro-2-methylphenol	Bis(2)-chloroethoxy)methane
1,3,5-Trinitrobenzene	4-Aminobiphenyl	Bis(2-chloroethyl)ether
1,3-Dichlorobenzene	(4-biphenylamine)	(2-chloroethyl ether)
1,3-Dinitrobenzene	4-Bromophenyl phenyl ether	Bis(2-chloroisopropyl)ether
1,4-Dichlorobenzene	4-Chloro-3-methyphenol	Bis(2-ethylhexyl)phthalate
1,4-Naphthoquinone	4-Chloroaniline	Butylbenzylphthalate
1-Naphthylamine	4-Chlorophenyl phenyl ether	Chlorobenzilate
2,3,4,6-Tetrachlorophenol	4-Methylphenol	Chrysene
2,4,5-Trichlorophenol	4-Nitroaniline	Di-N-butyl phthalate
2,4,6-Trichlorophenol	4-Nitrophenol	Di-N-octyl phthalate
2,4-Dichlorophenol	4-Nitroquinoline-1-oxide	Diallate
2,4-Dimethylphenol	4-Nitroquinoline-N-oxide	Dibenzo(a,h)anthracene
2,4-Dinitrophenol	5-Nitro-O-toluidine	Dibenzofuran
2,4-Dinitrotoluene	7,12-Dimethylbenz(a)anthracene	Diethyl phthalate
2,6-Dichlorophenol	Acenaphthene	Dimethyl phthalate
2,6-Dinitrotoluene	Acenapthylene	Dinoseb
2-Aminonaphthalene	Acetophenone	Ethyl methanesulfonate
(beta naphthylamine)	Alpha, Alpha	Fluoranthene
2-Chloronaphthalene	Dimethylphenethylamine	Fluorene
2-chlorophenol	Aniline	Hexachlorobenzene
2-Methylnaphthalene	Anthracene	Hexachlorobutadiene
2-Methylphenol (O-cresol)	Aramite	Hexachlorocyclopentadiene
2-Nitroaniline	Azobenzene	Hexachloroethane
2-Nitrophenol	Benzo(a)anthracene	Hexachloropropene
2-Picoline (alpha-picolene)	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene
3,3’-Dichlorobenzidine	Benzo(k)fluoranthene	Isophorone
3,3’-Dimethylbenzidine	Benzo(ghi)perylene	Isosafrole

Table 3.1-1

Modified Appendix IX List
(Continued)

Semivolatiles (con't.)		
Methapyrilene	Methyl methanesulfonate	Ni-nitroso-di-n-butylamine
N-nitroso-di-n-propylamine	Nitrobenzene	Pentachlorophenol
N-nitrosodiethylamine	Nitrosomethylethylamine	Phenacetin
N-nitrosodimethylamine	O-toluidine	Phenanthrene
N-nitrosodiphenylamine	P-dimethylaminoazobenzene	Phenol
N-nitrosomorpholine	P-phenylenediamine	Pronamide
N-nitrosopiperidine	Pentachlorobenzene	Pyrene
N-nitrosopyrrolidine	Pentachloroethane	Pyridine
Napthalene	Pentachloronitrobenzene	Safrole
Dioxins/Furans		
1,2,3,4,6,7,8-HPCDD	1,2,3,7,8-PECDD	HXCDF (Total)
1,2,3,4,6,7,8-HPCDF	1,2,3,7,8-PECDF	OCDD
1,2,3,4,7,8,9-HPCDF	2,3,4,6,7,8-HXCDF	OCDF
1,2,3,4,7,8-HXCDD	2,3,4,7,8-PECDF	PECDD (Total)
1,2,3,4,7,8-HXCDF	2,3,7,8-TCDD	PECDF (Total)
1,2,3,6,7,8-HXCDD	2,3,7,8-TCDF	TCDD (Total)
1,2,3,6,7,8-HXCDF	HPCDD (Total)	TCDF (Total)
1,2,3,7,8,9-HXCDD	HPCDF (Total)	
1,2,3,7,8,9-HXCDF	HXCDD (Total)	
Herbicides		
2,4,5-T (Trichlorophenoxyacetic acid)		
2,4,5-TP (Silvex)		
2,4-D		
Inorganics		
Cyanide		
Sulfide		
Total organic carbon		
Organophosphorus Pesticides		
Dimethoate	O,O,O-Triethylphosphorothioate	Phorate
Disulfoton	Parathion, ethyl	Sulfotep
Famphur	Parathion, methyl	Zinophos
PCBs		
1,2,4-Trichlorobenzene	Aroclor 1232	Aroclor 1254
Aroclor 1016	Aroclor 1242	Aroclor 1260
Aroclor 1221	Aroclor 1248	PCB, Total

- Contaminated groundwater plumes and NAPL that have historically entered the river within the Source Reach.
- Contaminated soils within riverbanks and floodplain soils.
- Contaminated sediments within the Housatonic River.

The contaminant transport processes affecting the fate and effects of PCBs within the Housatonic River and its floodplain are interrelated. For example, contaminated groundwater may discharge directly into the river, impacting Housatonic River surface waters and sediments via pore water diffusion and adsorption. Because of a relatively high partitioning coefficient (Koc), PCBs have an affinity for sediment particles. High-flow events and flooding may then suspend the contaminated sediment particles, carrying them farther downstream, or over the banks of the river to potentially contaminate both riverbank and floodplain soils. Contaminated riverbank and floodplain soils could then be carried back into the river by erosion or movement of the river channel and runoff during storm events, eventually settling out into the sediment. A simplified diagram illustrating these processes is provided in Figure 3.2-2.

The following discrete, but interrelated primary potential PCB transport pathways have been identified for the conceptual model of the site:

- Erosion and downstream transport of contaminated bank soils. Bank contamination has occurred as a consequence of historical cut and fill operations that used fill material contaminated with PCBs, as well as PCB spills and LNAPL seeps.
- Sediment contamination via runoff carrying suspended soil particles contaminated with PCBs.
- Sediment contamination via discharge of contaminated groundwater plumes, with subsequent contaminant adsorption.
- Surface water contamination from direct discharge of NAPL.
- Flux of soluble PCBs from contaminated sediments, and suspension of contaminated sediment particles.
- Floodplain soil and bank soil contamination via deposition of suspended river sediment during flood events.
- Erosion of contaminated floodplain soils (surface and subsurface) and subsequent deposition as contaminated river sediment.

- Bioaccumulation and cycling of PCBs within the terrestrial and aquatic food chains, where the organisms are exposed to contaminated soil, surface water, and sediment via diffusion across the epidermis or gill membrane, ingestion of contaminated food items, or direct contact with sediment/soil/surface water.

In addition to this generalized model of contaminant transport, review of data from prior investigations (02-0089) indicates that contamination originating within the Source Reach (as discussed earlier) is transported downstream. When historical data are averaged by river reach and plotted, the pattern of surficial floodplain soil is similar to riverbank soil contamination. Average surficial (0 to 0.5 ft bgs) total PCB concentrations in both riverbank and floodplain soils are highest within the Source Reach (Reach 3) and generally decrease consistently with distance from the Source Reach (Figure 3.2-3). This trend is consistent with the hypothesis that riverbank and floodplain soil contamination is a consequence of periodic flooding events that deposit suspended sediment particles onto the riverbank and floodplain areas.

In contrast, review of Figures 3.2-3 and 3.2-4 indicates that the historical average and maximum surficial (0 to 0.5 ft depth) sediment PCB concentrations follow a different pattern. The deposition of contaminated sediment is influenced by channel characteristics. Average surficial PCB concentrations in sediment do not decrease consistently from Reach 3 moving downstream (Figure 3.2-3), supporting the hypothesis that the pattern of PCB contamination is determined by the distribution of depositional areas along the river. Much of Reach 3 has been channelized and is relatively fast-moving, underlain by cobbles and till. As a result, PCB-contaminated soil particles in this reach would tend to be transported downstream to slower moving reaches of the stream, where they are deposited. Fine-grained PCB-contaminated sediments that are suspended in the water column would tend to be transported farther downstream, and would be expected to be deposited in large depositional areas such as Woods Pond and Rising Pond, or continue to travel downstream. This pattern is consistent with previous data reported on the distribution of contaminated sediments (02-0089).

Further evaluation of the historical data presented in Figures 3.2-3 and 3.2-4, including the data tables used to produce the charts, is provided in Section 3.3. Some of the data points on Figures 3.2-3 and 3.2-4 represent small numbers of samples, only limited conclusions may be made based on these data. The additional samples to be collected in accordance with this Work Plan will provide a sufficient data set to allow more conclusive data evaluations regarding the distribution of PCB contamination in the Lower Housatonic River.

3.3 SITE DATA EVALUATION

3.3.1 Historical Analytical Data Evaluation and Usability

A database of analytical data on soils and sediments in the vicinity of the Housatonic River has been compiled by MADEP and subsequently modified by EPA and its consultant, Signal Corporation. The database includes historical data collected by GE and its consultants over a period of 19 years, and is linked to a Geographic Information System (GIS) containing land use and other topographic feature information. The primary sources for the compiled data were:

- Housatonic River Study, 1980 and 1982 Investigations, Stewart Laboratories, Inc.
- MCP Phase II Report/Current Assessment Summary for Housatonic River, BB&L, 1991-1994.

These historical data for the Housatonic River were provided on several CD-ROMs to WESTON by EPA in May 1998. To supplement this tool, historical analytical data were compiled from various other electronic, tabular, and paper map sources, referenced by data source and sample locations, and the results added to the data set.

This historical database includes only data collected by Stewart Laboratories, GE, and its consultants prior to 1998. EPA data collected in the Source Reach (Reach 3) during 1998 have not been incorporated into the historical database. Additionally, any data associated with soil or sediment removed during GE's remedial operations has not been deleted from the historical database.

In May 1999, GE released its own database of analytical data for soils and sediments in the vicinity of the Housatonic River; this database contained some but not all of the historical data. The EPA and GE databases were compared, reviewed, and combined into one data set, with the new GE data replacing EPA data where the two databases overlapped. This combined data set has been used to prepare the evaluation of data presented in the following subsections, and to post the existing historical PCB soil and sediment data on maps of the river and surrounding areas.

The historical sampling was performed by GE and its contractors under the *Sampling and Analysis Plan/Data Collection and Analysis Quality Assurance Plan*, BB&L, May 1994 (01-0140). The GE SAP/QAP specifies the use of EPA SW-846 methods for organic and metal analyses. Many chemical analytes have method-specified detection limits listed in this document. The majority of analyses were for PCBs, which have listed detection limits of 0.07 mg/kg (parts per million [ppm]) in soil and 0.90 µg/L (parts per billion [ppb]) in water. The review of the data reports confirms that these methodologies and detection limits were followed in most cases.

These historical PCB analytical data for soils and sediment are shown on maps presented in Appendix D. This summary of data does not include all existing data, but represents the majority of usable data available at the time this Work Plan was developed. Recent data (after March 1998) and other data for which sampling locations were unknown are not included.

The data presented on the maps reflect conditions prior to any sediment or soil removal actions conducted by GE. GE has conducted removal actions in and along the river at the following locations:

- GE Facility—Building 68—Reach 3, North Bank.
- Various properties that underwent interim remedial measures in Reaches 2 and 4.
- ½-Mile Reach from Newell Street to Lyman Street—Reach 3.

WESTON reviewed representative GE data reports to determine the level of quality control (QC) information provided. Most data are presented in Phase I or Phase II Summary Reports. At least nine laboratories performed chemical data analysis for GE over 19 years of environmental sampling. The majority of the laboratory reports contain no QC information (i.e., calibrations, instrument tuning and system performance, internal standards, method blanks, surrogates, matrix spikes, blank spikes, laboratory control samples, laboratory duplicates, percent solids, method detection limits, chromatograms, spectra, and target compound identification).

In the absence of QC information in the GE reports, it is assumed that QC parameters were within quality control ranges that delineate usable from unusable data. Since the majority of critical data was for PCBs in soil, and most of the soil data had detectable levels of PCBs, the main concern in assuming the GE data are usable is that the accuracy or precision of reported PCB concentrations cannot be determined.

3.3.2 Sediment

3.3.2.1 Summary of Previous Investigations

A number of studies have been conducted on the sediments of the Housatonic River, with the earliest starting in the 1980s. The summary of previous investigations is based partially on the following studies: the Connecticut Agricultural Experiment Station (02-0016); Stewart Laboratories (02-0030); Lawler, Matusky, & Skelly Engineers (02-0090); GZA GeoEnvironmental (99-0276); Blasland & Bouck Engineers (02-0062); and Blasland, Bouck & Lee (02-0038, 02-0071,04-0004). Other information and data are available in reports prepared for other areas and in additional reports concerning the Lower River.

Average concentrations of PCBs in the sediments between the GE facility and Woods Pond have been reported as 29 ppm and the average depth of sediment as 2.4 ft (04-0004). Aroclor 1260 is the predominant PCB detected (85% of detections), with Aroclor 1254 (approximately 14%) and Aroclor 1242 (<1%) (04-0004) detected less frequently. PCBs have also been detected downstream of Woods Pond Dam throughout the Housatonic River in Massachusetts and Connecticut to its discharge point at Long Island Sound.

Earlier investigations in 1980 and 1982 (02-0030) detected PCB concentrations of 0.52 to 290 ppm in sediment between the GE facility and the New Lenox Road Bridge. From the New Lenox Road Bridge to Woods Pond, PCB concentrations ranged from below detection to 270 ppm, with an average concentration of 22 ppm (02-0030). Sediments from Woods Pond had PCB concentrations ranging from below detection to 220 ppm with an average of approximately 24 ppm (02-0030). Sediment PCB concentrations decreased downstream of Woods Pond, relative to upstream concentrations. PCB concentrations ranged from below detection to 22 ppm (average of 3 ppm) from Woods Pond Dam to Rising Pond Dam (02-0030). Sediment concentrations from Rising Pond Dam to the Connecticut border ranged from below detection to 2.3 ppm (average of 1 ppm) (02-0030).

In 1996, BBL (04-0004) estimated that approximately 785,000 yd^3 of sediment contain PCBs above 1 ppm between the GE facility and Woods Pond, with an additional 800,000 yd^3 from Woods Pond to the Connecticut border. The volume of sediments contaminated with PCBs above 10 ppm was calculated as 490,000 yd^3 and 170,000 yd^3 for the same two sections.

3.3.2.2 Extent of Contamination

Data available from many of the studies mentioned previously have been included in the EPA project database. Minimum, average, and maximum PCB concentrations are summarized in Tables 3.3-1 through 3.3-7. In surficial sediments (0 to 0.5 ft depth), average total PCB concentrations in sediment increased from Reach 1 to Reach 3, then decreased moving downstream until Reach 6, Woods Pond (Table 3.3-1). Concentrations increased at Woods Pond, a depositional area. The highest average and maximum total PCB concentrations in surficial sediments were in Reaches 3, 4, 5, 6, and 7 (Figures 3.3-1 and 3.3-2). These reaches are located downstream of the known source areas, indicating that PCBs are being transported to depositional areas within these reaches.

Existing data indicate that PCB concentrations in sediment vary significantly within each reach (Table 3.3-1). For example, total surficial PCB concentrations at sampling locations within Reach 3 varied from below detection to 20,200 mg/kg, while in Reach 4, they ranged from 0.041 mg/kg to a maximum of 1300 mg/kg.

Woods Pond (Reach 6) and Rising Pond (Reach 8) act as depositional areas for PCB-contaminated sediments transported downstream from the Source Reach (Reach 3). PCBs were detected in Woods Pond at depths greater than 3 ft (Table 3.3-6, Figures 3.3-3 and 3.3-4), and require additional vertical and horizontal delineation. PCBs were detected in sediment in Rising Pond, at concentrations as high as 15 mg/kg at a depth interval of 4.5 to 5.0 ft below the sediment surface, approximately 30 miles downstream from the Source Reach (Table 3.3-7, Figures 3.3-5 and 3.3-6). The presence of PCBs at higher concentrations with depth in the Rising Pond sediments suggests the greatest contamination occurred during prior periods of operation at the GE Plant.

Table 3.3-1
PCB Levels in Sediments (0 - 0.5 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	13	nd	0.108	0.4
2	6	nd	0.324	0.57
3	97	nd	1210	20200
4	104	0.041	33.8	1300
5	187	0.1	25.1	220
6	134	0.04	42.4	190
7	81	nd	12.7	210
8	54	0.046	3.57	12
9	280	nd	0.59	3.9

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-2
PCB Levels in Sediments (0.5 - 1 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	7	nd	0.05	0.08
2	3	0.045	0.168	0.28
3	59	nd	848	15300
4	23	0.11	43.5	290
5	82	0.02	31.9	270
6	96	0.02	37.2	170
7	38	nd	7.77	110
8	28	0.06	6.14	20.7
9	71	nd	0.741	2.7

Reaches

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-3
PCB Levels in Sediments (1- 2 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	6	nd	0.12	0.12
2	5	0.045	0.081	0.15
3	68	nd	582	6950
4	34	0.048	25.1	110
5	126	0.01	24.1	370
6	152	0.01	21.5	210
7	41	nd	3.56	16
8	41	0.05	5.19	25.5
9	119	nd	0.632	2.33

Reaches

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-4
PCB Levels in Sediments (2 - 3 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	3	0.24	2.20	6
3	34	nd	1150	5790
4	16	0.047	12.6	32
5	63	nd	61.6	2000
6	68	0.03	11.8	220
7	11	nd	2.92	13
8	25	0.05	9.2	37
9	9	nd	0.691	1.76

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-5
PCB Levels in Sediments (Greater Than 3 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	3	0.93	2.38	4.7
3	25	nd	7000	54000
4	9	0.048	17.3	43
5	27	0.03	60.8	610
6	81	nd	2.6	26
7	3	0.01	0.0167	0.02
8	15	0.05	11.38	22
9	0	na	na	na

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-6
PCB Levels in Woods Pond Sediments
Housatonic River—Historical Data
Pittsfield, MA

Depth	Depth Centroid	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
0-0.5	0.25	134	0.04	42.4	190
0.5-1	0.75	96	0.02	37.2	170
1.0-2.0	1.5	152	0.01	21.5	210
2.0-3.0	2.5	68	0.03	11.8	220
3.0+	3.5	81	nd	2.6	26

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-7
PCB Levels in Rising Pond Sediments
Housatonic River—Historical Data
Pittsfield, MA

Depth	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
0-0.5	54	0.46	3.57	12
0.5-1	28	0.06	6.14	20.7
1-1.5	23	0.05	4.49	25.5
1.5-2	18	0.07	6.08	22
2-2.5	14	0.05	8.75	28
2.5-3	11	0.06	9.71	37
3-3.5	6	2.8	12.2	17
3.5-4	4	12	15.8	22
4-4.5	3	0.05	6.42	15
4.5-5	2	0.05	7.53	15

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

3.3.2.3 Sediment Data Gaps

Given the variability in sediment PCB concentrations within the historical data set, and the insufficient sampling conducted in several reaches identified, further sampling and analysis are required to adequately characterize the PCB-contaminated sediments within the Housatonic River. The following specific data gaps were identified:

- Limited PCB results (as well as limited data on other chemical contaminants) are available for Reach 1 to characterize "background" concentrations for upstream portions of the river.
- Few samples have been collected from Reach 2 (Unkamet Brook to Newell Street). The existing sample results indicate PCB contamination at levels above 2 mg/kg at depths greater than 2 ft. Moreover, the number of samples is insufficient to fully characterize potential contamination resulting from suspected sources such as the landfill area, and PCB-contaminated sediments within the brook itself that could enter the river.
- Data from Reach 3 are highly variable, with surficial concentrations ranging from below detection limits to 20,200 mg/kg. Further intensive investigation of the extent of sediment contamination in this reach is required given the presence of LNAPL and DNAPL plumes in proximity to the river, observations of contaminated seepage in riverbank areas, riverbank contamination from historical fill material, and likelihood of PCB transport and adsorption onto sediments. These data were collected under the Preliminary Work Plan (02-0161).
- Sediment data from Reaches 4 and 5 indicate that total surficial PCB concentrations were as high as 1300 mg/kg and 220 mg/kg, respectively, within these reaches. These data, in conjunction with data collected by BBL on sediment depths (GE Monthly Status Reports, Massachusetts Contingency Plan, EPA EE/CA Corrective Action Activities, 00-0274), indicate the presence of sediment depositional areas that require further evaluation and delineation. Moreover, the detection of PCBs even in areas of Reaches 4 and 5 characterized by coarse-grained sediments indicates the widespread nature of PCB contamination within the river, thereby requiring further delineation. Reach 4 data will be collected under the EE/CA Work Plan (07-0001).
- Additional data are necessary to adequately characterize sediment contamination within Woods Pond. Some locations where PCBs were detected at elevated levels are separated by distances of up to 300 ft and further sampling is required to delineate the contamination both vertically and horizontally. A survey of accumulated sediment in the pond is also needed.
- Insufficient data exist to define the contamination in river reaches south of Woods Pond. For example, in some cases intervals of over 3,000 ft exist between adjacent samples. Moreover, many sections of these reaches are characterized with a single

sample, so comparisons between depositional areas within the channel and other locations are not possible.

3.3.3 Riverbank Soils

3.3.3.1 Summary of Previous Investigations

For this investigation, riverbanks are defined as the sideslopes of the channel between which river flow is normally confined. The lower bank is considered the portion of the bank located below the elevation of the average water level of the river.

Prior sampling results (04-0004) have indicated that sediments, riverbanks, and floodplain soils are contaminated with PCBs. Of principal concern are potential source areas identified within East Street Area 2, Lyman Street Parking Lot, and Newell Street Area II (as shown in Figure 1-1) and their potential impact on sediment, floodplain soils, and riverbank soils. These areas include the original tanks, pipelines, and operations areas, plus delineated areas of LNAPL, DNAPL, and soil contamination (00-0275).

The highest PCB concentrations in floodplain soils, banks, and sediment have been documented near source areas between Newell Street and Lyman Street in Pittsfield. Review of these prior results indicates that large portions of the riverbank soils are also contaminated with PCBs in excess of 1 mg/kg (00-0274), and in some cases as high as 2,410 mg/kg (BBL location 18-4-7-21, at a depth of 12 to 18 inches). Generally, concentrations remain elevated at depths of 3 ft or more.

3.3.3.2 Extent of Contamination

Review of the available historical data (i.e., prior to 1998) indicates that limited riverbank soil samples have been taken along the river (Tables 3.3-8 through 3.3-10). Samples have been taken only in Reaches 3 and 4. Average surficial (0 to 0.5 ft bgs) concentrations decreased from 352 mg/kg in Reach 3 to 27 mg/kg in Reach 4 as shown in Table 3.3-8 and Figure 3.3-7. Maximum concentrations also decreased from Reach 3 (5,800 mg/kg) to Reach 4 (380 mg/kg) (as shown in Figure 3.3-8). These results are consistent with trends in sediment results showing a general

Table 3.3-8
PCB Levels in Bank Soils (0 - 0.5 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	20	0.2	352	5800
4	482	nd	27	380
5	0	na	na	na
6	0	na	na	na
7	0	na	na	na
8	0	na	na	na
9	0	na	na	na

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes

na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-9
PCB Levels in Bank Soils (1.0 - 1.5 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	18	0.13	288	2500
4	514	nd	56	1100
5	0	na	na	na
6	0	na	na	na
7	0	na	na	na
8	0	na	na	na
9	0	na	na	na

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-10
PCB Levels in Bank Soils (2 - 2.5 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	18	nd	478	1700
4	442	nd	49	820
5	0	na	na	na
6	0	na	na	na
7	0	na	na	na
8	0	na	na	na
9	0	na	na	na

Reaches

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

decrease in concentrations with distance from the GE facility. Data collected at depth exhibit a similar trend, decreasing for Reaches 3 and 4 (Tables 3.3-9 and 3.3-10). However, while the highest maximum PCB concentration (5,800 mg/kg) was at the surface, the highest average PCB concentration (478 mg/kg) was at a depth of 2 to 2.5 ft bgs.

3.3.3.3 Data Gaps

Review of the available data in Reaches 3 and 4 (upstream of the study area) indicates that average riverbank soil PCB concentrations are higher at lower depths (2 to 3 ft bgs) than at the surface. Reported concentrations within Reach 4 were as high as 1,100 mg/kg; riverbank sampling apparently was not conducted downstream of Reach 4. Downstream surficial sediment concentrations were as high as 220 mg/kg within Reach 5 (Table 3.3-1) suggesting the possibility of riverbank contamination from suspension of river sediments during flood events. Thus, additional sampling is required to further delineate the horizontal and vertical extent of this contamination.

The following specific data gaps were identified upon review of the available data:

- Riverbank soil data may be needed in Reach 2 if the results of the sediment investigation indicate higher levels of contamination than indicated in the historical data set.
- Riverbank soil data from Reaches 3 and 4 indicate that surface and subsurface PCB contamination warrants further delineation.
- Additional data are necessary to adequately characterize riverbank soils in Reach 5, especially in the area between the confluence and the occurrence of the broad wetlands.
- Apparently no downstream riverbank samples from Reach 7 or 9 have been collected. PCBs were detected in sediments within Rising Pond at levels up to 10 mg/kg, well downstream of Reaches 3 and 4. Thus, riverbank soils as far downstream as Reach 9 may have become contaminated from periodic flooding and deposition of suspended PCB-contaminated sediments.

3.3.4 Floodplain Soils

3.3.4.1 Summary of Previous Investigations

Various studies have been conducted to characterize the floodplain soils of the Housatonic River. In 1988 and 1989, sampling of the Housatonic River floodplain soils on the DeVos Farm in Lenox indicated the presence of PCBs. The PCBs detected in floodplain soils of the DeVos Farm, and the possibility that historical flood events on the Housatonic River may have caused sediment deposition on the floodplain, led to additional characterization of the floodplain soils (04-0004).

As part of the investigations performed under the Massachusetts Contingency Plan (MCP), 253 floodplain soil samples were collected at 121 locations from a total of 11 floodplain transects along the Housatonic River from just above the GE facility to the Connecticut border, a distance of 56 miles. The results of this sample collection effort indicated that the area of the floodplain that exhibited PCBs above 1 ppm was generally limited to the area between the GE facility and Woods Pond Dam. Originally, GE reported that floodplain soils with PCB concentrations of 1 ppm or above were generally located within the approximate 10-year floodplain (02-0038), but the subsequent data analysis and HEC-2 modeling results led GE to revise its conclusions (04-0004). In the revised analysis, using an updated HEC-2 model, PCBs detected at concentrations of 1 ppm or above were generally within the approximate 5-year floodplain (04-0004). GE reports that the extent of the 5-year floodplain “does not vary significantly from the prior modeled 10-year floodplain limit, except in the Deming Street Area” (04-0004).

Additional floodplain sampling events were conducted as part of MADEP-required activities to evaluate the need for short-term measures at specific floodplain properties. These activities included the collection of approximately 250 additional floodplain soil samples on various occasions between August 1992 and April 1994. As part of further investigations to define the extent of PCBs in Housatonic River floodplain soils, a number of residential properties were the focus of sampling activities through December 1995. Each property was sampled at numerous locations and varying depths with the samples being analyzed for PCBs and TOC.

In May 1994, a total of 14 composites of floodplain soil were collected from wildlife habitat areas between New Lenox Road and Woods Pond and were analyzed for PCBs. PCB concentrations in these 14 samples ranged from non-detect to 0.97 ppm. In June 1994, 12 floodplain soil samples were collected from additional areas between New Lenox Road and Woods Pond and were analyzed for PCBs. The PCB concentrations of these samples ranged from 3.7 to 32 ppm (04-0004).

Between September 1994 and December 1995 additional sampling was conducted to further define the horizontal and vertical extent of PCB contamination in floodplain soil along the existing transects located downstream of the GE facility to below Sheffield, MA.

Additional floodplain soil sampling was conducted to further assess the presence and extent of PCBs in the floodplain below Woods Pond Dam. The justification provided for the additional sample collection was that the former and existing dams located downstream of Woods Pond Dam may have caused historical flooding in those areas and may have resulted in the deposition of PCBs onto the floodplain in these areas.

Revised HEC-2 modeling was used to estimate the approximate extent of the flood recurrence interval associated with the approximate 1-ppm PCB isopleth between the GE facility and Woods Pond Dam. A comparison of the data and the model for the area between the GE facility and Woods Pond Dam indicated that PCBs at concentrations of 1 ppm or greater were estimated to be generally limited to within the approximate 5-year floodplain. The upper portion of the river floodplain, between the GE facility and Holmes Road, is relatively narrow with steep banks, and includes portions of residential properties, some commercial properties, and some wooded areas. The flow of the Housatonic River is impacted by numerous bridges. Elevated PCB concentrations in floodplain soils were typically confined to areas close to the river and at low elevations; however, exceptions were observed in this section of the river, generally behind bridges and where local topographic irregularities interfered with flood flow conveyance (04-0004). The PCBs detected in Housatonic River floodplain soil consisted predominantly of Aroclor 1260, which constituted over 97% of the total PCBs detected in the floodplain (04-0004).

Downstream of Woods Pond Dam, the historical data indicate that the extent of the PCB-impacted floodplain soil is more limited, with floodplain soil PCB concentrations shown to be low (average PCB concentration of 1.7 ppm) and generally found only close to the river (usually within 150 ft).

3.3.4.2 Extent of Contamination

The available historical data (i.e., prior to 1998) for floodplain soils indicate the most significant PCB concentrations (i.e., greater than 1,000 mg/kg) were detected in samples collected from Reach 3 and Reach 4 as shown in Figures 3.3-9 and 3.3-10. Along all reaches, the concentrations vary significantly depending upon the depth interval from which the sample was collected as shown in Tables 3.3-11 through 3.3-15. These sample results are summarized below. The comparison is performed using data that were grouped by reach.

Reach 1 and Reach 2. Only limited floodplain soil sampling has been conducted in these areas.

Reach 3. Maximum PCB concentrations range from 9.6 mg/kg (> 3-ft interval) to 5,793 mg/kg detected in a sample collected from 0.0 ft to 0.5 ft bgs. Moreover, high concentrations (1,744 mg/kg to 2,477 mg/kg) of PCBs have been detected in samples collected from multiple intervals between 1 ft and 3 ft bgs, which indicates that PCB contamination exists at depth within floodplain soils along this ½-mile reach.

Reach 4. Data from floodplain soils collected from Reach 4 indicate a wide range of PCB concentrations. The maximum PCB concentrations range from 704 mg/kg (2.0 ft to 3.0 ft interval) to 5,904 mg/kg in a sample collected from 0.0 ft to 0.5 ft bgs. A significant amount of PCB contamination was detected in the samples collected at intervals of greater than 3 ft bgs. The average concentration of all samples collected from this depth was 75.5 mg/kg with a maximum concentration of 3,850 mg/kg.

Reach 5. This reach marks the beginning of the study area for this Supplemental Investigation. Reach 5 is much longer than any of the upstream reaches. Maximum concentrations of PCBs in samples collected from all depths were significantly lower than in Reaches 3 and 4. The maximum concentrations range from 71 mg/kg (>3.0 ft bgs) to 430 mg/kg in a sample collected

Table 3.3-11
PCB Levels in Floodplain Soils (0 - 0.5 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	5	0.582	3.38	7.43
3	21	0.2	343	5793
4	617	nd	29.7	5904
5	268	nd	12.0	230
6	11	nd	5.78	20
7	62	0.05	1.53	38
8	13	0.043	0.637	4.2
9	52	nd	0.289	1.7

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-12
PCB Levels in Floodplain Soils (0.5 - 1 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	4	0.21	2	6.32
3	3	2.18	6.95	11.1
4	586	nd	24.6	2250
5	185	nd	29.3	150
6	2	nd	1.10	2.2
7	59	0.043	1.25	13
8	11	0.041	0.503	2.9
9	51	nd	0.333	3.1

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-13
PCB Levels in FloodPlain Soils (1 - 2 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	18	0.1	287	2477
4	824	nd	32.4	2410
5	76	nd	41.9	280
6	0	na	na	na
7	10	0.23	6.69	22
8	4	0.39	0.753	1.6
9	6	nd	1.209	3.7

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-14
PCB Levels in Floodplain Soils (2 - 3 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	20	nd	167	1744
4	168	nd	54.6	704
5	52	nd	26.3	430
6	0	na	na	na
7	11	0.054	0.762	2.3
8	2	0.39	0.445	0.5
9	5	nd	nd	nd

***Reaches**

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

Table 3.3-15
PCB Levels in Floodplain Soils (Greater Than 3 Feet)
Housatonic River—Historical Data
Pittsfield, MA

Reach*	Total Number of Samples	Minimum PCB Level (mg/kg)	Average PCB Level (mg/kg)	Maximum PCB Level (mg/kg)
1	0	na	na	na
2	0	na	na	na
3	10	nd	1.80	9.6
4	188	nd	75.5	3850
5	52	nd	8.05	71
6	0	na	na	na
7	3	0.084	0.248	0.55
8	0	na	na	na
9	0	na	na	na

Reaches

1-Above Unkamet Brook
2-Unkamet Brook to Newell Street
3-Newell St.-Lyman St.
4-Lyman St.-Confluence of West and East Branches of the Housatonic
5-Confluence to Woods Pond
6-Woods Pond
7-Woods Pond-Rising Pond
8-Rising Pond
9-Downstream of Rising Pond

Notes
na - Not analyzed or not available.
nd - Not detected.

Sources:
1. Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
2. EPA Region 1 database, 1998.
3. General Electric database, May 1999.

from 2.0 to 3.0 ft bgs. The highest concentrations were detected in the samples collected at a depth of 2.0 to 3.0 ft bgs.

Reach 6. Limited data from the Woods Pond floodplain included a maximum PCB concentration of 20 mg/kg in a sample collected from 0.0 ft to 0.5 ft bgs.

Reach 7. Minimal sample collection has occurred along this reach from Woods Pond to Rising Pond. Maximum PCB concentrations range from 0.55 mg/kg (>3 ft bgs) to 38 mg/kg in a sample collected from 0.0 ft to 0.5 ft bgs. These concentrations are similar to the concentrations in the Woods Pond samples.

Reach 8. The few floodplain soil samples collected from Rising Pond have low PCB concentrations, ranging from 0.5 mg/kg (2.0 ft bgs to 3.0 ft bgs) to 4.2 mg/kg in a sample collected from 0.0 ft bgs to 0.5 ft bgs.

Reach 9. GE collected approximately 115 floodplain soil samples along transects below Rising Pond Dam and near the Connecticut border. The average PCB soil concentration for these Reach 9 floodplain soil samples is 0.345 mg/kg and the maximum concentration detected is 3.7 mg/kg (1-2 ft bgs).

3.3.4.3 Floodplain Data Gaps

The extent of the Housatonic River floodplain increases significantly south of the confluence with the West Branch (Reaches 5 through 9) with a corresponding increase in the diversity of wetland habitats and depositional environments. The existing data do not adequately characterize the full diversity of the floodplain. Additional sampling and analysis are required to address this data gap and adequately characterize the contaminated floodplain soils in these reaches.

Due to the limited extent of the floodplain in Reaches 1 and 2, their location upstream of most of the GE facilities, and the relatively low PCB concentrations detected in river sediments in the two reaches, no additional sampling and analysis are necessary. This evaluation may be revised if elevated sediment concentrations are detected in Reaches 1 and 2.

The following specific data gaps were identified:

- Limited PCB results are available for floodplain soils in Reaches 5 through 9 considering the extent and diversity of the areas under investigation. Only a minimal number of floodplain samples were collected and analyzed in Reaches 6 through 9 considering the length of these river reaches.

- The historic data do not adequately represent conditions for all the identified habitat and land use types in Reaches 5 through 9. Additional sampling and analysis are required to assess human health risks at specific properties and public access areas.

- The bulk of the historic floodplain soil data represents surface soil samples (1 ft or less). Additional data are necessary to characterize the floodplain soils deeper than 1 ft.

- Floodplain soil data for PCBs in Reach 5 are highly variable, ranging from below detection limits to 430 mg/kg. The variability of the floodplain soil data in Reach 5 suggests that a higher density of soil sampling is required to adequately characterize the extent of contamination.

3.3.5 Surface Water Quality

The physical characteristics of the Housatonic River are described in Subsection 2.3. The Housatonic River within Massachusetts is designated as Class "B" water; designated uses include "habitat for fish, other aquatic life, and wildlife, and for primary and secondary contact recreation. Where designated, they shall be suitable as a source of public water supply with appropriate treatment. They shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses" (Massachusetts Surface Water Quality Standards, 314 CMR 4.05). The Lower River is not used as a water supply with Massachusetts.

Historically, the water quality of the Housatonic River has suffered from industrial and municipal discharges, as well as nonpoint sources. In general, as governmental regulations have increased, discharges to the river have decreased.

The City of Pittsfield discharged untreated sewage into the Housatonic River until construction of a wastewater treatment plant (WWTP) in approximately 1908. The primary treatment units were upgraded in 1963 and plant expansions, including the addition of nitrification, were conducted in 1975 and 1976. In 1989 a sludge dewatering facility and a 5-acre lined sludge landfill were constructed.

It was reported that the discharge from the Pittsfield WWTP and nonpoint sources resulted in high phosphorus concentrations in the Housatonic River between Pittsfield, MA, and Stevenson, CT. The Pittsfield and North Lenox WWTPs and unnamed industries were reported to be responsible for low dissolved oxygen (DO) and high coliform concentrations. Water quality in the Housatonic River reportedly improved when the Pittsfield WWTP and Danbury, Bethel, and New Milford, CT, WWTPs began practicing seasonal phosphorus removal.

Nonpoint sources of pollution from agricultural and residential lands are presumed to have some impact on the water quality in the Housatonic River. Nonpoint sources could also include landfills and hazardous waste sites that are reported to exist close to the river. Historically, several industries in the Pittsfield area, including tanneries, textile manufacturers, paper mills, foundries, and a silk mill, are thought to have contributed other hazardous constituents to the Housatonic River. However, few of these industries are still in operation.

Water quality currently appears to be impacted by plumes of NAPL from the Source Reach (Reach 3). In addition, runoff from contaminated source areas (such as the Unkamet Brook area), as well as resuspension of PCBs and other contaminants from sediments, adversely affects the water quality of the river.

3.3.5.1 Summary of Previous Investigations

Water quality sampling has been conducted at multiple depths and under low- and high-flow conditions in the river and Woods Pond from 1980 through the present (04-0004) (01-0021). The focus of these sampling events has been to determine the presence, extent, and/or transport of PCBs and other hazardous chemicals in the water column and to characterize general water quality as a potential limiting factor for aquatic life in the river (04-0004).

3.3.5.1.1 Lower Housatonic River

Six locations between the GE facility and Great Barrington were sampled for PCBs monthly from July 1989 to June 1990 and October 1990 to September 1991, for a total of 24 rounds of data. An additional location in Great Barrington and downstream locations in Connecticut were sampled for PCBs eight times between 1991 and 1993 (04-0004).

Five locations in Massachusetts were sampled between May and October 1993 to determine general water quality. Parameters measured included nitrate, nitrite, total ammonia, total kjeldahl nitrogen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), DO, pH, and temperature.

Surface water samples were collected for dissolved and particulate PCBs and total suspended solids from 12 to 14 locations within the river during six sampling events between November 1995 and August 1996. Landmarks such as bridges, abutments, and roads identify these locations (monthly reports November 1995 to August 1996) (04-0004).

During six sampling rounds from late November 1996 through February 1998, unfiltered PCB samples were collected at 11 to 13 locations. From March 1998 through October 1998, unfiltered PCB samples were collected twice a month at seven locations.

3.3.5.1.2 Suspended Solids

Suspended solids (i.e., collection of suspended solids from water column samples) harvesting was first conducted in the Housatonic River and Woods Pond in 1980 (02-0030). In 1995, sampling for suspended solids was conducted by BBL at five key locations (Newell Street Bridge, first Pomeroy Avenue Bridge, New Lenox Road Bridge, headwaters of Woods Pond, and Schweitzer Bridge). Although two sampling attempts were made, only the second attempt provided usable data. In 1995, sediment trap sampling was conducted by BBL, resulting in one sample with inconclusive results.

Suspended solids collection at the five key locations identified above occurred daily from 12 March 1996 through 3 May 1996. On 14 to 15 April and 1 May, sampling was conducted every 4 hours during 24-hour periods, and on 16 and 17 April sampling was conducted every 2 hours during a 24-hour period. Total suspended solids have also been collected during many of the PCB water sampling events. The Housatonic River high-flow sediment loading study was conducted between April and May 1998 at multiple locations between Coltsville, MA, and Bulls Bridge, CT.

Dry weather suspended solids sampling occurred during 17 to 28 June 1996, and composite samples were collected during each 24-hour period at five locations. The most recent sampling events have included particulate organic carbon analysis (POC) and chlorophyll analysis.

During the Building 68 Area Removal Action (May through June 1998), PCB, TSS, and turbidity samples were collected at two locations on the Housatonic River.

3.3.5.1.3 Lyman Street Area

Surface water samples have also been collected as part of other investigations. Samples were collected near the Lyman Street site (U.S. EPA Area 5) in October 1994 and October 1995 as part of the investigation of product sheen on the river. Samples were analyzed for VOCs, SVOCs, and PCBs (01-0019).

3.3.5.1.4 Unkamet Brook Area

Surface water quality has been measured within Unkamet Brook, before it enters the Housatonic River, and within the Housatonic River near Unkamet Brook. Housatonic River surface water near Unkamet Brook was sampled from 1981 through 1990. Surface water sampling in 1981 at the Unkamet Brook area was conducted for VOCs and PCBs at an unknown flow condition (01-0021). April 1990 and September 1990 sampling was conducted for Appendix IX constituents. The April sampling event occurred under high-flow conditions, and the September sampling event occurred under low-flow conditions. May and September 1991 surface water sampling in the Unkamet Brook area was conducted for Appendix IX +3 constituents. As in the 1990 sampling events, the spring event was conducted under high-flow conditions and the fall sampling event was conducted under low-flow conditions.

3.3.5.1.5 Dawes Avenue Bridge Area

Housatonic River surface water samples were collected for 10 days in November 1996 at the Elm Street Bridge and Dawes Avenue Bridge during bank stabilization activities associated with the Deming Street Immediate Response Actions. The samples were analyzed for PCBs.

3.3.5.2 Extent of Contamination

3.3.5.2.1 Lower Housatonic River

The 1991 to 1993 sampling in Great Barrington and downstream in Connecticut showed PCB concentrations ranged from below detection limits to 0.0011 ppm. Total suspended solids concentrations ranged from below detection limits to 588 ppm. Reportedly, the highest PCB and total suspended solids concentrations were detected during the 1992 repairs to Rising Pond Dam.

The November 1995 samples contained both Aroclor 1254 and Aroclor 1260 at levels ranging from below detection limits to 0.00034 ppm. The 1995 high-flow and low-flow sampling events were performed at the same sample locations as the 1991 high- and low-flow sampling events. The 1991 and 1995 events yielded very similar results, showing the same detected compounds, but at slightly lower levels in 1995. The 1995 results showed that metals and VOC concentrations in surface water are lower downstream of the GE facility than upstream of the GE facility, or that they are only slightly elevated below the GE facility (04-0004).

The May 1996 to October 1998 sampling showed the highest concentration of total (unfiltered) PCBs at the Holmes Road Bridge in September 1997 at 0.000949 ppm. The highest concentration of dissolved (filtered) PCBs from May 1996 to August 1996 (0.000172 ppm) was detected in a sample at the New Lenox Bridge in August 1996.

3.3.5.2.2 Suspended Solids Harvesting

Suspended solids sampling from 1995 to October 1998 yielded surface water PCB concentrations ranging from below detection limits to 0.0011 ppm. Total suspended solids ranged from 1.4 to 2,800 ppm. Concentrations of PCBs in suspended solids ranged from 1.4 to 78 ppm, and concentrations of total organic carbon in suspended solids ranged from non-detect to 47%.

3.3.5.2.3 Lyman Street Area

A surface water sample collected from the storm sewer outfall immediately west of the Lyman Street Bridge in October 1994 was found to contain several VOCs (including acetone, benzene, chlorobenzene, vinyl chloride, and xylene) and two SVOCs (1,3-dichlorobenzene, and 1,2,4-trichlorobenzene) but no PCBs. In October 1995, samples were collected at locations upstream, adjacent to, and downgradient of the storm sewer outfall. Several VOCs were detected at higher concentrations adjacent to the storm sewer outfall than at upstream and downstream locations. The highest VOC concentration detected was trichloroethene at 0.180 ppm (01-0019).

3.3.5.2.4 Unkamet Brook Area

The 1981 sample collected in the Housatonic River upstream of the confluence with Unkamet Brook contained trichloroethylene at 0.011 ppm, and chloroform at 0.022 ppm. The 1981 sample collected in the Housatonic River downstream of the confluence (S-12) contained chlorobenzene at 0.025 ppm. Constituents detected within Unkamet Brook, but not the Housatonic River, include toluene and 1,1,1-trichloromethane.

The 1990 sampling events included samples from the Housatonic River in locations upstream and downstream of Unkamet Brook. Metals were generally detected at lower levels downstream of the confluence of Unkamet Brook than upstream of the confluence. Two VOCs, benzene and chlorobenzene, were detected under low-flow conditions at the downstream location. Results were 0.008 ppm and 0.024 ppm, respectively. Endosulfan was also detected under low-flow conditions at a maximum concentration of 0.00014 ppm.

The 1991 samples collected in Unkamet Brook, upstream of the confluence (USW-10), contained total dissolved PCBs at 0.000066 ppm, as well as volatiles, semivolatiles, and metals.

3.3.5.2.5 Dawes Avenue Bridge Area

The surface water samples collected during construction of the Dawes Avenue Bridge for PCB analyses indicated Aroclor 1254 and Aroclor 1260 were detected at a total concentration of 0.000051 ppm at the Dawes Avenue Bridge. Aroclor 1260 was detected at the Elm Street Bridge on 19 November 1996 at 0.000027 ppm (Golder Associates, 01-0196).

In summary, the existing surface water quality data indicate that surface water contamination is present near source areas and the potential exists for downstream impacts. PCBs ranged from nondetect to 0.0011 ppm in surface water and nondetect to 78 ppm associated with suspended solids.

3.3.5.3 Data Gaps

There has not been a consistent suite of analytes because surface water sampling has occurred over time and with several different purposes. The detection limit for PCBs was above the Ambient Water Quality Criteria. In addition, analytical data have not always been included in monthly reports, although references to the sampling activities were found.

Additional TSS and PCB samples collected under storm-event conditions and a comprehensive analysis of all surface water data over time at various flow conditions are needed to help quantify transport and redistribution mechanisms for TSS and PCBs in the Housatonic River. These data are also needed to support a comprehensive hydrodynamic/water quality/sediment transport/fate and effects modeling study of the Housatonic River.

3.3.6 Modeling

Several modeling studies of various sections of the Housatonic River have been performed. In 1988, Lawler, Matusky & Skelly (LMS) (referred to as the "Chapter 6 Report" in document 02-0090) performed a hydraulic and water quality modeling study of the Housatonic River from the Falls Village Reservoir in Connecticut (River Mile 81.2, referenced to the mouth of the Housatonic River at Long Island Sound) to Stevenson Dam (River Mile 19.2). The WASTOX (Ver. 1) computer code was used in the study.

In 1991, LMS performed another modeling study (02-0090) using the WASTOX2 (Ver. 2.5.1) computer code. The study area was expanded northward to include the section of the Housatonic River between the Division Street Bridge in Great Barrington and Falls Village Reservoir, in addition to the section of river previously modeled in 1988. The report stated that the model results were sensitive to the assumption of whether the upstream source of PCBs was increasing in concentration, constant, or decreasing in concentration. In its conclusion, the report stated that "…no clear conclusions can be reached presently regarding a trend in PCB transport at Great Barrington."

A report by Blasland, Bouck & Lee (04-0004) contains a reference to floodplain modeling performed with the HEC-2 model in November 1994. In 1996 (04-0004), the HEC-2 model was modified to include additional cross sections representing a former dam in the Deming Street area, approximately 250 ft upstream of the Dawes Avenue Bridge. The former dam would have affected the floodplain and the model was modified to delineate the historical floodplain. Various flow rates were entered into the model until the floodplain profile achieved a “best fit” with the elevations of the 1-ppm PCB soil concentration isopleth. The flow rate that achieved the “best fit” corresponded to 2,950 cfs at the Coltsville, MA, gage. According to the report (04-0004), this corresponds to a 1-in-5-year flood frequency. The report also notes that the modeled floodplain extent for the 10-year flow event, corresponding to 3,700 cfs at Coltsville, MA, was not much different from the floodplain extent for the 5-year flow event.

Some modeling of the Housatonic River with the SEDTRAN computer model was performed, but copies of the modeling report have not yet been made available.

3.4 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

An initial screening of potential ARARs has been conducted to assist in guiding the data collection effort. This preliminary identification of potential ARARs includes those pertaining to environmental media other than soils/sediments, including groundwater and air, for completeness. Depending upon the findings of the field investigation under this and/or related tasks and depending upon the type(s) of actions ultimately considered, ARARs for these media may warrant consideration. ARARs will be identified during the Corrective Measures Study (CMS), and a final determination of the ARARs applicable to on-site actions will be made when EPA selects a remedy.

ARARs are divided into the following categories:

- **Chemical-specific requirements** are health- or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants.
- **Location-specific requirements** are restrictions on activities that are based on the characteristics of a site or its immediate environment. An example would be

restrictions on work performed in wetlands or wetland buffers. In this example, the location-specific requirements necessitate restoration of wetlands impacted by contamination and/or remedial activities.

- **Action-specific requirements** are controls or restrictions on particular types of activities, such as hazardous waste management or wastewater treatment. Examples of action-specific requirements would be state and federal requirements for disposal of excavated and dredged contaminated materials exceeding certain threshold concentrations.

The potential chemical-, location-, and action-specific ARARs for the Lower River are summarized in Tables 3.4-1, 3.4-2, and 3.4-3. A complete list of action-specific ARARs will be developed following the selection of remedial alternatives; however, potential action-specific ARARs are listed in Table 3.4-3. The table also provides a citation and a brief synopsis of chemical- and location-specific ARARs.

3.5 POTENTIAL REMEDIAL TECHNOLOGIES

Based on the available information regarding the types and extent of contamination and the physical setting of the site, a preliminary list of remedial alternatives, including technologies and process options, has been developed that may be applicable for consideration in the modeling study and subsequently in the CMS. Preliminary identification of these technologies and options is important in order to help guide the collection of site data, which will assist in evaluating the applicability of various options in the remedial action alternatives. This initial list is not considered to be inclusive of all options that might apply. However, it consists of major categories of technologies that are likely to be considered as remedial alternatives. In addition, the alternative of "no action," which does not include a technology or process, will be considered. In each of the following sections, the technology type is defined and specific types of data requirements are identified. Different technologies may be applicable to different areas within the Lower River.

3.5.1 River Diversion Technologies

River diversion technologies include methods to manage river water to allow access to, and removal of, contaminated sediments and riverbank soils. Methods that may be considered for all or parts of the river segment include:

Table 3.4-1

Summary of Potential Chemical-Specific ARARs

Media	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Federal			
Soil	Federal - Toxic Substances Control Act (TSCA) (40 CFR Part 761) PCBs Manufacturing, Processing, Distribution & Use Prohibitions	Regulates the use, storage, and disposal of PCBs. Establishes requirements for incineration, decontamination, and PCB spill cleanup. Lists strict compliance criteria for disposal of different concentration levels of PCBs.	To be determined (TBD)
Surface Water	Clean Water Act, Ambient Water Quality Criteria, 33 USC 1314, 40 CFR 131.36(b)(1), 63 Fed. Reg. 68359	National recommended criteria for surface water quality. PCB Criteria: For protection of freshwater aquatic life due to chronic exposure: 0.014 ppb For protection of human health from consumption of water and organisms: 0.00017 ppb Various numerical criteria for other constituents.	TBD
State			
Groundwater	Commonwealth of Massachusetts (314 CMR 6.00)	Establishes groundwater classification, water quality criteria, and groundwater regulations.	TBD
Surface Water	Commonwealth of Massachusetts (314 CMR 4.00) Surface Water Quality Standards	Massachusetts Surface Water Quality standards for toxic pollutants in Class B waters are essentially the same as Federal Ambient Water Quality Criteria.	TBD
Guidances Considered			
All	Cancer Slope Factors Requirement (CSFs)	Guidance values used to evaluate the potential carcinogenic hazard caused by exposure to contaminants.	TBD
All	Reference Doses (RfDs)	Guidance values used to evaluate the potential non-carcinogenic hazard caused by exposure to contaminants.	TBD

Table 3.4-1

Summary of Potential Chemical-Specific ARARs (Continued)

Media	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
All	PCBs: Cancer Dose - Response Assessment and Application to Environmental Mixtures, EPA/600/P-96/001F (September 1996)	Guidance regarding EPA's reassessment of the carcinogenicity of PCBs. It includes revised cancer slope factors for PCBs based upon the exposure pathway.	TBD
Soil/Sediment	Federal-EPA Guidance on Remedial Actions for Superfund Sites with PCB Contamination (August 1990)	Describes various scenarios and considerations pertinent to determining the appropriate level of PCBs that can be left in each contaminated media to achieve protection of human health and the environment.	This guidance will be considered in determining the appropriate level of PCBs that will be left in the sediment/soil. Management of PCB-contaminated residuals will be designed considering this guidance.
Sediment	Federal – EPA Sediment Quality Criteria for the Protection of Benthic Organisms	Published criteria for sediment contaminants, including several PAHs, and pesticides	TBD
Sediment	Ontario Ministry of Environment and Energy (OMEE) Sediment Quality Guidelines (Persaud et al., 1996)	Published guidelines for sediment contaminants, including metals, semivolatiles, pesticides, and PCBs.	TBD
Sediment	National Oceanic and Atmospheric Administration (NOAA) Sediment Quality Guidelines (Long et al., 1995)	Published guidelines for sediment contaminants, including metals, semivolatiles, pesticides, and PCBs.	TBD
Sediment	Sediment Effect Concentrations (SECs) for *Hyalella azteca* and *Chironomus riparius* (Ingersoll et al., 1996)	Published guidelines for sediment contaminants, including metals, PAHs, and PCBs.	TBD

Table 3.4-2

Summary of Potential Location-Specific ARARs

Location	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Federal			
Surface Water	Federal -CWA Ambient Water Quality Criteria (AWQC), Protection of Freshwater Aquatic Life and Human Health (40 CFR 131.36)	AWQC are developed under the Clean Water Act (CWA) as guidelines from which states develop water quality standards. A more stringent AWQC for aquatic life may be found relevant and appropriate rather than maximum contaminant level (MCL), when protection of aquatic organisms is being considered at a site.	May be used to establish treatment goals for water to be discharged to surface water.
Surface Water	Federal – Rivers and Harbors Appropriations Act (33 USC Sec. 403)	Prohibits excavation or fill of any modification of the course, location, or capacity of any waterway.	TBD
Water Resources	Executive Order for Wetlands Protection Exec. Order 11990 (1977) 40 CFR 6.302(a) 40 CFR Part 6, App. A	Federal agencies are required to avoid adversely impacting wetlands whenever possible, minimize wetland destruction, and preserve the value of wetlands.	All practicable means must be used to minimize harm to wetland areas. Wetland areas disturbed during remediation must be restored.
Water Resources	Executive Order for Floodplain Management Exec. Order 11988 (1977) 40 CFR Part 6, App. A. 40 CFR 6.302(b)	Federal agencies are required to reduce the risk of flood loss, minimize impact of floods, and restore and preserve the natural and beneficial values of floodplains.	All practicable means must be used to minimize harm to floodplain areas. Floodplains disturbed during remediation must be restored.
Water Resources	Fish & Wildlife Coordination Act Requirements 16 USC 662, 663 40 CFR 6.302(g)	Requires consultation with appropriate agencies to protect fish and wildlife when federal actions may alter waterways. Must develop measures to prevent and mitigate potential loss to the maximum extent possible.	Identify species of concern and potential impact based on selected remedial alternative.

Table 3.4-2

Summary of Potential Location-Specific ARARs (Continued)

Location	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Water Resources	Clean Water Act ' 404 Requirements 33 USC 1344 33 CFR Parts 320-323 40 CFR 230	For discharge of dredged or fill material into water bodies or wetlands, there must be no practical alternative with less adverse impact on aquatic ecosystem; discharge cannot cause or contribute to violation of state water quality standard or toxic effluent standard or jeopardize threatened or endangered (T&E) species; discharge cannot significantly degrade waters of U.S.; must take practicable steps to minimize and mitigate adverse impacts; must evaluate impacts on flood level, flood velocity, and flood storage capacity.	Any activities that involve the discharge of dredge or fill materials to aquatic ecosystems shall be conducted in a manner using the alternative that would have the least adverse impact on the aquatic ecosystem and the environment. Wetlands and floodplains disturbed during remediation will be restored.
Endangered Species Habitat	Endangered Species Act 16 USC 1531 *et seq.* 50 CFR Part 402 50 CFR Part 17.11-17.12 40 CFR 6.302(h)	This Act requires action to avoid jeopardizing the continued existence of listed endangered or threatened species or destruction or adverse modification of critical habitat. Also must consult with Department of Interior.	Confirm whether endangered or threatened plant or animal species are present at the site, and if so, take actions to comply with act.
Water Resources	Federal – Wild and Scenic Rivers Act (30 CFR 297)	This act protects the aesthetic quality of rivers	TBD
Natural Resources	Federal – Wilderness Act (16 United States Code [USC] Section 1131 *et seq.*; 50 CFR 35.1 *et seq.*)	This act establishes nondegradation, maximum restoration, and protection of wilderness areas as primary management principles.	TBD
Historic Resources	Preservation of Historical and Archaeological Data Act and National Historic Preservation Act 16 USC 469 et seq. 36 CFR Part 65 16 USC 470 et seq. 36 CFR Part 800	Establishes requirements for the recovery and preservation of historical and archaeological data. Also requires measures to minimize harm to historic resources.	Actions required if historical or archaeological resources could potentially be encountered during remediation.

Table 3.4-2

Summary of Potential Location-Specific ARARs (Continued)

Location	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
State			
Floodplain	Hazardous Waste Facility Siting Regulations (990 CMR 1.00)	These regulations outline the criteria for the construction, operation, and maintenance of a new facility or increase in an existing facility for the storage, treatment, or disposal of hazardous waste. No portion of the facility may be located within a wetland or bordering a vegetated wetland, or within a 100-year floodplain, unless approved by the state.	Location of treatment facilities will be considered based on remedy selected.
Water Resources	Mass. Wetlands Protection Act and Regulations MGL c. 131 ' 40 310 CMR 10.00	Regulations restrict dredging, filling, altering, or polluting inland wetland resource areas and impose performance standards for work in such areas. Protected resource areas include: 10.54 (Bank); 10.55 (Bordering Vegetated Wetlands); 10.56 (Land under Water); 10.57 (Bordering Land subject to Flooding); and 10.58 (Riverfront Area).	Each remedial alternative will be evaluated for its ability to attain regulatory performance standards, including mitigation of impacted wetland. Whenever possible, remedial actions will be conducted so that impacts to wetlands and habitats will be minimized or mitigated.
Water Resources	Mass. Clean Water Act – Water Quality Certification Regulations 314 CMR 9.06 314 CMR 9.07	For discharge of dredged or fill material, there must be no practicable alternative with less adverse impact on aquatic ecosystem; must take practicable steps to minimize adverse impacts on wetlands or land under water; stormwater discharges must be controlled with BMPs; must be no substantial adverse impact to physical, chemical, or biological integrity of surface waters.	Any activities that involve the discharge of dredge or fill materials to aquatic ecosystems shall be conducted in a manner using the alternative that would have the least adverse impact on the aquatic ecosystem and the environment.
Areas of Critical Environmental Concern	Commonwealth of Massachusetts (301 CMR 12) Areas of Critical Environmental Concern	Designates areas within Massachusetts that are of regional, state, or national importance and/or that contain significant ecological systems with critical interrelationships among a number of components. Provides for preservation and/or restoration of these areas.	Determine if there are any Areas of Critical Environmental Concern within the project area. Each remedial alternative will be evaluated for its ability to preserve and/or restore designated areas.

Table 3.4-2

Summary of Potential Location-Specific ARARs (Continued)

Location	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Rare Species Habitat	Commonwealth of Massachusetts Wetlands Protection Program Policy 90-2; (310 CMR 10.37 and 10.59) Standards and Procedures for Determining Adverse Impacts to Rare Species	This policy clarifies the rules regarding rare species habitat.	Habitats of rare species, as determined by the Massachusetts Natural Heritage Program, will be considered in the mitigation plans. The study area will be surveyed for the occurrence of rare plants and animals and the likely habitat of any rare species present mapped.
Wetland Resource Area	Commonwealth of Massachusetts Regulations (310 CMR 19) Solid Waste Management	Outermost limits of the waste deposition area for new landfills ▪ 100 ft from property boundary ▪ 500 ft from residence ▪ 100-200 ft from a resource area protected by Wetlands Protection Act (Ch. 131, Section 40 of the Wetlands Protection Act)	TBD
Historic Resources	Mass. Historical Commission Act and Regulations MGL c. 9 ' 27C 950 CMR 71.07	Adoption of prudent and feasible measures to eliminate, minimize, and mitigate impacts on historic properties.	Actions required if historical or archaeological resources will be affected during remediation.

Table 3.4-3

Summary of Potential Action-Specific ARARs

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Federal			
Groundwater Monitoring	Federal – RCRA (40 CFR 264.90-264.101 and 265.90-265.94, Subpart F), Releases from Solid Waste Management Units	General facility requirements for groundwater monitoring at affected facilities and general requirements for corrective action programs if required at regulated facilities.	Groundwater monitoring should be conducted in accordance with these requirements.
Surface Water Discharge	National Pollution Discharge Elimination System (NPDES) (40 CFR 122)	Regulates the discharge of water into public surface waters. Among other things, major requirements are: ▪ Use of best available technology (BAT) economically achievable is required to control toxic and non-conventional pollutants. Use of best conventional pollutant control technology (BCT) is required to control conventional pollutants. Technology-based limitations may be determined on a case-by-case basis. ▪ Applicable federally approved state water quality standards must be complied with. These standards may be in addition to or more stringent than other federal standards under CWA.	If wastewater will be discharged off-site via surface water, any discharge will comply with the substantive provisions of these regulations.
Surface Water Discharge	TSCA Regulations 40 CFR 761.50(a)(3)	Prohibits discharge of water containing PCBs to navigable waters unless PCB concentration is less than approximately 3 ppb or in accordance with discharge limits of NPDES permits.	Surface water discharge should comply with this requirement.
Stormwater Discharges	Clean Water Act NPDES Regulations 40 CFR 122.26(c)(l)(ii)(C) 40 CFR 122.44(k) 40 CFR 125.100-.104	Best management practices to control pollutants in stormwater discharges during construction activities.	Best management practices for erosion and sedimentation control will be adopted to minimize the potential for rainfall or flood-induced migration of soils and sediments from disturbed areas.

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Soil/Solid Waste Management	Federal – RCRA (40 CFR 264.110-264.120 and 265.110-265.120, Subpart G), Closure and Post Closure Disposal Units. Requirements for closing the landfill and routine monitoring of the groundwater around the landfill for a period of up to 30 years after closure of the landfill.	Owners or operators of a landfill must develop and submit plans that identify the activities that would be performed to close (i.e., cap) the landfill and the activities that would be conducted during the post-closure.	TBD
Floodplains Treatment	Federal – RCRA General Facility Standards (40 CFR 264.18(b))	Facility where RCRA hazardous wastes would be treated, stored, or disposed of, that lies within a 100-year floodplain must be designed to prevent washout of any hazardous wastes in the event of a 100-year flood.	TBD
Floodplains/Fault Zones siting	Federal – Criteria for Location Acceptability and Existing Regulations for Evaluating Locations (40 CFR 264.18)	Guidance on what parameters should be evaluated when selecting the location for a RCRA site.	TBD
TSD Facility Standards	Federal – RCRA (40 CFR Part 264.30.37 Subpart C) Preparedness and Prevention	Identifies requirements that must be met during design, construction, and operation of Treatment Storage and Disposal (TSD) facilities to minimize the possibility of fires, explosions, or unplanned releases of wastes.	Remedial activities relating to any TSD facilities should be conducted in accordance with these requirements.

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Contingency Plan Preparation	Federal – RCRA (40 CFR Part 264.50-264.56 Subpart D), Contingency Plan and Emergency Procedures	Identifies requirements that must be addressed in a contingency plan. Each TSD facility must have a contingency plan that identifies all procedures to be followed in the event of a fire, explosion, or planned release from the facility.	Remedial activities relating to any TSD facilities should be conducted in accordance with these requirements.
Tank System Design, Installation, and Operation	Federal – RCRA (40 CFR Part 265.190-198, 265.190-265.197 Subpart J) Requirements for the design, installation, and operation of any tanks or tank systems that are used to store or treat hazardous liquids or sludges.	Tanks or tank systems that are to be used to temporarily store hazardous liquids or as part of a treatment system for hazardous liquids or sludges must be designed, installed, and operated in accordance with the RCRA standards.	Tanks used in any groundwater or soil treatment systems should comply with these regulations.
Hazardous Waste Identification	RCRA Hazardous Waste Regulations (Identification and Listing of Hazardous Wastes; Toxicity Characteristics)	Identifies concentration of contamination, which, if present, make a waste hazardous due to toxicity. The analytical test set forth in Appendix II of 40 CFR part 261 is referred to as the Toxicity Characteristic Leaching Procedures.	TBD
TSD Facility Operation	Federal – RCRA (40 CFR 264.10-264.18 Subpart B) General Facility Standards	This subpart applies to all owners and operators of hazardous waste facilities. The subpart identifies procedures that must be followed for the operation and maintenance of a hazardous waste TSD facility.	Any groundwater or soil treatment systems should comply with all applicable portions of this requirement.
Storage of Hazardous Soil	Federal – RCRA (40 CFR Part 264.250-264.259, 265.250-265.258 Subpart L) Design and operation procedures for waste piles that are used to temporarily store hazardous soils or sludges.	General design and operation requirements for temporary storage of hazardous soils. Locations must have an impermeable liner and materials stored in piles must be free of standing liquid.	The temporary stockpiling of excavated soil on-site should be performed in compliance with these regulations.

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Storage of Hazardous Waste	Federal – RCRA (40 CFR 264.170-264.178 and 265.170-265.178 Subpart I) Use and Management of Containers	This subpart contains requirements for owners and operators of TSD facilities that store containers of hazardous wastes.	Any storage of hazardous wastes should comply with all applicable portions of these requirements.
Storage of PCB Remediation Waste	TSCA Regulations (Storage for Disposal), 40 CFR 761.61(c), 40 CFR 761.65	Provides for risk-based approval to store PCB-remediation waste based upon demonstration that storage plan will not pose an unreasonable risk of injury to health or the environment.	Any storage of PCB remediation waste should comply with temporary storage area requirements.
Excavating/ Dredging	TSCA Regulations re PCB Remediation Waste 40 CFR 761.61(c)	Establishes cleanup options for PCB remediation waste, including PCB-contaminated soils and sediments. Options include risk-based approval by EPA. Risk-based approval option must demonstrate that cleanup plan will not pose an unreasonable risk of injury to health or the environment.	TBD
Hazardous Waste Disposal	Federal - RCRA (40 CFR 264 Subpart L) Waste Pile Requirements (Subtitle C)	Requires two or more liners and a leachate collection and removal system above and between such liners. In addition, the waste pile must be designed and constructed to control runon and runoff.	Excavated materials are not expected to be classified as listed or hazardous waste under federal law. However, technical requirements may be considered relevant and appropriate.
Hazardous Waste Disposal	Federal - RCRA (40 CFR 264 Subpart N, Subtitle C) Landfills	Requires two or more liners and a leachate collection and removal system above and between such liners. In addition, the landfill must be designed and constructed to control runon and runoff.	Excavated materials are not expected to be classified as listed or hazardous waste under federal law. However, technical requirements may be considered relevant and appropriate.
Thermal Treatment	RCRA Hazardous Waste Regulations, Subpart P 40 CFR 265.370	Operating standards for thermal treatment units	TBD

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Ambient Air Regulations	Federal - Clean Air Act (CAA) (40 CFR 50.6)	Air quality regions must maintain maximum primary and secondary 24-hr National Ambient Air Quality Standards (NAAQS) concentration for particulate emissions below 150 $\mu g/m^3$, 24-hour average for particulates having a mean diameter of 10 micrometers or less. The annual standard is 50 $\mu g/m^3$, annual arithmetic mean.	If remedial actions may cause the air quality region to exceed standards, air dispersion monitoring will be performed to evaluate potential impacts of remedial actions to ambient air.
Air	Federal - New Source Performance Standards (NSPS) (40 CFR 60) and National Emissions Standards for Hazardous Air Pollutants (40 CFR 63)	Selected remedies should be evaluated to determine if they meet any of the air emission devices regulated under these requirements. These requirements typically include emission standards for specific pollutants and monitoring and recordkeeping.	TBD
State			
Dewatering	Commonwealth of Massachusetts Ground Water Discharge Permit Program (314 CMR 5.00)	These standards require any facility that discharges a liquid effluent onto or below the land surface to obtain a permit. The discharge shall not result in a violation of Massachusetts Surface Water Quality Standards 314 CMR 4.00 or Massachusetts Ground Water Quality Standards 314 CMR 6.00.	TBD
Surface Water Discharge	Commonwealth of Massachusetts (314 CMR 3.00) Surface Water Discharge Permit Program	Regulates discharges of pollutants to surface waters of the Commonwealth. Regulates outlets and/or treatment works associated with these discharges. Discharges shall not result in a violation of Massachusetts Surface Water Quality Standards (314 CMR 4.00) or Groundwater Quality Standards (314 CMR 6.00)	Any surface water discharge will comply with the substantive provisions of these regulations.

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Surface Water Discharge	Commonwealth of Massachusetts (314 CMR 4.00) Surface Water Quality Standards	These standards designate the most sensitive uses for which the various waters of the Commonwealth shall be enhanced, maintained, and protected. Minimum water quality criteria required to sustain the designated uses are established. Federal AWQC are to be considered in determining effluent discharge limits. Any on-site water treatment and discharge is subject to these requirements.	TBD
Stormwater Management	Commonwealth of Massachusetts 310 CMR 3.00 Surface Water Discharge Permits, 314 CMR 4.00 Massachusetts Surface Water Quality Standards, 314 CMR 9.00401 Water Quality Certification (40 CFR 125.1-125.3)	New stormwater performance standards will be established to set uniform criteria for adequate stormwater management and best management practices manual as supplementary guidance. These standards will be consistent with requirements of the Acts listed and named the Stormwater Initiative.	Remedial actions taken within the river will be consistent with the Stormwater Initiative.
Wastewater Discharge	Commonwealth of Massachusetts-Sewer System Extension and Permit Program (314 CMR 7.00), Operation and Maintenance and Pre-Treatment Standards for Wastewater Treatment Works and Indirect Discharges (314 CMR 12.00)	Regulates the discharge of industrial wastewater into the sanitary sewer system.	If wastewater cannot be discharged on-site or to surface water, it may be discharged off-site via the sanitary sewer. Wastewater will be pretreated if necessary.

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Wastewater Treatment	Commonwealth of Massachusetts Supplemental Requirements for Hazardous Waste Management Facilities (314 CMR 8.00)	Water treatment units that are exempt from M.G.L.21C and which treat, store, or dispose of hazardous wastes generated at the same site are regulated to ensure that such activities are conducted in a manner that protects public health and safety and the environment.	If on-site treatment of wastewater is performed, all processes will comply with Massachusetts's requirements regarding location, technical standards, closure and post-closure, and management standards.
Excavating/ Dredging	Commonwealth of Massachusetts Water Quality Certification for Discharge of Dredged or Fill Material, Dredging and Dredged Material Disposal in Waters of the United States within the Commonwealth (314 CMR 9.00)	The substantive portions of these regulations establish criteria and standards for the dredging, handling, and disposal of fill material and dredged material.	TBD
Hazardous Waste Disposal	Commonwealth of Massachusetts Hazardous Waste Regulations (310 CMR 30.640 – 310 CMR 30.649 – Waste Pile Requirements)	Requires a liner that is a minimum of 4 ft above the probable high groundwater level and a leachate collection and removal system above the liner. In addition, the waste pile must be designed and constructed to control runon and runoff. Each owner using a single-lined waste pile shall comply with 310 CMR 660: Groundwater Protection.	TBD
Hazardous Waste Disposal	Commonwealth of Massachusetts Hazardous Waste Regulations (310 CMR 30.620 – 310 CMR 30.633 – Landfill Requirements)	Requires a double liner composed of, at a minimum, a composite liner, a drainage layer, and a leachate collection system. The bottom liner shall be at least 4 ft above the probable high groundwater level. In addition, the landfill must be designed and constructed to control runon and runoff.	TBD

Table 3.4-3

Summary of Potential Action-Specific ARARs (Continued)

Action	Requirement	Requirement Synopsis	Action To Be Taken To Attain Requirements
Hazardous Waste Management	Mass. Hazardous Waste Management Facility Regulations (General Management Standards) 310 CMR 30.513-30.516 and 30.521-30.524.	Requirements regarding waste analysis, security, inspections, personnel training, contingency plans, and standards for emergency prevention and response.	TBD
Air	Commonwealth of Massachusetts Air Pollution Control Regulations (310 CMR 7.00, 310 CMR 7.00 Appendix C: Operating Permit Program)	310 CMR 7.02 requires a Limited Plan Application (LPA) prior to construction if potential emissions exceed 1 tpy (including fuel combustion products) or if fuel input to the process exceeds 10 MBtu/hr natural gas, propane, or distillate oil. A Comprehensive Plan Application (CPA) is required if potential emissions exceed 5 tpy or if the fuel input to the process exceeds 40 MBtu/hr natural gas or propane or 30 MBtu/hr distillate fuel. 310 CMR 7.02 generally requires the source to achieve Best Available Control Technology (BACT). Massachusetts regulates PCBs as a Hazardous Air Pollutant (HAP). If the source has the potential to emit greater than 10 tons per year (tpy) of a single HAP, 50 tpy of VOC or NO_x, or 100 tpy of any other regulated air pollutant, an operating permit is required. Furthermore, the selected remedial actions may fall under the definition of an incinerator per 310 CMR 7.08.	TBD

- Open channel diversion (intrusive, e.g., sheetpiling).
- Open channel diversion (non-intrusive, e.g., Jersey barriers).
- Gravity feed bypass piping.
- Bypass pump and piping.
- Alternate river channel.

Data needed to evaluate these methods include river flow characteristics, channel geometry, information on sediment characteristics and depth, topography of the floodplain, and geotechnical information for the riverbed, riverbanks, and floodplain.

3.5.2 Sediment and Riverbank Soil Removal Technologies

This technology would consist of physical removal of contaminated sediments and soils above the cleanup criteria. Removal of sediments and soils can be accomplished with excavation or dredging equipment, either below the water (in the "wet") or by diverting the river in sections around the removal area to access the material. Excavation/dredging along the river may use conventional equipment or a variety of excavation or dredging methods that are commercially available to meet specific requirements. Technologies that minimize ecological impacts must be considered. Several site-specific factors may require special consideration, including the following:

- Access to the river from surrounding topography may be difficult due to the configuration of the stream channel in some sections. This difficulty of access may require the use of long-reach excavators or other specialized techniques.

- Sediment contamination may be found at relatively shallow depths (less than 2 ft) in the river sediment and may require the use of thin layer excavation techniques to minimize unnecessary disturbance of the stream channel and to minimize the quantity of sediment to be disposed of.

- The banks of the river and the wetland/floodplain areas may be relatively soft, requiring the use of low ground pressure (LGP) equipment in these areas.

- The wetlands and floodplain areas will need to be protected and/or restored to regain the habitat, structure, and functions that currently exist.

- Sediment in ponds and/or behind dams and in deeper runs of the river may occur at a significant depth below the water surface and require barge-mounted dredging equipment to access these sediments for removal.

- In general, the sediments in impoundments are likely to be very fine-grained as opposed to the coarser materials that may be found in the river. This may affect the selection of excavation/dredging and/or dewatering methods

- For reaches where hydraulic dredging may be implemented, dredged material will need to be pumped to a dewatering pond for initial settling and clarification of excess water unless it is pumped directly to a confined disposal facility.

Data and information that are needed to evaluate these issues include:

- Information on contaminant distribution.

- Topographical information along the stream reach (particularly at major changes in topography) to evaluate construction access.

- Information on floodplain and wetlands locations and ecological characterization.

- A geotechnical evaluation of the soil characteristics and subsurface conditions on the floodplain, riverbanks, and riverbed relative to construction requirements.

- Settling data pertinent to hydraulically dredged sediments.

- Grain size versus PCB concentration data.

3.5.3 Treatment and Disposal Technologies

3.5.3.1 Soil/Sediment Treatment

EPA guidance indicates that the CMS alternatives should consider the CERCLA preference for treatment over containment or land disposal to address site threats. The CMS will identify technologies, process options, and alternatives for evaluation that include treatment of contaminated soils/sediments. Based upon preliminary evaluation, treatment of the excavated media may include thermal treatment, physical/chemical treatment, biological treatment, and soil washing or solvent extraction technologies to remove PCBs or other contaminants from the materials. On-site and off-site disposal alternatives may also require treatment to meet disposal facility acceptance requirements such as moisture limitations and RCRA characteristics.

It is also likely that these sections of the river may exhibit relatively low levels of contamination, including contaminant levels marginally above cleanup criteria. Therefore, the CMS should carefully consider any suitable in situ treatment technologies to address these areas.

Evaluation of treatment technologies will require:

- Chemical data (contaminants of concern and RCRA characteristic parameters).
- Physical properties of the soils/sediments such as moisture content, particle size distribution, etc.
- Remedy screening and/or remedy selection treatability testing that may be appropriate during the CMS process.
- An assessment of the availability of off-site TSD facilities.
- Evaluation of potential on-site treatment, disposal, and consolidation areas.

RCRA characteristics data are considered to support the evaluation of off-site disposal.

3.5.3.2 Natural Attenuation

The CMS for the Lower River may consider natural processes as a potential approach for some or all stretches of the river. Natural processes that could be considered may range from natural attenuation (degradation and/or immobilization in the soil/sediment matrix) to natural recovery by deposition of clean sediments as a barrier layer above the contamination.

The concept of natural attenuation by biologic degradation and physicochemical processes has been reasonably established for certain constituents (petroleum and simple chlorinated organics) in groundwater, but limited information exists for PCBs. GE has already evaluated biodegradation in both Woods Pond and Silver Lake sediments and has site-specific data regarding the potential for this alternative, but has not to date issued a report summarizing its findings. These data typically include analyses for the constituents of concern, characteristic breakdown products, and data on redox conditions and electron acceptors and soil/sediment partitioning data. In the case of chlorinated organics, redox and electron acceptor data are used to evaluate the potential for reductive dechlorination and more generally to evaluate the potential for anaerobic or aerobic microbial processes. Since both aerobic and anaerobic dechlorination mechanisms may apply to at least some PCB congeners, these data may be of use in examining natural attenuation. Both the spatial and temporal distribution of natural attenuation data are important in evaluating the results. In addition, data on soil/sediment properties that may result in attenuation by physical/chemical processes (such as adsorption) should be included in this analysis.

Evaluation of natural recovery would focus primarily upon evaluating the sediment data at depth and modeling of the rate of sediment deposition as a protective layer.

3.5.3.3 In Situ Capping

This alternative would consist of using engineered methods to cover the sediments and hydraulically stabilize the stream channel to prevent erosion of the materials and transport downstream. Potential technologies for accomplishing this could range from channelization of the stream, to the use of synthetic covers combined with riprap or similar methods to prevent erosion, simple placement of clean material, or possibly more innovative methods yet to be determined. In general, the evaluation of such options will require:

- Data on the extent of contamination.
- Data on physical soil properties.
- Data on the physical configuration of the stream bed (i.e., topographic data).
- River flow properties (flow and flood characteristics).
- Investigation to determine design cap thickness and cap composition.
- Groundwater infiltration rate(s) into the riverbed.

3.5.3.4 Off-Site Disposal

Soil and sediment excavation from the river may require loading, transport to, and disposal at a licensed facility. Information for evaluating this option will include:

- Chemical characteristics of the soil and sediment relative to disposal criteria (chemical data and/or RCRA characteristics).

- Information on physical properties of soil and sediment (moisture content, grain size, etc.) since disposal will require the absence of free liquids and dewatering of the excavated materials may therefore be required.

3.5.3.5 On-Site Disposal

As an alternative to off-site disposal, redisposal on-site (GE facility) may be considered as an option. The on-site disposal would involve excavation, loading, and transport to a suitable location for consolidation in prepared containment cells. The specific location and configuration of this cell would be determined based upon the soil/sediment volume requiring consolidation, its physical/chemical characteristics, site constraints, and regulatory requirements. The location could include construction of a Confined Disposal Facility (CDF) adjacent to the river.

Siting of an on-site disposal facility will be subject to the ARARs finally determined to be applicable to such a facility (see Subsection 3.4 of this Work Plan). These requirements may include the following prohibitions:

- Disposal of material within a floodplain or within a minimum setback (typically 100 ft) from the floodplain.
- Disposal of material in a wetland area or within a minimum setback (typically 100 ft) from the wetland.
- The base of the disposal cell must be a minimum of 4 ft above the probable high groundwater level.
- The presence of endangered or threatened plant or animal species or a historic or archaeological resource.

Exemptions from some of the siting prohibitions may be obtained on a case-by-case basis providing certain qualifying criteria are met.

Soil and sediment data requirements for this option are similar to those for off-site disposal, i.e.:

- Chemical characteristics of the sediment relative to disposal criteria (PCB chemical data and/or RCRA characteristics). These data will determine, in part, pretreatment requirements for consolidation.
- Information on physical properties of soil/sediments (moisture content, grain size, etc.) since disposal will require the absence of free liquids and dewatering of the excavated materials may therefore be required.

3.5.4 Restoration Technologies

Riverbank and riverbed restoration technologies will be necessary in areas where soils and sediments have been removed to provide for both the long-term stability of the stream channel and an appropriate ecological habitat. Technologies that may be evaluated include:

- Riverbank Restoration

1. Revegetation with native species
2. Bioengineered structures
3. Hard structures

- Riverbed Restoration

1. Improving substrate conditions
2. Erosion protection systems
3. Pool/riffle construction
4. Aquatic cover

Data needed to evaluate these alternatives include river flow characteristics, channel geometry, sediment characteristics, and information on the current ecological conditions along the stream.

4. WORK PLAN RATIONALE

4.1 SUPPLEMENTAL INVESTIGATION OBJECTIVES

The main objectives of the SI are as follows:

- Provide surface water, hydrology, and sediment data to support the development of a site-specific hydrodynamic sediment transport and PCB fate and transport models.
- Characterize and sample biological media and ecological communities to support human health and ecological risk assessments and analysis of remedial alternatives in the context of risk.
- Develop site-specific human health and ecological risk assessments (RAs) for the Lower River.
- Understand the nature and extent of the soil and sediment contamination in the Lower River and associated floodplain by PCBs and other contaminants and provide pathways of contaminant migration for use in the modeling study and human health and ecological risk assessments.

An evaluation of the current set of data available for the Lower River is also presented in Section 3 of this SIWP. The evaluation includes a summary of available data from previous reports prepared for GE and a brief review of data quality and usability. The data evaluation provides the information required to: (1) identify potential spatial and temporal data gaps, (2) evaluate the quality of the analytical data and the completeness of the analytical parameters investigated and/or reported, and (3) formulate the conceptual models for the risk assessments and modeling study.

4.2 DATA REQUIREMENTS

Various types of site-related data are required to support the investigation objectives identified above. Although all of the data collection efforts will provide better definition of the location and concentration of PCBs and other contaminants, the principal data requirements are discussed separately in the following subsections. Data collection and evaluation efforts identified with a specific objective, e.g., to support the ecological risk assessment, can often be used for other objectives as well. Data of all types will be entered into a site GIS database and will be available for use where appropriate in addition to the application to the principal objective. The studies and data collection programs proposed for this investigation and their general purposes are listed in Table 4.2-1.

4.2.1 Hydrodynamic and Fate and Effect and Water Quality Modeling

The objectives of the hydrodynamic and fate and effect and water quality modeling task are to:

1. Quantify future spatial and temporal distribution of PCBs (both dissolved and particulate forms) within the water column and bed sediment.
2. Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment.
3. Quantify the historical and relative contribution of various PCB sources to bioaccumulation in targeted species.
4. Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of “clean” sediment (i.e., natural recovery).
5. Estimate the time required for PCB concentrations in fish tissue or other biota to be reduced to levels that no longer pose either a human health or ecological risk based on various remediation and restoration scenarios, including natural recovery.
6. Quantify the relative risk(s) of extreme storm event(s) contributing to the resuspension of sequestered sediment or the redistribution of PCB-laden sediment within the area of study.

The modeling tools and data collection tasks were selected to meet these objectives. The modeling study will be more fully described in the Modeling Framework Design document.

The modeling study consists of three separate but interrelated models. Each model has its own data requirements, which are described below. The three models are:

1) Watershed Model

   The Hydrological Simulation Program—Fortran (HSPF) (Bicknell et al., 99-0146) will be used as the watershed model. HSPF will be used to simulate watershed hydrology including runoff, sediment transport, and runoff water quality.

Table 4.2-1

Investigations Summary

Data Collection or Sampling Program	Data Purposes: Human Health Risk Assessment	Ecological Risk Assessment	Ecological [a] Characterization	Hydrodynamic/Water Quality/Fate and Effects Model
Abiotic Investigations				
Sediment Sampling	x	x		x
Soil Sampling	x	x		x
Pore Water Sampling				x
Surface Water Sampling	x	x		x
Channel Geometry Cross Sections				x
Flow Monitoring				x
Stormwater Sampling				x
Air Sampling	x[b]			x
Biological Investigations				
Characterization				
Rare Plants & Natural Communities Survey			x	
Dragonfly Survey			x	x
Freshwater Mussel Survey			x	x
Reptile and Amphibian Use Survey		x	x	
Raptor and Waterfowl Surveys			x	
Forest and Marsh and Wading Bird Surveys			x	
River Otter, Mink, and Bat Surveys			x	
Risk Assessment				
Macrophytes Sampling		x		x
Filamentous Algae Sampling		x		x
Periphyton Sampling		x		x
Plankton/Detritus Sampling		x		x
Benthic Macroinvertebrate Survey		x		x
Sediment Macroinvertebrate Toxicity, Bioaccumulation & Stressor Testing		x		x
In situ Freshwater Mussel Bioaccumulation Study		x		x
Crayfish Tissue Analysis		x		x
Bullfrog Tissue Analysis	x	x		
Amphibian Vernal Pool Reproductive Success Study		x		
Amphibian Toxicity Testing		x		
Fish Tissue Sampling and Processing	x	x		x
Fish Health and Toxicity Testing		x		x
Soil Invertebrate Tissue Analysis		x		
Duck Collection and Tissue Analysis	x	x		
Tree Swallow Study		x		
Small Mammal Use Study		x		
Mink Toxicity Testing		x		
Dairy Land Use/Practice Investigation	x			
Corn Sampling	x			
Edible Vegetation Sampling	x			

[a] Studies performed primarily for ecological characterization may also be discussed in the ecological risk assessment.
[b] Air sampling data will be used in the human health risk assessment if the PCB concentrations in air are found to be a significant source of exposure.

2) Hydrodynamic Model

The Environmental Fluid Dynamics Code (EFDC) (Hamrick, 99-0147) will be used to simulate the hydrodynamics of flow and sediment transport in the Housatonic River.

3) Fate and Effect and Water Quality Model

The AQUATOX model will be used to simulate water quality and fate and effect of contaminants, such as PCBs, in aquatic organisms.

The three models are connected sequentially as follows: the watershed model, HSPF, simulates runoff, interflow, and groundwater recharge to the river as well as sediment and water quality mass loadings to the river. The hydrodynamic model, EFDC, will accept runoff information from the watershed model, HSPF, and provide a dynamic (time-varying) picture of flow and sediment movement in the river. The fate and effect model, AQUATOX, will use the dynamic flow and sediment movement information from EFDC as input to simulate contaminants in the water and on sediment and their fate and effect in target aquatic organisms.

The data needed to support the watershed model, HSPF, include weather data (precipitation, air temperature, dew point, cloud cover, etc.) and watershed data (area, slope, land use/land cover, soil characteristics, and other characteristics affecting runoff and sediment transport from the watershed).

The hydrodynamic model, EFDC, requires data on river channel geometry, slope, river segment connectivity, weather data, tributary, and direct runoff and sediment loadings. Also required are calibration and validation data sets of measured flow in the river over a wide range of seasonal and flow conditions. The monthly stormflow sampling activities were designed to address these data needs.

The data needed to support the fate and effect model, AQUATOX, include dynamic water quality data on nutrients and contaminants in the river, uptake and utilization rates of the target aquatic organism(s), and information on how nutrients cycle through the ecosystem.

4.2.2 Risk Assessment Data Requirements

A preliminary conceptual site model (Figure 4-1) for the human health risk assessment was developed for the Lower River, based on the current understanding of PCB contamination in the river and the adjacent floodplains, the environmental setting, and the current floodplain and river use. The conceptual site model identifies the sources of PCBs to the Lower River, the release mechanisms from those sources, migration pathways, and potentially exposed receptors. The model also identifies the exposure routes that will be evaluated both quantitatively and qualitatively for each proposed exposure scenario. A comparison of available data with the conceptual site model was made to determine the need to obtain additional characterization information necessary to support the human health risk assessment. The data needs were developed based on the amount of usable data, the current and reasonably foreseeable future land uses, the potential human receptors, and the site-specific conditions and the degree to which this information is sufficient to support a baseline human health risk assessment.

A conceptual site model for the ecological risk assessment is presented in Subsection 7.2.4. This conceptual model identifies the PCB fate and transport mechanisms within the study area, complete exposure pathways, and basic questions regarding the relationship of measurement endpoints to the assessment endpoints. Table 4.2-2 presents the assessment and measurement endpoints that will be evaluated and the corresponding sections of the Work Plan that provide the rationale and procedures that will be followed to evaluate these key portions of the ecological risk assessment process.

As a brief introduction, an endpoint is an ecological characteristic (e.g., fish community) that may be adversely affected by site contaminants; an assessment endpoint is a statement regarding an ecological characteristic to be evaluated or protected (e.g., reproduction in resident fish species); and a measurement endpoint provides the means to evaluate the assessment endpoint (e.g., embryo mortality as measured in laboratory rearing of eggs from adult fish collected from the site area). Detailed discussions of assessment and measurement endpoints are presented in Subsections 7.2.3.1 and 7.2.3.2, respectively.

Following development of the conceptual models for the risk assessments, the objectives of additional characterization efforts presented in Section 5 and Appendix A related to the risk assessment requirements were identified, including:

Table 4.2-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site

Receptor	Assessment Endpoint	Measurement Endpoint	Cross Reference
Benthic Invertebrates	Community Structure	Community composition; species diversity, evenness, and density; and other metrics compared with similar metrics at reference locations. Sediment Triad Evaluation – Evaluation includes benthic community composition, sediment toxicity testing, and sediment chemistry.	Appendix A.13
	Survival, Growth, and Reproduction	Sediment macroinvertebrate chronic toxicity testing using *Hyalella azteca* to determine survival, growth, and reproduction; and *Chironomus tentans* to determine survival, growth, and emergence.	Appendix A.14
		In situ toxicity studies using *C. tentans, Daphnia magna, H. azteca,* and *Lumbriculus variegatus* to determine survival and growth. (Growth evaluated only in C. tentans.)	Appendix A.14
		Toxicity Identification Evaluation (TIE) laboratory 24-hour study using *Ceriodaphnia dubia* to determine survival for different pore water fractions. Sediment Triad Evaluation – Evaluation includes benthic community composition, sediment toxicity testing, and sediment chemistry.	Appendix A.14
		Comparison of sediment chemistry with benchmarks including, but not limited to, EPA SQG, Long et al. ER-Ls and ER-Ms, and Ontario LELs and SELs.	Subsections 5.2.1 and 7.3.3.1.1
	Survival and Physiological Condition of Freshwater Mussels	In situ toxicity study using mussels collected from a reference area in the Connecticut River and deployed in the Housatonic River upstream and downstream of the GE facility. Toxicity endpoints include mortality and general health, as determined from glycogen levels measured in mantle tissue.	Appendix A.15
Amphibians	Community Condition	Semiquantitative sampling of larval amphibians in breeding habitats with different sediment concentrations of stressors. Endpoints include species richness per habitat type; species abundance; gross pathology; body, tail, and total length measurements.	Appendix A.9
	Reproductive Success	Surveys of vernal pools to quantitate amphibians entering vernal pools and determine breeding behavior and condition; egg laying, hatching success, and larval growth and development; metamorphosis and emigration.	Appendix A.18

Table 4.2-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site
(Continued)

Receptor	Assessment Endpoint	Measurement Endpoint	Cross Reference
Amphibians (continued)	Reproduction, Development, and Maturation	Amphibian toxicity tests using bulk sediments and surface water collected over a range of stressor concentrations in site sediments. Toxicity endpoints include morphology of embryos and juveniles, limb development, skin maturation, and tail resorption of *Rana pipiens.*	Appendix A.19
		Gravidity of females; egg count; necrotic eggs; oocyte maturity; sperm count, morphology, and viability; fertilization rate; embryo viability; hatching success; mortality; and teratogenesis of *Rana pipiens* collected from the study area compared with a reference area.	Appendix A.19
Fish	Survival, Growth, and Reproduction	Fish toxicity tests using fish eggs injected with extracts from Housatonic River fish and adult fish from the study area. Toxicity endpoints include mortality, time to hatch, growth, gross pathology, histopathology, weight and length, apoptosis, and cytochrome P4501A induction in eggs and fry; and ethoxyresorufin-*O*-deethylase (EROD) induction, and plasma 17β-estradiol, testosterone levels, and vitellogenin in adult fish.	Appendix A.21
		Comparison of surface water chemistry with surface water benchmarks, including but not limited to AWQC.	Subsections 5.3.1 and 7.3.3.1.1
		Comparison of stressor concentrations in forage and adult fish tissue with reference area concentrations and with residue effects levels from literature.	Appendix A.20 and Subsection 7.3.3.1.1
Insectivorous Birds	Reproduction and Survival	Reproductive performance of tree swallows *(Tachycineta bicolor)* based on a nest box study conducted in areas of varying stressor sediment concentrations. Parameters for evaluation include: egg presence/absence, number of eggs, and hatching success.	Appendix A.24
		Comparison of site-specific tissue concentrations in tree swallows with reference area concentrations and with residue effects levels from literature.	Appendix A.24 and Subsection 7.3.3.1.1
	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors by tree swallows from emergent aquatic insects using site-specific stressor levels in insects and comparison with literature-based effect values.	Appendix A.24 and Subsection 7.3.3.1.1

Table 4.2-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site
(Continued)

Receptor	Assessment Endpoint	Measurement Endpoint	Cross Reference
Piscivorous Birds and Mammals	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific fish tissue concentrations and site-specific stressor levels in other aquatic-related food items (e.g., crayfish and frogs), and comparison with literature-based effect values.	Appendices A.16, A.17, and A.20 and Subsection 7.3.3.1.1
	General Condition, Survival, Growth, and Reproduction of Mink	Mink toxicity tests using Housatonic River fish. Toxicity endpoints include body weight, feed composition, length of gestation, reproductive success (measured by number of females whelping, newborns/female, litter weight, etc.), survival, histopathology, cytochrome P450 analysis and other biochemical analyses, and organ weights.	Appendix A.26
Carnivorous Birds	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in earthworms, and comparison with literature-based effect values.	Appendix A.22 and Subsection 7.3.3.1.1
Small Mammals (Omnivorous and Carnivorous)	Reproduction of Omnivorous and Carnivorous Small Mammals	Reproductive evidence in trapped small mammals (e.g., examination of placental scars to determine number of litters, and number/ litter).	Appendix A.25
	Survival, Growth, and Reproduction of Carnivorous Small Mammals	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in earthworms and other soil invertebrates and comparison with literature-based effect values.	Appendix A.22 and Subsection 7.3.3.1.1
Omnivorous Mammals	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in a variety of small mammals collected in the impacted area, and comparison with literature-based effect values.	Appendix A.25 and Subsection 7.3.3.1.1
Special Status Species (Endangered, Threatened)	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific media concentrations and comparison with literature-based effect values.	Subsection 7.3.3.1.1

- Collecting additional information regarding the location and concentrations of PCBs and other chemicals throughout the Lower River and its floodplains.
- Verifying the quality of the existing data that were collected using older sampling and analytical methods.
- Obtaining additional information on the human and ecological receptors potentially exposed to PCBs in the Lower River.
- Obtaining additional information to characterize PCB migration pathways, including food chain transport.
- Obtaining additional media-specific data to estimate potential exposure to both human and ecological receptors.
- Collecting additional data to document the potential toxic effects of PCB exposure to aquatic and wildlife populations and communities inhabiting the affected portions of the watershed.
- Collecting sufficient information on all potential contaminants to determine the COCs for the risk assessments.

Section 5 of this Work Plan outlines additional tasks to be conducted for the Supplemental Investigation. For soils and sediment, Subsection 5.2 presents a description of the data needs and the proposed sampling and analytical requirements. Water quality sampling and sampling specifically to support the modeling study are described in Subsection 5.3, and air sampling is outlined in Subsection 5.4. Subsection 5.5 presents the biological investigations that will be performed to support both the ecological and human health risk assessments. These investigations include tissue residue sampling, toxicity testing, reproductive testing, developmental testing, and community analysis of a number of terrestrial and aquatic taxa potentially affected by PCB contamination of the river and floodplains.

4.3 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are qualitative and quantitative statements that specify the quality of data required to support decisions during remedial response activities (EPA, 99-0337) and derive from the concept that the end uses of the data should drive the type and quantity of data to be collected. DQOs are established during the planning process and the results become an integral component of documents such as the Quality Assurance Project Plan (QAPP) and, in general, the Work Plan for the site. Because DQOs are uniquely defined for each component of the overall project, they are included in the specific Study Plans presented in Appendix A to this document and will only be discussed generally here.

To obtain data of known and adequate quality, measurement performance criteria, commonly known as Data Quality Indicators, are established for the various data types necessary to achieve the objectives of each study component. These indicators are both quantitative (e.g., precision, accuracy/bias, completeness, sensitivity) and qualitative (e.g., selectivity, representativeness, comparability) and need to be established for each matrix, analytical parameter, concentration level, and analyte. DQIs may be used to evaluate the amount of error in the data collection process and the analytical measurement system.

The DQOs for this project, which are necessarily broader in scope that those specified in the individual Work Plans, are provided in the Final Quality Assurance Project Plan (QAPP) (WESTON, 00-0458). The following tables can be found in the QAPP and provide important information on DQOs and DQIs.

- QAPP, Table 4-1—Field Measurement Quality Control Specifications
- QAPP, Table 4-2—Analytical Measurements Quality Control Requirements
- QAPP, Table 4-3—Spike Accuracy and Precision Limits
- QAPP, Table 4-4—Surrogate Spike Recovery Limits

As noted above, these tables can be found in the QAPP, not in this Work Plan. Analytical reporting limits shown in Table 4.2-3 will be used for the project to meet the investigation objectives.

4.3.1 Data Types

In general, three distinct types of data, each with its associated data quality, will be used to complete this scope of work.

Type I—Field Screening Data. The quality of field screening data, because of the instrumentation used to collect it and the conditions under which it is collected, is the lowest of the three data types, in that field screening data are expected to have less accuracy and/or precision. These data, however, have the advantage of providing the most rapid results and are of sufficient quality to assist in optimizing sampling locations and for health and safety support.

Table 4.2-3

Analytical Reporting Limits for Soils, Sediments, Water, and Biological Tissue

Parameter	PCBs 1,2,4-TCB[a]	PCBs	PCB Congeners	Dioxins/Furans	Chlorinated Pesticides	Organophosphorus Pesticides	Semivolatile Organics
Method[b]	Modified 8082 Field Lab (GC-ECD)	8082 Fixed Lab (GC-ECD)	Modified 1668 (GC/MS)	8290 (GC/MS)	8081A (GC)	8141A (GC)	8270C (GC/MS)
Matrix							
Soil	500 µg/kg	17 µg/kg	0.05 ng/g	0.1-0.5 pg/g	1.7-17 µg/kg[c]	33 µg/kg	330-800 µg/kg
Sediment	500 µg/kg	17 µg/kg	0.05 ng/g	0.1-0.5 pg/g	1.7-17 µg/kg[c]	33 µg/kg	330-800 µg/kg
Water	20 µg/L	0.014 µg/L	0.50 ng/L	1.0-5.0 pg/L	0.05-0.5 µg/L[d]	1.0 µg/L	10-25 µg/L

Parameter	PCBs - Total & Aroclors (GC-ECD)		PCB Congeners (GC-ECD)	Dioxins/Furans (High Resolution GC/HRMS)	Chlorinated Pesticides (GC-ECD)		
Method[b]	SOP-9810B		SOP-9811	SOP-9722	SOP-9810A		
Biological Tissue[e] (10g)	50 ppb		0.01 ppb	1-10 ppt	10 ppb		
Biological Tissue[e] (0.1g)	1 ppm		1 ppb	100 ppt-1 ppb	0.1 ppm		
Biological Tissue[f] (5g)	<1 ppb		<1 ppb	1-5 ppt	<5 ppb		

[a] 1,2,4-TCB = 1,2,4-Trichlorobenzene
[b] Details on methods can be found in the QAPP (00-0458)
[c] 170 µg/kg for toxaphene
[d] 5 µg/L for toxaphene
[e] Biological tissue will be analyzed at Texas A&M Geochemical and Environmental Research Group Laboratory
[f] Biological tissue will be analyzed in conjunction with the mink and fish toxicity studies at Columbia Environmental Research Center.

Field screening data are often binary, providing information only on presence/absence of certain constituents, and are generally qualitative rather than quantitative.

Type II—Field Analyses. Data resulting from analyses conducted in the field are characterized by greater accuracy and precision than field screening data and are therefore more representative and comparable. Field analyses typically are obtained from analytical instruments that are carried in the field (such as pH meters, electrical conductivity meters, and turbidimeters). Depending on factors such as instrumentation and environmental matrices, field analytical data can be either qualitative or quantitative.

Type III—Laboratory Analyses. This data type is derived from carefully controlled laboratory analytical procedures following EPA SW-846 methods or modifications of these methods. The analytical details are provided in the *Quality Assurance Project Plan* (WESTON, 00-0458). The quality of laboratory analytical data is usually well known and documented and such data quality indicators as accuracy and precision are carefully measured. Data of this type can be used for most purposes, including determination of the source and extent of contamination, site characterization, risk assessment, and to support evaluation of treatment technologies and treatability studies. These data are both qualitative and quantitative.

4.3.2 DQOs for Field Screening Data

Field screening will be performed using either a photoionization meter or a flame ionization meter. Calibration of these instruments to gas standards on a regular basis, as described in the *Field Sampling Plan* (FSP) (00-0334), provides assurance that the measurements registered are as accurate and comparable as practicable. Because these data are qualitative rather than quantitative, rigorous limits for precision and accuracy are not applicable. The representativeness of the data collected is ensured by the procedures for field screening detailed in the FSP.

4.3.3 DQOs for Field Analytical Data

Calibration of field instruments (e.g., pH meters, electrical conductivity meters, and turbidimeters) and collection of these data according to the procedures outlined in the FSP ensure accuracy, representativeness, and comparability.

4.3.4 DQOs for Laboratory Analytical Data

4.3.4.1 Precision of Laboratory Analytical Data

Precision is the level of agreement among repeated independent measurements of the same characteristic under similar conditions. Analytical precision is measured by relative percent difference (RPD) for duplicate (two) analyses or percent relative standard deviation (%RSD) for replicate (more than two) analyses. Objectives for precision and corrective actions are independent of the laboratory producing the measurement and are listed in the QAPP (00-0458).

4.3.4.2 Accuracy of Laboratory Analytical Data

Accuracy is the degree of agreement of an analytical measurement with the true or expected concentration. When applied to a set of observed values, accuracy will be a measure of both random error and systematic error (bias). Analytical accuracy is expressed as the percent recovery of an analyte that has been used to fortify a field sample or a standard matrix at a known concentration prior to analysis. The quality assurance (QA) objectives and corrective actions for accuracy are listed in the QAPP. The QA/QC control limits are independent of the laboratory producing the measurement.

4.3.4.3 Representativeness of Laboratory Analytical Data

Representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter, variation at a sampling point, process condition, or environmental condition. Representativeness shall be achieved through use of standard field, sampling, and analytical procedures, and through appropriate program design. The methods to be used to select samples that are representative of the area or process are described in the QAPP (00-0458) and FSP (00-0334).

4.3.4.4 Completeness of Laboratory Analytical Data

Completeness is a measure of the relative percentage of analytical data points that are determined to be usable (i.e., not qualified with an “R” flag). The level of completeness can also be affected by loss or breakage of samples during transport, as well as external problems that prohibit collection or satisfactory analysis of the sample. The QA objective for completeness is described in the QAPP.

If the completeness goal is not met because of controllable circumstances, then the samples will be recollected and reanalyzed, as necessary, to meet the completeness objective. If the completeness goal is not met because of uncontrollable circumstances, such as inaccessible sample points, matrix interferences, etc., then the deficiency will be evaluated for potential corrective action.

4.3.4.5 Comparability of Laboratory Analytical Data

Comparability expresses the confidence with which one data set can be compared to another. The comparability of the data is influenced by sampling and analytical procedures. By providing protocols to be used for obtaining and analyzing samples, data sets should be comparable regardless of the individual or sampling team that obtains the sample or performs the analysis. Additionally, the consistent use of units of measure, participation in external performance evaluation programs, and the periodic use of traceable reference materials aid in ensuring the comparability of data sets.

Ten percent of samples analyzed in the on-site field laboratory will also receive off-site laboratory analysis, and the results will be compared to the on-site laboratory results. Criteria for RPD are provided in the QAPP. If RPD values fall outside QAPP criteria, the condition and potential causes will be evaluated.

4.3.4.6 Sensitivity of Laboratory Analytical Data

Sensitivity is the ability of the method or acceptable sensitivity instrument to detect the contaminant of concern and other target compounds at the level of interest. Quantitative measurement performance criteria need to be determined for acceptable sensitivity to ensure that the quantitation limits can be routinely achieved for each matrix, analytical parameter, and concentration level. Specifications for instrumentation to ensure appropriate sensitivity are contained within the QAPP.

4.3.5 DQOs for Biological/Ecological Data

A wide variety of types of biological and ecological data will be collected in this project and study-specific DQOs for these data types are delineated in the respective Study Plans included in Appendix A. In general, however, most biological studies involve the collection of data on species types (i.e., taxonomic data) accompanied by data on either density (counts, often per unit area) and/or biomass. Quality of taxonomic data will be ensured by having all species determinations conducted by individuals who are trained and experienced in the taxonomy of the particular faunal or floral groups included in the study, supplemented by reference to the appropriate scientific literature. Questions will be resolved by reference to peers and/or outside authorities, and documentation will be maintained in the form of voucher collections. Accuracy of counts will be ensured by recounting aliquots of samples and comparing results. Discrepancies will usually lead to reprocessing of samples and/or retraining of staff.

Quality of biomass data will be ensured by conducting biomass determinations using calibrated balances of appropriate sensitivity. Calibration frequencies for analytical balances will follow criteria established in the QAPP.

4.4 DATA MANAGEMENT

Data management for the project will be handled through a centralized database managed by WESTON. Details on the system are described in the *Environmental Information Management Systems-Data Management Plan* (00-0459).

The major components of the system are the following:

- Historical Data Capture/Management—For the purpose of capitalizing on previous data to support data gaps analysis, site mapping, and risk assessment.

- Field Data Collection/Management—For the collection of location, field sampling, and analytical data. Data management requirements to guide sample collection, standardize sample and sample attribute identification, and standardize data storage and retrieval.

- Data Management/Control—For the review, validation, and management of geologic, geotechnical, analytical, and spatial data.

- Central Database Repository/Warehouse—For central storage and integration of technical data.
- Data Marts—For providing access and retrieval of information from the central database repository. The data mart(s) will contain critical data that are routinely accessed by the end-user for making decisions. The smaller size of these databases increases the speed of data querying and reporting. The data marts also accommodate non-routine or typical data types.
- Analytical Tools—A suite of custom and commercial applications used in the analysis and presentation of the data from the central database or data mart.
- PC-Based Geographic Information System (GIS) (ESRI ArcView 3.1)—For the storage of map files and linking to the data mart to enable posting and analysis of the geo-environmental results, geospatial referencing, and large-scale mapping.

5. FIELD INVESTIGATION TASKS

This section presents the rationale and technical approach to be used to meet the investigation objectives outlined in Section 4. Details of the specific field protocols are presented in the project *Field Sampling Plan (FSP)* (00-0334). Additional field sampling protocols, not presented in the FSP, are provided in Appendix A of this Work Plan. DQOs and detection limits for the laboratory analyses for the field investigation are discussed in Section 4. Additional task-specific protocols prepared directly by other investigators as a component of the Supplemental Investigation (SI) are provided in Appendix A. Further detail on the DQOs, analytical methods, and detection limits can be found in the project Final QAPP (WESTON, 00-0458). Table 4.2-1 summarizes the relationship of and responsibilities for the different components of the Work Plan.

Overview of PCB Analyses—Soil, sediment, and biological samples collected as part of the SI will be analyzed for PCBs. The field laboratory at WESTON's project office in Pittsfield, MA, will use modified EPA Method 8082 to conduct the majority of the total PCB and Aroclor analyses of soil and sediment samples. Samples will be delivered daily to the laboratory. At least 10% of all soil and sediment samples will be analyzed for PCB Aroclors using EPA Method 8082 by a fixed laboratory as specified in the QAPP (00-0458). Approximately 500 of the sediment and soil samples will be analyzed for PCB congeners by a fixed laboratory using modified EPA Method 1668. The number of samples for PCB congener analyses may change because of the iterative sampling strategy. In general, the samples for PCB congener analysis will be collected after the evaluation of the results of the PCB Aroclor analysis to provide a comparative data set for different media types and across a gradient of PCB concentrations. The PCB congener data will be used, to the extent possible, to develop a correlation between the total PCB/Aroclor data set and the observed congener patterns. The congener data set will also be used in connection with specific components of the human health and ecological risk assessments and in the PCB fate and transport modeling.

Overview of Other Analyses—Approximately 10% of all soil and sediment samples will be analyzed for a modified Appendix IX compound list, including semivolatile organic compounds (SVOCs), organochlorine pesticides/PCBs, dioxins, furans, and inorganics (see Table 3.1-1) and as outlined in the QAPP (00-0458). In addition, about 2% of all samples will be analyzed for a modified list of Appendix IX organophosphate pesticides and herbicides. These samples will be selected to represent varying depths and locations. One or more Appendix IX chemical analyses for soil and sediment sampling may be deleted based on the data results as they become available (i.e., analytes consistently not detected).

Total organic carbon (TOC) and grain size analyses will be performed on all sediment samples and on approximately 10% of the floodplain and riverbank soil sampling locations. Samples for grain size and TOC analyses will be collected from the floodplain and riverbank locations when changes in soil type and organic matter content are noted by the field sampling teams.

Analysis of samples for volatile organic compounds (VOCs) is not proposed for this study, since prior investigations did not detect VOCs in many samples or at high enough concentrations to warrant including VOCs in the analytical parameters for this study. Because of the distance of the study area from the Source Reach, the detection of VOCs in sediments is not expected due to the agitation and volatilization of these compounds.

Overview of Sampling Approach—The sampling approach includes the collection of samples from historical data locations (i.e., at locations previously sampled by GE contractors) and at other locations in support of the human and ecological risk assessments and the modeling study. Sampling will be conducted out to the 10-year floodplain to support the longer term objectives of the modeling study. The approach is designed to optimize the sampling by conducting it in an iterative manner, with both systematic (an unbiased approach to obtain data by using a spatially driven approach at regular intervals) and discrete sampling to address specific data quality objectives. The objective of collecting additional data at historical sampling locations is to evaluate the comparability of the data to the historical data on both spatial and temporal scales. Observed differences may reflect changing contaminant levels, migration of materials, or differences in sampling and analytical methods. A target of approximately 5% of the samples planned under the SIWP will be located at or in proximity to previous sample locations. Sample locations may not exactly duplicate prior positions or sample conditions because the positions of previous sample locations were estimated in most cases. All SI sampling locations will be surveyed using GPS.

Quality control samples will include duplicate samples at 5% of the sample locations and matrix spike/matrix spike duplicate analyses on 5% of all samples as specified in the QAPP.

In addition to soil and sediment sampling, surface water, air, and biological samples will also be analyzed for PCBs and other parameters in support of the project objectives. Detailed descriptions of these other sampling efforts are provided in Subsections 5.3 through 5.5.

5.1 POTENTIAL SOURCE AREA ASSESSMENT

Potential source areas consist of the bank and floodplain soils identified on the GE facility, Housatonic River sediments, and surrounding tributaries, lakes, and oxbows containing PCB-contaminated fill as described in Subsection 3.1.

In addition to the sources noted above, several other areas have been identified as probable or potential sources of PCBs and other contaminants. Unkamet Brook is known to be contaminated with PCBs as it flows through an old landfill that contains drums and transformers. Areas of Unkamet Brook and the adjacent wetland were sampled by GE and by EPA under the Superfund Technical Assistance and Response Team (START) contract. The results of the sampling indicated elevated concentrations of PCBs in both brook and wetland sediments. Additional samples will be collected in the East Branch from the floodplain and sediments both upstream and downstream of the brook's discharge to the East Branch of the Housatonic River.

The Pittsfield Municipal Landfill (Pittsfield Landfill; Facility ID: MAD980520803) located off East Street and Hubbard Street is a potential source of contaminants to the Housatonic River because of the disposal of PCB-contaminated waste at the site. Leachate generated by the landfill may be discharging and contributing PCBs to the river. Drums containing PCBs were found at the landfill adjacent to the river and subsequently removed by the City of Pittsfield and overseen by MADEP. The landfill is located east/northeast of the mouth of Unkamet Brook. Because of the landfill's proximity to Unkamet Brook, data from the transects in this area of the river will be used to characterize both potential sources. Further relevant information regarding any previous studies and the closure of the Pittsfield Landfill will be obtained as available during the course of the Supplemental Investigation. If sediment data indicate elevated PCB concentrations in the river, additional sediment and/or floodplain and bank soil samples may be collected as necessary.

Goodrich Pond and its tributary to the Housatonic River have also been identified as a potential source of PCB contamination. The tributary borders residential properties that have undergone PCB remediation. Samples will not be collected from these areas; rather, the data generated from previous EPA/START sampling, fish tissue residue concentrations, and planned GE sampling will be used to define the potential and relative magnitude of this area as a contaminant source.

A data search of the upstream watershed (e.g., Dalton, West Branch) will be conducted to determine if there are any additional records of contaminant releases (e.g., PCB spills). The data will be reviewed to determine if any historical releases could have reached the Housatonic River and contributed to contamination in the river. In addition, sampling locations in the upstream watershed will be established to determine background levels of contaminants and to support background locations specific to individual studies.

As part of the scope of work, reasonably available historical sources of information such as aerial photographs, land use records, and maps will be reviewed to determine previous land uses, areas of disturbance, changes in the river channel, and potentially impacted floodplain areas. In addition, any information uncovered during investigation of other areas will be reviewed for its impact to the supplemental investigation.

5.2 SEDIMENT AND SOIL SAMPLING

The sediment and soil sampling program described in the following subsections will support the human health risk assessment, ecological risk assessment, and modeling study. The data resulting from the sampling program, therefore, will be used for multiple purposes.

Sediment is defined here as the material that settles to the bottom of any body of water, including vernal pools. The primary components of sediment are interstitial (pore) water, organic matter, and inorganic matter. Soils are defined here as those substrate materials outside the river channel and other open water areas, and include riverbanks, floodplains, and uplands of the study area.

Two sampling strategies are proposed for soil and sediment under this SIWP—systematic (transect) sampling and discrete sampling. The objective is to obtain representative samples that will produce data to support the DQOs (EPA, 99-0136).

Systematic Sampling—Systematic samples are collected at regular intervals over the "population" (i.e., river reach) to assess the PCB contamination. Systematic sampling was selected over other types (e.g., random, stratified) because regular intervals and coverage were needed to characterize the horizontal and vertical (e.g., sediment profile) extent of contamination to focus future sampling efforts. Historical (i.e., GE) data only sparsely covered some areas of the river and did not provide a comprehensive database from which to define a complete pattern of contamination. Therefore, for each river reach, regular transect intervals were chosen that reflected the anticipated concentrations and the distance from sources. For each river reach, the systematic sampling interval was selected to characterize the reach as a whole and not to delineate potential areas of elevated PCBs. For example, additional information on the extent of contamination in Reach 5 was needed to better define the overall concentrations and location of PCBs in the sediments and floodplains. Large linear distances between historical (GE) samples precluded use of these data in predicting reach-wide and subreach contaminant concentrations.

Discrete Sampling—The discrete sampling program of soils and sediments is designed to obtain information on specific areas (generally smaller scale) or in support of other data quality objectives (e.g., ecological studies, human health exposure area). This strategy involves collecting judgmental samples at distinct locations. Judgmental samples involve collecting samples at small-scale substrates (e.g., aggrading bars) and/or within a defined habitat or location (e.g., within a vernal pool). Additional samples may be collected in any of the areas after an iterative review of data collected to date to improve the characterization with regard to the data quality objectives.

Sediment and Soil Sampling Locations—River Reaches 1 through 9 have been defined (see Figures 2.4-1 and 2.4-2) to facilitate description of the proposed sampling in the river. The approximate length of each reach, the proposed transect interval, and the resulting number of proposed transects are shown in Table 5.2-1. Systematic sampling along transects will occur in all reaches except Reach 9. Discrete sampling will be performed in Reach 9 for potential use in the risk assessments. Sediment, riverbank, and floodplain soil sampling will occur along these transects to characterize the current PCB contamination and to support the objectives of the SIWP. The proposed transect frequencies for Reach 5 (Confluence to Woods Pond) and Reach 7 (below Woods Pond to Rising Pond) are shown in Figures 5.2-1 and 5.2-2, respectively. Figure

Table 5.2-1

Housatonic River - Proposed Sampling Transects Per Reach

Reach	Approximate Length (ft)	Transect Interval (ft)	Number of Proposed Transects
1[a]	7,400	200	37
2	10,900	200	55
3[b]	*3,200*	*50*	*63*
4[c]	*7,400*	*100*	*74*
5	49,400	1500	37
6	1,050	NA[d]	3
7	92,000	2500	36
8	4,000	NA[d]	7
9	108,000	NA	0
Total	290,750	NA	312

NA = Not Applicable

[a]Lower section of Reach 1 only (Hubbard Street Bridge in Dalton to Unkamet Brook).

[b]Addressed in Preliminary Work Plan (02-0161).

[c]Addressed in EE/CA Work Plan (07-0001).

[d]Samples will be collected as part of the coring program.

Reach No.	Description
1	Upstream of Unkamet Brook (Reach 1 is limited to Hubbard Street Bridge for transect purposes)
2	Unkamet Brook to Newell Street Bridge
3	Newell Street Bridge to Lyman Street Bridge (Source Reach)
4	Lyman Street Bridge to the West Branch Confluence (EE/CA Reach)
5	West Branch Confluence to Woods Pond
6	Woods Pond
7	Woods Pond Dam to Rising Pond
8	Rising Pond
9	Downstream of Rising Pond to Connecticut Border

5.2-3 shows a cross-sectional view of the proposed riverbank and sediment sampling array along a typical transect, and a plan view of floodplain sample locations on a typical transect.

Each transect will be positioned perpendicular to the river channel, with sampling starting from one side of the floodplain across the river channel to the opposite side of the floodplain. On a typical transect, there will be nine samples collected from three locations in the floodplain on each side of the river, three to nine samples (from one to three locations) from each riverbank (where a distinct riverbank is present), and 12 samples from three locations in the river channel. The numbers of samples were chosen to characterize the soil and sediment profiles. This standard number of samples per habitat and transect will provide a current and accurate representation of the floodplain, riverbank, and sediment profile.

For example, aggrading or eroding sediment patterns in the river channel will dictate the depth of accumulated sediment when looking at a cross section of the river. The numbers of sediment samples collected will provide data on the sediment depth and contaminant variation across the river channel. To achieve the specific objectives of this investigation, discrete sample intervals are needed to define the surface layers (e.g., 0 to 6 inches) of soil and sediment, as well as the concentrations of contaminants at depth. As indicated, these data will be evaluated to determine if additional samples are needed to fulfill the data quality objectives in either a horizontal or vertical direction in support of the investigation's objectives.

5.2.1 Sediment

Sediment sampling will be conducted along designated reaches of the Housatonic River to provide information and data for the human health and ecological risk assessments and the modeling study. Several types of sediment samples will be required to meet the various objectives of these studies. Each type is described in subsequent sections with reference to the study for which the information will be used.

The scope of the sediment investigation will be from upstream of Unkamet Brook (Reach 1) downstream to the Connecticut border, pending review of the data collected in the downstream reaches and the data collected historically in Connecticut, a distance of approximately 63 river miles. Based on currently available and reviewed data, the most upstream source of significant PCB contamination appears to be Unkamet Brook, which forms the downstream boundary of Reach 1.

However, samples will be collected upstream to ascertain the possibility of PCB-contaminated fill upstream of Unkamet Brook or the existence of other PCB sources. Reference locations will also be sampled upstream of the Hubbard Avenue Bridge and on other tributaries (e.g., West Branch) to compare to downstream concentrations of contaminants.

The following relevant terms are used in this SIWP and are consistent with those defined by prior investigations (02-0089): *Channel* – channel deposits typically occur in parts of the riverbed that are permanently inundated during low to moderate flow conditions. *Terrace* – terrace deposits occur in parts of the riverbed that are usually inundated during high-flow conditions, but are exposed during low-to-moderate flows. *Aggrading Bar* – Aggrading bar deposits, or small islands or mounds, are typically composed of coarse-grained material (i.e., sands and gravels) and usually occur along the inner sides of channel curves. *Backwater Areas* – Backwater areas are quiescent areas adjacent to the main river channel that maintain a hydraulic connection to the river channel.

Previous sediment and floodplain sampling was initiated under the Preliminary Work Plan (02-0161). The Preliminary Work Plan identified field investigation tasks that included sediment, bank, and floodplain sampling in the following three areas:

- The Source Reach (1/2-mile section of the Housatonic River from the Newell Street Bridge to the Lyman Street Bridge), and the section of the Housatonic River from Elm Street to Dawes Avenue to support the Removal Action Memorandum for the Upper 2 Miles of the Housatonic River.
- The modeling transects between the confluence of the East and West Branch and Woods Pond.
- Initiation of other characterization sampling to define study areas for the ecological investigations.

Sediment sampling is complete in the Source Reach. Approximately 600 sediment samples were collected in the Source Reach. A summary of this sampling effort is presented in the *Final Comprehensive Data Report—the Source Reach (the First ½ Mile)* (August 1999) (07-0028). Sediment samples were collected in the EE/CA Reach (from Lyman Street Bridge to the confluence of the East and West Branches of the Housatonic River) under the EE/CA Work Plan (07-0001).

5.2.1.1 Systematic Sediment Sampling by Reach

The conceptual model discussed in Section 3 was used to define the sampling rationale for numbers and locations of samples. The size of the area potentially impacted, evaluation of historical data, and sources of contamination were all considered in developing a systematic approach to sampling sediments in the Housatonic River watershed. As previously indicated, systematic transect sampling refers to a sampling strategy in which samples are collected at regular intervals over the study area (e.g., river reach). The interval distance for each reach was determined based on several factors, including expected contaminant concentrations, distance from sources, and length of river reach. River reaches close to known or potential sources will be sampled at closer intervals; whereas reaches farther downstream from these sources will be sampled at intervals of greater distances.

Table 5.2-2 lists the proposed number of samples for each of the seven river reaches to be sampled. Reach 3 was sampled under the Preliminary Work Plan, and Reach 4 was sampled under the EE/CA Work Plan. Numbers of samples associated with these two reaches are included in Table 5.2-2 but are not described in detail in this Work Plan. However, the data generated through those efforts will be used in this SI to better delineate the potential sources of contaminants to the study area and also in determining the contaminants of potential concern.

In each river reach, the sediment profile will be determined by conducting a comprehensive survey of sediment depth. A sediment probe will be used to determine the approximate depth of accumulated sediment (i.e., to first refusal) at transects along the river. Transects will be positioned at intervals as indicated in Table 5.2-1. Data on sediment depth will be collected at three to five points along each transect perpendicular to river flow (i.e., bank to bank). These data will assist in determining sediment depth, volume, and distribution across the river channel, and in positioning sediment sampling locations. Depth of water and approximate distance (i.e., height) from the water surface to the top of the riverbank will also be recorded for each transect.

Sediment sampling will be conducted at three approximately equidistant points on every transect in every reach (right side, mid-channel, and left side), unless the sediment depth probing indicates significant or unusual accumulations of sediment in other areas along the transect. Sediment

Table 5.2-2

Proposed Number of Sediment Samples
Housatonic River - Supplemental Investigation

Reach #	Systematic Samples	Recrea. Public Areas	Residential	Aggrading Bars	Former Meander	Temp./ Perm. Pools	Impound-ments	Sediment Cores	Benthic Macroinvert.	Frog Locations	Sediment Toxicity	Tree Swallow	Mussel Locations	Fish Locations	Total Samples
1	468								12				3	5	488
2	660														660
3	481 [a]														481
4	482 [a]														482
5	732 [b]	65	110	500	54	280		198	108	8	15	180	12		2262
6	384	5	10					54							453
7	432	tbd	tbd				114								546
8	212	tbd													212
9	150 [c]	tbd	tbd												150
Reference Location									36	2	5	80	3	7	133
Total Samples	4001	70	120	500	54	280	114	252	156	10	20	260	18	12	5867

[a] Collection completed under separate work plans.

[b] 444 samples at 37 transects (1,500-ft)
204 samples at 17 channel geometry/modeling transects
84 samples at 7 West Branch PCB extent transects

[c] These will be collected as discrete samples in areas to be defined in Reaches 7 and 9
tbd = to be determined; sampling in these reaches may be performed.

sampling will focus, within the discrete sampling area on the transect, on areas of sediment accumulation, where possible, to provide sufficient volume for analyses.

Samples will be collected at depths of 0 to 6 inches, 6 to 12 inches, 12 to 18 inches, and 18 to 24 inches. The rationale for these depth intervals is to conserve sample numbers while generating a profile of contamination at a given location with depth. Contingency for deeper sampling is allowed for in the discrete sampling program, should this sampling suggest that further delineation is required. All sediment samples will be analyzed for PCBs (total and Aroclors), grain size, and TOC. In addition, approximately 10% of sediment samples will be analyzed for PCB congeners and homologs, Appendix IX SVOCs, organochlorine pesticides/PCBs, dioxins/furans, and inorganics, and approximately 2% of sediment samples will be analyzed for Appendix IX organophosphate pesticides and herbicides. The samples to be analyzed for the full suite of parameters will be chosen in most reaches by selecting one sediment sample on every transect. The location (right side, mid-channel, left side) and depth (one of four depths) of the full suite of analysis samples will be varied per transect to ensure that adequate characterization will be performed both horizontally and vertically. In other areas, preliminary PCB results will be used to minimize the number of samples for the full suite of analyses.

5.2.1.1.1 Reach 1. Upstream Reference Locations

Reach 1 is being sampled to support all aspects of the SI, including the human health and ecological risk assessments, and the modeling study. This reach may contain an appropriate upstream reference location based on the assumption that Unkamet Brook is the most upstream source of PCBs from the GE facility. However, because of occasional detections of PCBs in upstream surface waters, the presence of the Pittsfield Landfill just upstream of Unkamet Brook, and the potential for fill to have been used in properties along the river, Reach 1 will be sampled from Unkamet Brook up to the Hubbard Avenue Bridge. The Pittsfield Landfill may be contributing contaminants to the river via leachate discharges, soil erosion, and runoff. Systematic sampling will be conducted in this reach at 200-ft intervals. This equates to a total of 37 transects and approximately 444 sediment samples.

Additional sediment samples will be collected at the surface water sampling locations at the Crane Paper Company approximately 200 ft downstream of the dam at Housatonic Street in Dalton and upstream of the Hubbard Avenue Bridge. The gradient in this reach is fairly steep with a cobble/boulder substrate indicating high erosional areas. A total of 24 sediment samples will be collected on the two transects in this area. Therefore, approximately 468 systematic sediment samples will be collected at 39 transects in Reach 1.

5.2.1.1.2 Reach 2. Unkamet Brook to Newell Street Bridge

Sediment sampling in Reach 2 will also support the objectives of the risk assessments and modeling study as described above. Only limited data are available for this river reach and additional information is required to determine if there is any background contamination and the potential contribution of contaminants to downstream locations. This reach is approximately 2 miles long and has a low to moderate gradient. This area has numerous potential sources and needs to be examined more closely to determine the extent and concentrations of PCBs in the sediments. One potential source of PCBs in Reach 2 is Unkamet Brook. The brook may be contributing contaminants to the river via soil erosion, sediment transport, and runoff. Transect intervals of 200 ft will be sampled, resulting in a total of 55 transects and 660 sediment samples. Transects or subreaches consisting solely of a cobble substrate will be not be sampled unless adequate sediment can be collected.

5.2.1.1.3 Reach 3. Newell Street Bridge to Lyman Street Bridge (Source Reach)

Reach 3 contains the largest number of potential and historical PCB sources (e.g., GE facility). This portion of the Housatonic River was channelized in the 1940s by the City of Pittsfield and USACE as a flood control measure. This reach is approximately 1/2 mile long and is adjacent to GE property. Transects were positioned at 50-ft intervals under the Preliminary Work Plan (02-0161) and were previously sampled. Approximately 481 sediment samples were collected from these transects. These data are summarized in the *Final Comprehensive Data Report—the Source Reach (the First ½ Mile)* (07-0028).

5.2.1.1.4 Reach 4. Lyman Street Bridge to the Confluence with the West Branch

This reach is approximately 1 1/2 miles long and includes that portion of the Housatonic River that is the subject of the EE/CA. This reach also contains several different riverine environments including riffle, run, and pool habitat. The substrate is composed of a high percentage of cobble between the Elm Street Bridge and Dawes Avenue Bridge. Transects were established at 100-ft intervals, and approximately 482 samples were collected in 1998 under the EE/CA Work Plan (07-0001).

5.2.1.1.5 Reach 5. West Branch Confluence to Woods Pond

Reach 5 and Reach 6 constitute the initial focus of the modeling study, human health and ecological risk assessments, and the associated biological sampling. More detail can be found later in this section describing the additional soil and sediment sampling that will be performed in support of these efforts. Reaches 5 and 6 were selected for more intensive investigation because this 10-mile reach, bounded on the downstream end by Woods Pond Dam, historically has had the highest concentrations and most frequent detections of PCBs other than the Source Reach, has PCB contamination in multiple different habitat types and exposure areas, and would be the next logical area if any additional remediation is required upon completion of the 1½ mile EE/CA Reach.

In Reach 5, the Housatonic River returns to a meandering low-gradient river, with depositional areas increasing in extent as the river nears Woods Pond. This reach is approximately 10 miles long and includes broad floodplains (up to 3,000 ft width) with associated wetlands, backwater areas, and large contiguous areas of valuable wildlife habitat. Transects will be established at 1,500-ft intervals, resulting in a total of 37 transects, and approximately 444 sediment samples in Reach 5.

Several transects will also be established on the West Branch of the Housatonic River to determine the PCB concentrations in the sediments of the West Branch just upstream of the confluence with the East Branch (i.e., upstream of Reach 5) to establish background concentrations of contaminants entering the study area. It is estimated that up to 7 transects at 200-ft intervals will be sampled, resulting in a total of 84 sediment samples.

In addition, 17 transects that cross the entire width of the 10-year floodplain will be established in Reach 5 to define the channel geometry for the modeling study (see Subsection 5.3.4) and co-occurring PCB concentrations. These transects will be sampled in a similar manner to that of the systematic sampling (described in Subsection 5.2.2.1). These samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size.

In summary, it is estimated that a total of 732 systematic sediment samples will be collected in Reach 5, including the West Branch of the Housatonic River under the following categories:

- Reach 5, 1,500-ft transects—444 samples at 37 transects.
- Reach 5, Channel Geometry/Modeling—204 samples at 17 transects.
- West Branch, PCB Extent—84 samples at 7 transects.

Sampling locations for PCB congener analysis will be selected subsequent to review of the Aroclor data results. Locations with detectable PCBs will be considered for congener analysis with approximately 10% of these locations resampled and analyzed for congeners.

5.2.1.1.6 Reach 6. Woods Pond

Reach 6 consists of the Woods Pond impoundment from the upstream portion of the Housatonic River where it enters the backwater area associated with Woods Pond to the downstream dam. Additional sediment sampling is planned to fill data gaps and verify previous data collected by BBL (02-0089). Woods Pond has acted as a sink for PCBs because of its depositional nature and its location (i.e., the first dam/impoundment downstream of the source areas). Data gaps identified include large concentration differences between sampling locations and incomplete vertical characterization. Sampling locations will be based on the results of the sub-bottom profiling survey. This survey will map the accumulated sediment in Woods Pond and its upstream backwater areas. The map will be compared to the existing database to determine areas where the extent of contamination has not been completed. Additional detail on the sub-bottom profiling follows in Subsection 5.2.1.3.

Due to the depositional nature of Woods Pond, a series of sediment cores is proposed to further characterize the pond. Approximately 25 cores will be collected as indicated in Figure 5.2-4. Cores will be collected to first refusal and sediment samples collected every 6 inches for PCBs (total and Aroclor), TOC, and grain size. In addition, approximately 10% of the samples will be analyzed for modified Appendix IX compounds and PCB congeners and homologs. Approximately 2% of these samples will be analyzed for Appendix IX organophosphate pesticides and herbicides. The core locations will be selected based on the following criteria:

- The locations provide improved horizontal coverage and better define contaminant concentrations.

- The locations provide additional vertical coverage at prior (GE) sampling locations or provide new coverage in areas where sediment has not been characterized based on the depth of accumulated sediment.
- The locations duplicate prior (GE) samples (at selected locations).

In addition to these sediment samples, one transect will be established in Reach 6 to define the channel geometry for the modeling study (see Subsection 5.3.4). Sediment samples will be collected approximately every 100 ft at 6-inch depth intervals to a depth of 2 ft across this transect, which will be oriented in a generally east/west direction across Woods Pond. These samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size.

It is estimated that a total of approximately 384 sediment samples will be collected in Woods Pond.

5.2.1.1.7 Reach 7. Woods Pond Dam to Rising Pond

Additional data are needed to assist in defining the magnitude and distribution of contamination downstream of Woods Pond to refine efforts in evaluating areas for human and ecological risk. Previous data have indicated that PCB concentrations are lower in river sediments and floodplain soils downstream of the Woods Pond Dam (02-0089). However, only limited data are available for this large stretch of river, which is approximately 17 miles long. This reach ends at the beginning of Rising Pond (Reach 8), another downstream impoundment that, because of its depositional nature, has also acted as a sink for PCBs. It is proposed that transects be established approximately every 2,500 ft in this reach, which equates to a total of 36 transects and 432 sediment samples.

The samples from this reach will provide data to assess human health and ecological risk.

5.2.1.1.8 Reach 8. Rising Pond

Data exist for sediment concentrations of PCBs in Rising Pond. However, additional data are needed to more accurately define the vertical and horizontal extent of contamination and PCB concentrations in this pond. Sampling locations will be determined based on the completion of the sub-bottom profiling survey. This survey will map the accumulated sediment in Rising Pond in the same manner as Woods Pond and its upstream backwater areas. This map will be compared to the existing database to determine where there are data gaps. Additional detail on the sub-bottom profiling is provided in Subsection 5.2.1.3.

Because of the depositional nature of Rising Pond, a series of sediment cores is proposed to further characterize the pond. Approximately 20 cores will be collected as indicated in Figure 5.2-5. Cores will be collected to first refusal; and sediment samples collected every 6 inches for the same analyses as listed for the core samples from Woods Pond. The core locations will be selected based on the following criteria:

- The locations provide improved horizontal coverage and better define contaminant concentrations.
- The location provides additional vertical coverage at prior (GE) sampling locations or provides new coverage in areas where sediment has not been characterized based on the depth of accumulated sediment.
- The location duplicates a prior (GE) sample (at selected locations).

It is estimated that an additional 212 samples will be collected.

5.2.1.1.9 Reach 9. Downstream of Rising Pond Dam

This final reach was included in the sampling design to assess the levels of PCB contamination that have been transported beyond Rising Pond. The portion of this river reach that lies within Massachusetts is approximately 20 miles long and includes low-gradient meandering river habitat as well as moderate gradient riffle habitat. The Connecticut portion of this reach has yet to be defined dependent upon findings in the more upstream reaches and in-depth review of the historical data. Systematic sampling is not planned, rather this reach will be sampled at selected locations based on the potential for significant human exposure, such as recreational access points as described in the following subsections, and areas of potential ecological exposure.

5.2.1.2 Discrete Sediment Sampling

As described above, discrete sampling refers to random, judgmental, or focused samples collected at distinct locations (e.g., aggrading bars, sediment toxicity study areas). This sampling supports specific needs of the risk assessments or modeling efforts and includes samples collected at specific habitats (e.g., temporary pools), specific locations (e.g., depositional areas behind dams), or areas of frequent human exposure (e.g., residential or recreational areas).

5.2.1.2.1 Recreational and Residential Areas

There may be a risk posed to individuals who come in contact with contaminated sediments in the Housatonic River. Individuals may be exposed through incidental ingestion of sediments and dermal absorption of contaminants across skin. For the human health risk assessment, the areas of the Housatonic River most likely to be frequented by residential occupants and/or recreational and other users of the river need to be adequately characterized so that the potential risks can be assessed. Recreational uses may include, but are not limited to swimming, wading, hiking, picnicking, hunting, fishing, and canoeing. A number of Public Access Areas have been identified in Reaches 5 and 6, as shown in Figure 5.2-6. Figures 5.2-7 through 5.2-13 show the specific locations of these public access areas:

- Paintball Area (Figure 5.2-7)
- Canoe Meadows (Figure 5.2-8)
- John Decker Canoe Launch (New Lenox Road Bridge) (Figure 5.2-9)
- Lenox Sportsmans Club (Figure 5.2-10)
- Three access areas off October Mountain Road (Figure 5.2-11)
- Duck Blind Areas (Figure 5.2-12)
- Woods Pond Boat Launch Areas (Figure 5.2-13)

Table 5.2-3 shows the sediment sampling approach for both recreational and residential areas in Reaches 5 and 6. For each of the public access areas described above, as well as those identified in further investigations, one sediment sample (0- to 6-inch) may be collected per 50 ft of shoreline, and they will be concentrated in areas of easiest access.

The number of sediment samples (0- to 6-inch depth interval) for the residential areas immediately adjacent to the river in Reach 5 will be based on the number of residentially zoned properties and their length of shoreline. As shown in Table 5.2-3, up to three sediment samples will be collected for each residentially zoned property. Additional samples will be considered for any properties with extensive shorelines. Up to 190 samples are estimated for Reaches 5 and 6 for recreational and residential areas.

Table 5.2-3

Sediment Sampling by Exposure Scenario - Reaches 5 and 6

RECREATIONAL	
No. Samples	Up to 70
Sample Location	Reaches 5 and 6
Sample Depth	0-6 inches
Sampling Rationale	Up to 1 sample per 50-ft shoreline *Paintball Area* - approx. 20 samples; 1,000-ft shoreline *Canoe Meadows* - approx. 20 samples; 1,000-ft shoreline *John Decker Canoe Launch* - approx. 5 samples; 200-ft shoreline *Lenox Sportsmans Club* - approx. 4 samples; 200-ft shoreline *3 October Mountain Road access points* - approx. 9 samples; 150-ft shoreline each access point *Woods Pond Boat Launch Area* - approx. 5 samples; 250-ft shoreline *Duck Blinds (9)* - approx. 9 samples (1 per blind area)
Chemical Analyses	All samples - PCBs (total and Aroclors) Approximately 10% samples - PCB congeners/homologs, modified Appendix IX
RESIDENTIAL	
No. Samples	Up to 120 Approximately 40 existing and zoned residential properties in Reaches 5 and 6.
Sample Location	Reaches 5 and 6
Sample Depth	0-6 inches
Sampling Rationale	Up to 3 samples taken at each residentially zoned property in Reaches 5 and 6 Additional samples possible for residences with shoreline > 150 ft
Chemical Analyses	All samples - PCBs (total and Aroclors) Approximately 10% samples - PCB congeners/homologs, modified Appendix IX

In addition, residential and/or recreational areas on the river below Woods Pond may also undergo significant recreational use (e.g., swimming, wading, and fishing) and will also be evaluated.

Sediment samples will be collected at recreational and residential areas below Woods Pond (Reaches 7 through 9), but in an iterative nature and at a reduced frequency given the anticipated lower levels of contamination. Specific properties located in the floodplain will be targeted and the sampling strategy for the individual properties will be based on existing GE transect data and the land use. Approximately 150 sediment samples will be collected.

All sediment samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size, and in Reaches 5 and 6 up to 10% of the samples will be analyzed for PCB congeners/homologs and the modified Appendix IX parameters. Approximately 2% of these samples will also be analyzed for Appendix IX organophosphate pesticides and herbicides. Below Reach 6, other parameters will only be analyzed after determining that PCBs are present at concentrations that may be of concern.

5.2.1.2.2 Aggrading Bars and Terraces

Sampling of aggrading bars and terraces will be conducted to characterize potentially contaminated sediments that are exposed during low-flow conditions. In addition, these data will be used in the modeling study as characteristic of the depositional patterns in the river. Samples will be collected from aggrading bars and terraces primarily along Reach 5.

Aggrading bars and terraces are defined in Subsection 5.2.1. Based on 1997 MADEP maps (Appendix C) and information provided in reports prepared for GE, there are approximately 50 terraces and aggrading bars in Reach 5. Two cores will be collected at each terrace and aggrading bar. One of the cores will be collected toward the maximum depth of accumulated sediment, and the other core will be collected equidistant from the first core and the farthest end of the bar or terrace. Cores will be collected to first refusal and samples will be divided into 6-inch sections. Each section will be analyzed for PCBs (total and Aroclors), grain size, and TOC. It is estimated that approximately 100 cores will be collected with an average length of 2.5 ft, resulting in a total of approximately 500 samples.

In addition, approximately 10% of the samples will be analyzed for the modified Appendix IX parameters and PCB congeners and homologs. Approximately 2% of these samples will be analyzed for Appendix IX organophosphate pesticides and herbicides.

5.2.1.2.3 Former Meander Sampling

The primary objective of sampling former meanders is to characterize these river remnants for the modeling effort. In addition, contaminant information may provide some insight into the historical hydrodynamics and contaminant deposition of this system. Existing data from GE and the evaluation performed to determine former meanders mapped by Woodlot Alternatives (02-0135) will be used in addressing this concern.

"The extent to which a river meanders depends on the slope of the channel, the sediment load, and the degree of river regulation" (99-0120). When flooding occurs, these waters deposit sediments and nutrients (as well as associated contaminants) onto the floodplain. The dynamics of fluvial landscapes are determined by the interaction between the channel and the floodplain (99-0120). During flooding there is a rapid overflow of water onto the floodplain. This storage of floodwaters is followed by a varying rate of drainage to the river, dependent on the physical characteristics of the river and floodplain. Backwater areas and temporary/permanent pools can hold substantial amounts of flood water with a slow discharge to the river. This results in a settling of suspended sediments and a concomitant settling of contaminants in the bed sediment.

The Housatonic River has changed its course due to historical manmade alterations and natural fluvial processes. This has included the erosion/accretion cycle in river bends that leads to meanders and oxbows. Meanders on the river have been mapped by Woodlot Alternatives (02-0135) with several meanders occurring in Reach 5. These former meanders of the Housatonic River will be sampled as part of the transect sampling described previously. Based on the available information and data collected to date, selected former meanders will be sampled, with additional transects added if the established transects do not intersect these areas. Depending on the current status of the former meanders, either sediment or soil samples will be collected (i.e., the sample type will depend on whether standing water is present or not). The selection of locations for these samples will also be reviewed in terms of the results of the terrace and aggrading bar samples. All samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size.

5.2.1.2.4 Temporary and Permanent Pool Sampling

A screening sediment sampling program will be conducted to assess the concentrations of PCBs in temporary and permanent pools located in the floodplain of Reach 5. These pools include those that meet the definition of a vernal pool as defined by the Massachusetts Natural Heritage and Endangered Species Program, although not all pools chosen for sampling meet the definition. Sediment samples will be collected from approximately 56 pools located in the floodplain of the Housatonic River. These pools have been selected previously during ecological characterization efforts for ecological sampling (e.g., amphibians). The approximate sizes of these pools range from less than 1,000 ft^2 to 180,000 ft^2. The locations of the pools are shown in Figure 1, Appendix A.18. Depending on pool size, three to five samples will be collected in a cross-section pattern across the long axis of the pool. Samples will be collected from the 0- to 6-inch depth using either a Ponar dredge or 3-inch-diameter acetate core tube, depending on substrate characteristics. All samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size. It is estimated that between 168 and 280 samples will be collected. Sample locations will be recorded with GPS, and characteristics of the pool and sample will be recorded. This initial screening analysis may be followed by a coring program to be developed after the review of the initial data.

5.2.1.2.5 Impoundment Sampling

Suspended sediment transport of PCBs in the Housatonic River results in an accumulation of these solids and their adsorbed contaminants in depositional areas, at least for the silt and larger grain-size fractions. Concentrations of PCBs in Woods Pond are a good example of this transport and subsequent accumulation in the sediments. Therefore, it is important to characterize the accumulation of PCBs in other downstream depositional areas. This effort will provide data to support the risk assessments and modeling effort.

Sediment samples will be collected upstream of the remaining dams located between Woods Pond Dam and Rising Pond Dam. This includes two small dams in Lee (Columbia Mill Dam and

Willow Mill Dam), and the Glendale Dam (Figure 5.2-2). At least one transect of three sampling locations will be sampled at each depositional area. Multiple transects (i.e., systematic sampling) will be used if the sizes of the depositional areas are found to be extensive. Exact sampling locations and numbers of samples will be selected after field probing of sediment depths, site characteristics, and review of existing data. All samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size. It is estimated that approximately 60 samples will be collected.

Sediment samples will also be collected at depositional areas upstream of former dams. This will include five former dams in Reach 7:

1. Niagra Mills
2. Lee/Eagle Mills
3. Eaton-Bikeman
4. Monument Mills #2
5. Monument Mills #3

In addition to the former dams in Reach 7, the depositional area associated with the former Southern Berkshire dam in Reach 9 will also be sampled. The same sampling and analytical approach used for the remaining dams will result in approximately 54 samples collected in these areas of the former dams.

5.2.1.2.6 Sediment Cores

This sampling effort refers to the collection of discrete sediment cores from the channel of the Housatonic River as well as from impoundments. These cores will be placed primarily in Reaches 5 and 6 based on the iterative review of data collected to date. The results will be used to evaluate the PCB locations and concentrations and to support the modeling study. The primary objectives of this sampling are to provide data on the levels of PCBs and TOC, and to evaluate the sediment grain sizes. Secondary objectives for selected cores include pore water sampling and analysis and radioisotope dating to estimate sediment deposition rates.

Non-Transect Sediment Cores

Sediment cores will be collected as part of the discrete sampling program to assess the location and concentration of PCBs in areas of the river not associated with the systematic transect sampling. The sample locations will be based on the review of chemical data collected to date as well as observations of the river flows and sedimentation patterns. All samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size.

Grain Size Fractionation

A series of sediment cores will be collected from the river channel, Woods Pond, and backwater areas to provide data for the hydrodynamic and water quality modeling effort. Cores will be collected at 11 transects in Reach 5, resulting in a total of 33 cores (three cores per transect). Additional cores will be collected from Woods Pond (six cores) and its backwaters (three cores). Locations of the Woods Pond and backwater cores will be selected based on the sub-bottom profiling survey and will coincide with the cores collected as part of the systematic sampling of Woods Pond. Sampling will occur in those areas that have an adequate depth of accumulated sediments.

Analyses will include PCB analysis on the bulk samples and PCB and TOC analysis of three grain size fractions for each sample. Core samples will be collected at 0- to 6-inch and 12- to 18-inch depth intervals and samples from each interval will be sieved into separate grain size groups for analysis. Multiple cores may be collected to ensure that an adequate volume of sediment is available for the analyses. This will result in approximately 66 samples from the Reach 5 transects and 18 samples from locations in Woods Pond and three backwater areas (Reach 6). This results in a total of 84 core samples for PCB analysis. Additional analyses (such as redox) may be performed to evaluate the anoxic condition of river and impoundment sediment.

Each core sample will be fractionated into the following size fractions:

- $< 62\ \mu m$
- $62 – 250\ \mu m$
- $>250\ \mu m$

The three sediment fractions per core will be analyzed for PCBs and TOC, for a total of 252 fractionated samples.

Pore Water

Sediments will also be collected for pore water (interstitial water) analysis from the 0- to 6-inch depth interval at selected locations. These data will provide information on the partitioning of PCBs between the sediment and water phase (pore water). In particular, pore water sampling will provide data that can be used to determine the potential for sediments to be a source of PCBs to surface waters. Sediment cores will be capped, sealed, and shipped to the subcontract laboratory for pore water extraction. Cores will be extracted by centrifugation with the supernatant collected, filtered, and analyzed for PCBs and dissolved organic carbon. A total of 6 to 15 pore water samples are estimated. The procedure for collection and extraction of pore water samples is included in Appendix A.2.

Radionuclide Dating

Up to 10 of the cores will be used for dating to estimate the sediment deposition rate in Woods Pond and its backwaters. The need for additional cores in these areas or in the river will be evaluated after the initial data assessment. Cores will be sectioned every 2 cm for the top 15 cm (0 to 4 inches), every 4 cm for the next 30 cm (~4 to 12 inches), every 10 cm for the next 60 cm (~12 to 36 inches), and every 15 cm to a depth of approximately 183 cm (72 inches). This will result in approximately 22 samples per core for dating analysis. Various methods are available for dating sediment. These include:

- ^{137}Cs
- ^{210}Pb
- ^{7}Be
- Pollen
- Other isotopes such as U and Th with long half-lives

This study will use both Cesium-137 and Lead-210 for dating. Use of Beryllium-7 will be limited to the surface layers (i.e., top two to three measurements) of the sediment cores. A subcontract laboratory using instruments to measure the radioisotopes (i.e., to measure gamma radiation) will conduct the analyses. Pollen and U and Th isotopes will not be used in this study. The following is a discussion of the Cesium-137, Lead-210, and Beryllium-7 methods.

Cesium-137—Cesium-137 is an artificial radionuclide with a half-life of 30.17 years that was produced as a by-product of past atmospheric testing. Detectable Cesium-137 began in 1954 with a first peak in 1958-1959 and a second peak in 1962. The maximum peak was in approximately 1963. Generally the use is semiquantitative with maximum data peaks correlated to 1963 and the first detection in 1954. It is necessary that the core is deep enough so that background (nondetect) corresponding to the early 1950s is discernible. Previous data collected in the Housatonic River were to maximum depths of 18 to 28 inches and did not appear to go deep enough for interpretation. To derive quantitative estimates of rates of accumulation, it is necessary to establish a relationship between the magnitude of the deviation from the reference inventory and the extent of sedimentation. However, adequate reference data are generally not available. Cesium-137 is frequently used in connection with Lead–210 for confirmation.

Lead-210—Lead-210 is a natural product of the U-238 decay series, with a half-life of 22.26 years. It is derived from the decay of gaseous Radon-222, the daughter of Radium-226. Diffusion of radon into the atmosphere introduces Lead-210 to the surface, and this “fallout” Lead-210 is not in equilibrium with its parent radium. The fallout component is termed unsupported or excess Lead-210 because it cannot be accounted for by the in situ decay of the parent. The amount of unsupported Lead-210 can be calculated by measuring both Lead-210 and Radium-226 (or surrogate) and subtracting the supported component. Both Lead-210 and Cesium-137 are strongly and rapidly absorbed, but fallout input for lead is essentially constant.

Beryllium-7—Beryllium-7 is a cosmogenic radionuclide produced in the upper atmosphere by the breakdown of nitrogen and oxygen by cosmic rays. This radionuclide is very short lived with a half-life of 53.3 days and as such is capable of providing a measure of erosion dynamics over a much shorter time span. Previous sediment work did not detect much, if any, Beryllium-7, and sedimentation rates may be too slow for this to be a useful measurement.

5.2.1.2.7 Benthic Invertebrate Community Evaluation Locations

Sediment samples will be collected as part of the benthic macroinvertebrate community evaluation, which is part of the Sediment Quality Triad Evaluation (see Subsection 7.3.3.1.1). Two core subsamples for analysis of sediment chemistry, grain size, and TOC will be removed from each of the 156 Ponar grab samples (i.e., 12 replicates at each of the 13 locations). These subsamples will be collected by inserting an approximately 1-ft-long section of 37.5-mm diameter acetate core liner into the undisturbed sediment surface within the Ponar to a depth of 5 cm, capping the top of the core, and removing the sediment (55 cm^3 each subsample). The two core subsamples will be composited in a clean stainless-steel bowl and separated into two aliquots of approximately 30 cm^3 and 80 cm^3 for PCB (total and Aroclors) and TOC analyses, respectively. Approximately 10% of these samples will also be analyzed for dioxins/furans, OC pesticides, and grain size. A subset of these locations corresponds to those described below for the sediment toxicity tests.

5.2.1.2.8 Sediment Macroinvertebrate Toxicity, Bioaccumulation, and Stressor Identification Study Locations

Sediment samples will be collected at six locations for use in the macroinvertebrate sediment toxicity study, which is another component in the Sediment Quality Triad. In addition, this sampling may support the third component of the Sediment Quality Triad, the sediment chemistry component. The six samples include sediments collected at two reference locations, three sites with low to moderate PCB concentrations, and one location with high PCB contamination. Whenever possible, sample locations will be chosen to have similar grain size and TOC concentrations. Samples will be collected with 3-inch-diameter cores or with an Ekman dredge or Petite Ponar at a depth of 0 to 6 inches.

All samples will be analyzed for TOC and grain size. In addition, at least one sediment sample per location will be analyzed for total PCBs, PCB congeners, and modified Appendix IX parameters. Additional sediment chemistry analyses will be conducted to support individual tasks specified in the sediment toxicity study plan in Appendix A.14.

5.2.1.2.9 Mussel Bioaccumulation and Growth Locations

Three sediment samples will be taken for chemical analyses from each of the six stations where mussel racks will be deployed. Samples will be collected from the 0- to 6-inch interval using either a Ponar dredge or 3-inch-diameter Lexan core tubes, depending on substrate characteristics. All samples will be analyzed for PCBs (total and Aroclors), ammonia, TOC, and grain size. In addition, one sediment sample from each station will also be analyzed for PCB congeners and homologs and Appendix IX OC pesticides.

5.2.1.2.10 Amphibian Toxicity Locations

Sediment samples will be collected in conjunction with the collection of leopard frogs for use in the amphibian toxicity study. One composite sediment sample will be collected from each sector where frogs are harvested (the study plan for the frog collection and toxicity testing approach is provided in Appendix A.19). These samples will include adequate volume so that sufficient sediment is available for both the toxicity test and chemical analysis. Sediments will be collected using 3-inch-diameter cores or an Ekman dredge. Only the top 0 to 6 inches of sediment will be collected for each sample. A maximum of 10 samples will be collected and analyzed for PCBs (total and Aroclors), dioxins/furans, OC pesticides, PCB congeners and homologs, TOC, and grain size.

In addition to the sediment samples required for the toxicity test and chemical analysis, corresponding surface water composite samples will be collected at each sector. Surface water samples will be analyzed for PCBs (total and Aroclors), PCB congeners and homologs, dioxins/furans, and OC pesticides.

5.2.1.2.11 Fish Collection Areas

For the ecological and human health assessment, various life stages of fish will be collected from seven locations—five downstream of GE facility contamination, and two from reference areas. Sediment sampling will be conducted in four of the seven locations under the systematic sampling. One location, Goodrich Pond, was previously sampled by GE and will be sampled again by GE contractors. The two reference locations (Three-Mile Pond and the Upper Housatonic River in Dalton) will require additional sediment sampling to characterize the contaminant concentrations.

Approximately seven sediment samples will be collected from Three-Mile Pond at random points within the area from which fish were collected. Approximately five sediment samples will be collected from Center Pond, located on the Housatonic River upstream of East Housatonic

Street in Dalton, MA. Samples from 0 to 6 inches will be collected at each location and analyzed for PCBs (total and Aroclors), grain size, and TOC. In addition, approximately one sample will be analyzed from each area for modified Appendix IX compounds.

5.2.1.2.12 Tree Swallow Study

Sediment samples will be collected as part of the study designed to measure the potential effects of PCB contamination in tree swallows (*Tachycineta bicolor*) from ingestion of aquatic insects. Nest boxes have been erected within three separate reaches of the river, as well as at three reference sites.

The proposed sampling was designed to characterize the quality of the sediments within the immediate vicinity of the nest boxes and within the 400-m average foraging radius of the adult tree swallow during breeding season (99-0145). In addition, sampling will focus on open water areas since tree swallows forage on aquatic insects.

At each nest box cluster, samples will be collected at 100-ft intervals to cover the linear extent of the area encompassed by the nest boxes along the river. Each sediment sample will be collected at a position midway between the bank opposite the nesting box and the centerline of the stream.

Sediments from backwater areas and portions of the river greater than 100 ft away from the nest boxes will be sampled according to a stratified random design conducted radially from the box locations. Proposed sediment sampling locations were established by superimposing a radial grid with a 400-m radius on the nest box locations shown on the map. The grid encompassed a total of 0.502 square kilometers (km^2), and was graduated according to the following radii: 100 m, 200 m, and 400 m (Figure 5.2-14). It was further divided into eight sectors corresponding to major compass points (N, NE, E, SE, S, SW, W, NW). Hence, a total of 24 sectors was created. The eight inner sectors each encompassed an area of 3,925 square meters (m^2), the eight median sectors each encompassed an area of 11,775 m^2, and the eight outer sectors each encompassed an area of 47,112 m^2. If a backwater area or portion of the river fell within a sector, a dot representing the proposed sampling location was placed on the map at random within that habitat. This sampling strategy, when integrated with the stream sampling at 100-ft intervals, will be used to characterize sediment quality within areas the birds are most likely to use.

Approximately 260 sediment samples are proposed for collection in support of the tree swallow study. Forty samples are proposed to characterize the Holmes Road cluster of nest boxes, 65 samples are proposed in the vicinity of the New Lenox Road cluster of nest boxes, and 75 samples are proposed for the cluster of boxes located immediately north of Woods Pond. In addition, 80 samples are proposed to characterize sediment quality within the reference areas. The difference in sample numbers proposed for each of these reaches is a result of the differing amounts of backwater and river habitat requiring characterization. The area immediately north of Woods Pond has extensive backwater marsh areas available for foraging, whereas habitat near Holmes Road is primarily limited to the river itself.

Sediment will be collected at a depth of 0 to 6 inches using a dedicated coring device. Samples will be analyzed for PCBs (total and Aroclors), TOC, and grain size, with approximately 10% of the samples in each reach analyzed for modified Appendix IX parameters.

Sampling points from the systematic sediment investigation (Subsection 5.2.1.1) will be incorporated into the sampling effort, as will sediment sampling associated with benthic macroinvertebrate sampling and sediment core samples, wherever possible.

5.2.1.3 Sub-Bottom Profiling

A survey using sub-bottom profiling techniques will be conducted to determine the depth of accumulated sediments in two impounded areas of the Housatonic River (Woods Pond and Rising Pond). The profiling in these areas will result in the production of maps showing depths of accumulated sediment and bathymetry of each area. A high-resolution sub-bottom profiler (X-Star) will be used to conduct the surveys in conjunction with differential GPS (DGPS) and navigational systems to allow accurate spatial data to be collected. Because of the amount of organic material in the sediments and associated gas production (due to microbial degradation), the sub-bottom profiler may have limitations, in which case electronic data collections will be supplemented with manual probing in areas that were not conducive to electronic surveying to determine accumulated sediment depths. Sediment probes will be conducted every 200 ft along 200-ft transect spacings in Woods Pond, backwater areas, and the outflow arm. Due to the smaller size of Rising Pond, probes will be conducted every 100 ft on 100-ft transect intervals.

The survey will be initiated and completed before ice forms on the ponds. A summary report describing the techniques used, data interpretation, and associated maps will be produced after completion of the field work and used in conjunction with the coring program for both ponds.

5.2.2 Riverbank Soils

Collection of soil samples from the riverbanks will support the human health and ecological risk assessments. Secondary objectives include determining the contaminant concentrations in riverbanks for possible evaluation in the modeling study. The sampling design for riverbank soils is based upon results of prior studies discussed in Section 3. The proposed design calls for decreased sampling effort moving downstream, as previous data suggest that PCB concentrations in bank soils are likely to decrease moving downstream from the source area. The most intensive sampling for Reaches 3 and 4 has been completed under the Preliminary Work Plan (WESTON, 02-0161) or under the EE/CA Work Plan (WESTON, 07-0001). Table 5.2-4 lists the riverbank samples.

The sampling approach for the previous studies focused on areas of the river where banks are most evident, and where bank soils are potentially most contaminated. Riverbanks are most prominent (i.e., steepest and highest) near the Source Reach and immediately adjacent reaches because the river was channelized in the 1940s where it passed through the City of Pittsfield. Potential sources of bank contamination include:

- Contaminated groundwater, including free product, leaching through the banks within Reach 3.
- Potentially contaminated fill material used to create the banks when the river was channelized.
- Deposition of suspended contaminated sediments onto bank slopes and terraces during high-flow or flood events.
- Deposition of contaminated soils from adjacent areas as a consequence of erosion and runoff.

Table 5.2-4

Proposed Riverbank Soil Sampling
Housatonic River - Supplemental Investigation

Reach #	Systematic Bank Samples [a]	Recreational/ Public Areas	Residential	Commercial/ Utility Easements	Total Samples
1					0
2					0
3	*993* [b]				993
4	*719* [b]				719
5	132	164	240	40	576
6					0
7		tbd	tbd	tbd	0
8		tbd	tbd	tbd	0
9		tbd	tbd	tbd	0
Reference Location					0
Total Samples	1844	164	240	40	2288

[a] Discrete sampling of riverbanks in Reaches 7 through 9 may be performed.

[b] Collection completed under separate work plans.

tbd = to be determined; sampling in these reaches may be performed.

Except for the deposition of suspended sediments, these processes are most likely to occur within or adjacent to the Source Reach. Therefore, the majority of the bank sampling was conducted within Reaches 3 and 4, which are not the subject of this Work Plan. However, some bank sampling will occur within Reach 5 in areas where human exposure is possible. To support the human health risk assessment, additional bank sampling may occur in Reaches 6 through 9 at locations where human exposure is possible.

5.2.2.1 Systematic Riverbank Soil Sampling by Reach

Systematic sampling on riverbanks was conducted in Reaches 3 and 4 in the same manner as systematic sediment sampling (WESTON, 02-0161 and 07-0001). In summary, sample transects were oriented perpendicular to the river and extended across both sides of the river. Sampling locations on each bank included the following:

- Bottom of the bank (toe of slope).
- Mid-bank, or terrace.
- Top of bank.

Samples were collected at three discrete depth intervals below ground surface (bgs). These were 0 to 6 inches bgs, 12 to 18 inches bgs, and 24 to 30 inches bgs. Sampling protocols followed WESTON standard operating procedures (SOPs) for soil sampling (00-0334).

All soil samples were analyzed for PCBs (total and Aroclors). Approximately 10% of the samples were analyzed for grain size and TOC. An additional 10% of the samples were sampled for the modified Appendix IX compound list.

5.2.2.1.1 Reach 1. Upstream Reference Locations

No bank sampling is proposed due to low likelihood of contamination within this reach, as prior sampling has indicated. Sediment sampling is proposed in order to support the risk assessments. Bank sampling may be conducted if elevated contaminant concentrations are detected in the sediment samples from this reach.

5.2.2.1.2 Reach 2. Unkamet Brook to Newell Street Bridge

No bank sampling is proposed for Reach 2, because it is upstream of the Source Reach and is less likely to be contaminated. However, bank sampling may be conducted if elevated contaminant concentrations are detected in the sediment samples from this reach.

5.2.2.1.3 Reach 3. Newell Street Bridge to Lyman Street Bridge

Riverbank soils were sampled along 63 transects at 50-ft intervals in Reach 3 during August and September 1998 (Preliminary Work Plan for Engineering Evaluation/Cost Analysis (EE/CA) and Remedial Investigation (RI) Work Plan for OU 2 – Housatonic River; 02-0161). A total of approximately 993 samples were collected in this reach.

5.2.2.1.4 Reach 4. Lyman Street Bridge to the Confluence with the West Branch

Samples were collected on transects at 100-ft intervals on both sides of the bank. Approximately 719 riverbank samples were collected along transects in this reach. This sampling was covered under the EE/CA Work Plan and the EPA START contract. Riverbanks located on residential lots were sampled through the EPA START contract.

5.2.2.1.5 Reach 5. West Branch Confluence to Woods Pond

Because only a few sizable banks exist in this reach and the presence of contaminated fill in the riverbanks is improbable, sampling of banks will be conducted only when they are encountered during the floodplain sampling program. In that event, the banks will be sampled at a single location in the side of each bank, according to the sampling protocol described above. For the purposes of this Work Plan, it is assumed that banks will be encountered on a total of 5 transects, for a total of 30 samples (one location per bank, 2 banks on each of the 5 transects, and 3 samples per location). In addition, samples are proposed in residential areas (Holmes Road area and the vicinity of Joseph Drive) as well as recreational and utility easement areas (described in Subsection 5.2.2.2) to support the human health risk assessment.

In addition to the 5 systematic transects, 17 transects were established in Reach 5 to define the preliminary channel geometry for the modeling study (see Subsection 5.3.4). These transects may also be sampled for riverbank soils when a defined bank is present. Samples will be collected in the same manner as the systematic samples. It is estimated that 102 samples may be collected. These samples will be analyzed for PCBs (total and Aroclors), and approximately 10% will be analyzed for TOC, grain size, and modified Appendix IX compounds. Two percent will be analyzed for Appendix IX organophosphate pesticides and herbicides. These data will also supplement the systematic data for use in the risk assessments. A total of 132 samples are estimated for this reach.

5.2.2.1.6 Reaches 6 through 9. Woods Pond to Downstream of Rising Pond

Systematic bank sampling along transects is not proposed for Woods Pond since the backwater areas are characterized by a broader floodplain with low banks. Moreover, prior sampling results indicated that the area downstream of Woods Pond has lower relative PCB concentrations. Therefore, systematic bank sampling along transects is not proposed for Reaches 6 through 9. Discrete bank sampling may be conducted in support of the human health risk assessment as discussed below.

5.2.2.2 Discrete Riverbank Soil Sampling

5.2.2.2.1 Recreational, Residential, and Commercial Areas

There may be a risk posed to individuals who come in contact with contaminated riverbank soils along the Housatonic River. Individuals may be exposed through incidental ingestion of soils and dermal absorption of contaminants across skin. For the human health risk assessment, the riverbanks in the areas of the Housatonic River most likely to be frequented by recreational and other users of the river need to be adequately characterized. In the Reach 5 area, there is limited riverbank because of the broad floodplains characteristic of the river in this reach; therefore, the actual number of samples taken may be less than the number proposed.

Table 5.2-5 shows the riverbank sampling approach for recreational, residential, and commercial areas in Reach 5. For riverbank soils at the public access areas described in Subsection 5.2.1.2, up to two samples (0- to 6-inch and 6- to 12-inch depth intervals) will be collected per 50 ft of shoreline. However, this does not include the Woods Pond Boat Launch Area, which does not have riverbanks, or those riverbank samples previously identified as part of the systematic sampling. The table shows each of the applicable public access areas, the estimated length of shoreline, and the proposed number of samples in Reach 5.

The number of riverbank samples adjacent to the residential properties will be based on the number of residentially zoned properties and their length of shoreline with existing riverbanks. For residential properties with less than 150 ft of riverbank, up to one sample location at two sample depths (0- to 6-inch and 6- to 12-inch) per 50 ft will be collected. Because all the residential properties in Reach 5 appear to have less than 150 ft of shoreline, a maximum of three riverbank samples will be collected at each existing or zoned residential property.

For areas where utility easements occur in riverbanks in Reach 5 (see Figure 5.2-15), it is estimated that up to 20 total locations will be sampled. The composite samples will be taken at 0 to 6 inches and 6 inches to 6 ft for a total of up to 40 samples. As noted above, it may be difficult to identify 20 locations in these areas with existing riverbanks. If this is the case, the number of locations will be reduced accordingly. The samples from the 6-inch to 6-ft depth interval will be composited by taking aliquots from each auger interval.

Additional riverbank samples may be collected at recreational, residential, and commercial areas below Woods Pond (Reaches 7 through 9). All samples will be analyzed for PCBs (total and Aroclors), and approximately 10% of the samples from Reach 5 will be analyzed for PCB congeners/homologs, TOC, grain size, and the modified Appendix IX list compounds. Below Reach 6, other parameters will only be analyzed after determining that PCBs are present at concentrations that may be of concern.

Table 5.2-5

Riverbank Soil Sampling by Exposure Scenario - Reaches 5 and 6

RECREATIONAL	
No. Samples	Up to 164
Sample Location	Reaches 5 and 6
Sample Depth	0-6 inches and 6 inches - 1 ft
Sampling Rationale	Up to 1 sample location (2 samples per location) per 50-ft shoreline, depending on existence of riverbanks in specific area *Paintball Area* - Approx. 40 samples; approx. 1,000-ft shoreline *Canoe Meadows - approx. 40 samples; approx. 1,000-ft shoreline* *John Decker Canoe Launch* - 8 samples; approx. 200-ft shoreline *Lenox Sportsmans Club* - 40 samples; approx 1,000-ft shoreline *October Mountain Road, 3 access points* - 18 samples; approx. 150-ft shoreline each access point *Duck Blinds (9)* -18 samples (1 per blind area)
Chemical Analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples will be evaluated for PCB congeners/homologs, modified Appendix IX
RESIDENTIAL	
No. Samples	Up to 240 Approximately 40 existing and zoned residential properties in Reaches 5 and 6
Sample Location	Current residences or zoned residential areas with properties extending to river with riverbanks
Sample Depth	0 - 6 inches and 6 inches - 1 ft
Sampling Rationale	Up to 3 surface sample locations (2 samples per location) per residence or zoned residential properties abutting riverbanks, or 1 per 50 ft of existing riverbank
Chemical Analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples - PCB congeners/homologs, modified Appendix IX
COMMERCIAL/INDUSTRIAL (Utility Worker)	
No. Samples	Maximum of 40
Sample Location	Up to 20 locations on riverbanks of easements
Sample Depth	Composited from 0-6 inches and 6 inches-6 ft
Sampling Rationale	Reaches 5 and 6 have few riverbanks; therefore, sampling will occur where easements abuts riverbanks
Chemical Analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples - PCB congeners/homologs, modified Appendix IX

5.2.3 Floodplain Soils

Sampling of the floodplain soils will be conducted primarily in areas downstream of the Source Reach and EE/CA Reach because of the limited floodplain that remains above the study area and the unlikely occurrence of PCB contamination in these areas given the locations of the potential source areas as currently known. The sampling strategy includes the collection of both systematic (transect) and discrete samples. The data generated will be used to support the human health and ecological risk assessments, as well as the modeling study. Because of the dynamics of the riverine system, including annual high flows and flooding, contaminant deposition has occurred throughout this watershed downstream of the known and potential sources. Comprehensive data are needed to ascertain the extent of contamination on both a horizontal and vertical scale to define areas for further evaluation for the human health and ecological risk assessments and the modeling effort. Systematic sampling is proposed through Reach 7, and discrete sampling specific to risk assessment requirements will be conducted through Reach 9.

5.2.3.1 Systematic Floodplain Sampling by Reach

The 10-year floodplain is shown on the historical data maps (in Appendix D) and also in Figure 5.2-3. GE previously estimated that the extent of the PCB contamination lies within the 10-year and possibly closer to the 5-year floodplain (04-0004). The 10-year floodplain will be systematically sampled using a series of transects similar to those for the sediments, oriented perpendicular to the Housatonic River. The distance between transects will increase moving downstream, as the contaminant concentrations are expected to decrease with increasing distance from the Source Reach. Each transect will be sampled at three locations on each side of the river, with the samples apportioned between the river and 10-year floodplain in equal segments. As a result, floodplain transects will consist of six sampling locations, each to be sampled at three depths (0 to 6 inches, 12 to 18 inches, and 24 to 30 inches).

The proposed number of floodplain samples is summarized by reach in Table 5.2-6. All samples will be analyzed for PCBs (total and Aroclors), with approximately 10% of the samples analyzed

Table 5.2-6

Proposed Floodplain Soil Sampling
Housatonic River - Supplemental Investigation

Reach #	Systematic Floodplain Samples	Agricultural	Recreational/ Public Areas	Residential	Commercial/ Industrial	Small Mammals Locations	Earthworm Locations	Cornfield	Total Samples
1									0
2									0
3									0
4	*340* [a]								340
5	1266	150	200	400	215	120	20	30	2401
6	56		20						76
7	648 [b]	tbd	tbd	tbd	tbd			tbd	648
8	36		tbd	tbd	tbd				36
9	350 [b]	tbd	tbd	tbd	tbd			tbd	350
Reference Location							10		10
Total Samples	2696	150	220	400	215	120	30	30	3861

[a]Collection completed with separate work plans.

[b]These will be collected as discrete samples throughout Reaches 7 and 9 as appropriate.

tbd = to be determined; sampling in these reaches may be performed.

Grand Total Samples:	
Sediment	5,867
Riverbank	2,288
Floodplain	3,861
	12,016

for TOC, grain size, and the modified Appendix IX parameters. In addition, approximately 2% of the samples will be analyzed for organophosphate pesticides and herbicides. After review of the initial sampling results and available data, up to 10% of the sampling locations may be sampled and analyzed for PCB congeners and homologs.

The approach for each reach is summarized below. The actual number and location of samples or transects may be altered based upon field conditions, review of available data, and concerns of stakeholders.

5.2.3.1.1 Reaches 1 and 2. Upstream Reference Locations; and Unkamet Brook to Newell Street Bridge

Based upon prior sampling results indicating relatively low PCB contamination within river sediments upstream of the Source Reach, and the limited floodplain area associated with these reaches, no systematic floodplain soil sampling is currently proposed for Reaches 1 or 2. This evaluation may be revisited if elevated sediment PCB contamination is detected within either reach or the presence of contaminated fill in the floodplain is confirmed.

5.2.3.1.2 Reach 3. Newell Street Bridge to Lyman Street Bridge

The 10-year floodplain in Reach 3 is relatively narrow due to the steep banks on both sides of the river. For this reason the riverbank soil samples collected represent floodplain samples for this reach. Additional floodplain samples were not collected in this reach as part of the Preliminary Work Plan. Data from this reach will be available for use in the modeling effort.

5.2.3.1.3 Reach 4. Lyman Street Bridge to the Confluence with the West Branch

Floodplain samples in this reach were collected under the EE/CA Work Plan and under the EPA START contract. Each location was sampled at the three depths described in Subsection 5.2.3.1. Approximately 340 samples were collected in this reach. Data from this reach will be available for use in the modeling effort.

5.2.3.1.4 Reach 5. West Branch Confluence to Woods Pond

A total of 37 transects are proposed at 1,500-ft intervals in Reach 5 (Figure 5.2-1). On each transect, floodplain soil samples will be collected at three locations on each side of the river. A total of 18 floodplain soil samples will be collected from each transect (six locations, three depths). Thus, the number of floodplain soil samples planned for this reach is 666.

In addition to the 37 systematic transects, 17 transects were established in Reach 5 to define the preliminary channel geometry for the modeling study (see Subsection 5.3.4). These transects may also be sampled for floodplain soils with samples collected every 50 ft across the 10-year floodplain. Samples will be collected at 0 to 6 inches at every location, and at 6 to 12 inches at every other location (i.e., every 100 ft). Approximately 600 samples will be collected. These samples will be analyzed for PCBs (total and Aroclors) with approximately 10% analyzed for TOC, grain size, and modified Appendix IX parameters and 2% for Appendix IX organophosphate pesticides and herbicides. These data will also supplement the systematic data for use in the risk assessments.

These data will be used extensively for the ecological risk assessment to define the contaminant concentrations in the various habitats in this reach. The data will also be used to define the concentrations of contaminants in those areas of the floodplain where human exposure is possible. In addition, the data generated will be used in validation and calibration for the modeling study.

5.2.3.1.5 Reach 6. Woods Pond

The 10-year floodplain is limited in Reach 6 to a narrow strip of land along the eastern, western, and southern shores of the pond. The area between Woods Pond Dam and the footbridge will be sampled to assess the potential of floodplain soil contamination as a result of flooding. Approximately 36 samples will be collected at 12 locations. Sampling locations will be chosen in the field and biased toward potential depositional areas. These locations will be sampled at the three depths described above.

In addition to these floodplain samples, one transect was established in Reach 6 to define the channel geometry for the modeling study (see Subsection 5.3.4). A limited number of soil samples will be collected on the east and west shores (approximately 20 total) of Woods Pond, which correspond to the 10-year floodplain. These samples will be analyzed for PCBs (total and Aroclors), and approximately 10% of the samples will be analyzed for TOC, grain size, and modified Appendix IX parameters, and 2% for Appendix IX organophosphate pesticides and herbicides. An estimated total of 56 samples will be collected in Reach 6. Additional samples may be collected to further identify areas based on preliminary review of study data.

5.2.3.1.6 Reach 7. Woods Pond to Rising Pond

The floodplain downstream of Woods Pond needs to be better characterized in terms of historical contaminant deposition. This effort will support the human health risk assessment and provide data for the modeling effort. This reach will be sampled with 36 transects at 2,500-ft intervals. A total of 18 floodplain samples per transect will be collected, resulting in 648 samples.

5.2.3.1.7 Reach 8. Rising Pond

Up to 36 soil samples will be collected within the floodplain surrounding Rising Pond. Due to the limited extent of the 10-year floodplain, sample locations will be positioned in a linear pattern of approximately six locations on each side of the pond. These data will support the human health risk assessment. A total of 36 samples will be collected.

5.2.3.1.8 Reach 9. Downstream of Rising Pond

Sampling locations will be selected based on the potential for exposure in areas of the floodplain and the location of potential depositional areas. Due to the extensive length of river involved and the potential number of areas, it is estimated that up to 350 floodplain soil samples will be collected from this reach. This effort will support the risk assessments.

5.2.3.2 Discrete Floodplain Soil Sampling

This subsection describes floodplain samples that will be collected either in association with specific biological studies (i.e., soil invertebrate and small mammal) or areas of frequent human exposure. Further detail on the biological studies is included in Subsection 5.5.

5.2.3.2.1 Soil Invertebrate Sampling

Soil invertebrate tissue sampling will be conducted at several floodplain locations within the study area. Sampling locations will be chosen to represent a range of PCB concentrations in soil, one of which will be considered a reference area. In addition, locations will be selected in habitats that are suitable to soil invertebrate-ingesting species that may be selected as target receptors in the ecological risk assessment. Further details on the proposed soil invertebrate sampling are presented as part of the soil invertebrate sampling efforts discussed in Subsection 5.5.3.10 and Appendix A.22.

It is estimated that 5 to 10 plots will be delineated for soil invertebrate sampling within each of the three locations. One composite soil sample will be collected from each plot, resulting in an estimated total of 15 to 30 additional soil samples.

All soil samples collected will be analyzed for PCBs (total and Aroclors), TOC, and grain size. A subset of all composite soil samples will be analyzed for modified Appendix IX list compounds.

5.2.3.2.2 Small Mammal Sampling

A screening floodplain soil sampling program was conducted during August and September 1998 under the Preliminary Work Plan (WESTON, 02-0161) at 12 locations selected as potential small mammal trapping locations. Further detail on the proposed small mammal sampling is presented in Subsection 5.5.3.13. Approximately 10 soil samples were collected from the 0- to 6-inch depth interval from each area at flagged locations. All samples were analyzed by the field laboratory for PCBs (total and Aroclors). All sample locations were recorded with GPS.

Results from this initial screening will be reviewed and used to determine specific trapping areas for small mammals. Additional soil samples may be collected in each selected area to better define the extent of PCB contamination. This will result in an estimated total of 120 soil samples.

5.2.3.2.3 Recreational, Residential, Agricultural, and Commercial/Industrial Areas

There may be a risk posed to individuals who come into contact with contaminated soils in the Housatonic River floodplain. Individuals may be exposed through incidental ingestion of soils and dermal absorption of contaminants across skin. In addition, individuals may be exposed indirectly through the consumption of vegetables grown in contaminated soil and possibly through the consumption of dairy products from cows that may have consumed PCBs in silage and pasture from the floodplain. Groundskeepers and utility workers may also be exposed to surface soils during daily work routines. For the human health risk assessment, contamination in the floodplain areas of the Housatonic River most likely to be frequented by residential, recreational, agricultural, and commercial/industrial users of the river needs to be adequately characterized.

Recreational

Table 5.2-7 shows the floodplain sampling approach for the exposure scenarios in Reaches 5 and 6. For each of the public access areas listed in the table (including the DeVos Farm shown in Figure 5.2-16) for which the floodplain represents a potential source of exposure, as well as those identified in further investigations, up to 40 floodplain surface soil samples (0 to 6 inches and 6 to 12 inches at 20 locations) will be collected.

Residential

For each of the current residential properties in Reaches 5 and 6, and for those properties zoned for future residential development that extend into the 10-year floodplain, up to five surface sample locations will be sampled at two depths (0 to 6 inches and 6 to 12 inches) at each property. Samples collected from residential properties under other programs will not be duplicated.

Table 5.2-7

Floodplain Soil Sampling by Exposure Scenario - Reaches 5 and 6

RECREATIONAL	
No. Samples	Up to 220
Sample Location	Reaches 5 and 6
Sample Depth	0-6 inches and 6 inches - 1 ft.
Sampling Rationale	Up to 20 sample locations per recreational area (2 depths per location) *Paintball Area* - Approx. 40 samples (20 locations) *Canoe Meadows* - approx. 20 samples (10 locations) *John Decker Canoe Launch* - 20 samples (10 locations) *DeVos Farm* - 40 samples (20 locations) *Lenox Sportsmans Club* -20 samples (10 locations) *3 October Mountain Road access points* - 20 samples (10 locations) *Woods Pond Boat Launch Area* -20 samples (10 locations) *Duck Blinds (9)* -40 samples (20 locations)
Chemical analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples will be evaluated for PCB congeners/homologs, modified Appendix IX
RESIDENTIAL	
No. Samples	Up to 400 samples Approximately 40 existing and zoned residential properties in Reaches 5 and 6
Sample Location	Reaches 5 and 6
Sample Depth	0 - 6 inches and 6 inches - 1 ft.
Sampling Rationale	*Samples taken where floodplain soils coincide with residential property* Up to 5 samples at each depth for each residence or residentially zoned property
Chemical Analyses	All samples - PCBs (total and Aroclors) Approx. 10% PCB congeners/homologs, modified Appendix IX
AGRICULTURAL	
No. Samples	Up to 150 - Sample numbers may be reduced based on field observations of land use.
Sample Location	Reaches 5 and 6
Sample Depth	0 - 6 inches and 6 inches - 1 ft.
Sampling Rationale	Up to 5 sample locations (2 depths per location) per 5 acres of agricultural land (approx. 75 acres based on land use maps) Reaches 5 and 6 - Tilled or potentially tilled floodplain soils.
Chemical analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples will be evaluated for PCB congeners/homologs, modified Appendix IX

Table 5.2-7

Floodplain Soil Sampling by Exposure Scenario - Reaches 5 and 6

COMMERCIAL/INDUSTRIAL	***(Groundskeeper)***
No. Samples	Approx. 100
Sample Location	Reach 5
Sample Depth	0-6 inches and 6 inches - 1 ft.
Sampling Rationale	Based on initial review of current land use
Chemical analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples - PCB congeners/homologs, modified Appendix IX
COMMERCIAL/INDUSTRIAL	***(Utility Worker)***
No. Samples	Approx. 115
Sample Location	Reaches 5 and 6
Sample Depth	0-6 inches and 6 inches - 1 ft and 1 ft - 6 ft
Sampling Rationale	Reaches 5 and 6 utility easements *Tennessee Gas/El Paso Energy* - 10 locations; 30 samples (3 depths) *AT&T* - 5 locations; 15 samples (3 depths) *Western Mass. Electric* - 20 locations; 40 samples (2 depths) *Sewer Easement* - 10 locations; 30 samples (3 depths)
Chemical analyses	All samples - PCBs (total and Aroclors) Approx. 10% samples will be evaluated for PCB congeners/homologs, modified Appendix IX

Agricultural

Agricultural floodplain soil sampling is based on the total area in Reach 5 currently zoned for agricultural use. Up to five soil sample locations at two depths (0 to 6 inches and 6 to 12 inches) will be sampled per 5 acres of tillable cropland or pastureland as noted in Table 5.2-7. Farmers may currently till soils to a depth greater than 1 ft. It is anticipated, however, that given the likely extent of contamination in floodplain areas that are farmed, the majority of contamination would occur in the top 1 ft of soil. It is estimated that up to 150 discrete floodplain samples may be required in Reach 5, but additional site analyses will be performed as part of the risk assessment to confirm or modify this estimate.

Commercial/Industrial

For the commercial/industrial land use areas, two separate scenarios are presented in Table 5.2-7: the groundskeeper and the utility worker. The groundskeeper is assumed to work at a commercial or industrial job and to contact surface soils as part of the daily routine. While there is apparently a limited amount of this type of land use in Reaches 5 and 6, it has not been clearly defined. Therefore, it is assumed that a maximum of 50 discrete surface soil sample locations (0- to 6-inch and 6- to 12-inch depth intervals) will provide adequate coverage for risk assessment purposes. The sample number and locations may be modified based on more detailed site analysis as part of the risk assessment effort.

For the areas where utility easements exist, samples will be taken at 0- to 6-inch and 6-inch to 12-inch depth intervals from each location. In addition, composite samples will be taken from 1 ft to 6 ft unless there are limitations from the sampling equipment or presence of utility lines at shallower depths. Figure 5.2-15 shows the locations of the various utility easements (including sewer, electric, and gas) throughout Reach 5. For the purposes of this Work Plan, it is estimated that 10 locations will be sampled for a total of 30 samples for each of the gas and sewer easements. Five locations will be sampled for a total of 15 samples at the AT&T telephone company easement. Samples at depth will not be collected in areas with overhead utility lines. Therefore, the Western Massachusetts Electric Company easement will require 20 locations for a total of 40 samples.

Additional Discrete Sampling

Additional discrete sampling is planned for areas below Woods Pond (Reaches 7 through 9). These areas include recreational, residential, agricultural, and commercial/industrial areas in the 10-year floodplain. A field reconnaissance will be conducted in each area to determine its physical characteristics (e.g., size, location), potential for human exposure, and contaminant transport pathways (e.g., floodplain depositional areas). A strategy will then be formulated for each area to be sampled. Approximately 350 soil samples will be collected, as shown in Table 5.2-6.

All samples will be analyzed for PCBs (total and Aroclors), and in Reach 5 approximately 10% of the samples will be analyzed for TOC, grain size, PCB congeners/homologs, and the modified Appendix IX parameters. Approximately 2% of those samples will also be analyzed for Appendix IX organophosphate pesticides and herbicides. Below Reach 6, other parameters will only be analyzed after determining that PCBs are present at concentrations that may be of concern.

5.3 WATER QUALITY SAMPLING AND MODELING STUDY

The watershed/hydrodynamic model (HSPF) will be capable of simulating the flow dynamics in the watershed and the river; however, the primary objective of this model is to provide boundary conditions for the other two component models. The sediment transport/hydrodynamic model (EFDC) will simultaneously compute hydrodynamics, sediment transport, and abiotic PCB fate and transport. The fate and effects model (AQUATOX) will estimate both biotic and abiotic fate and effects of PCBs, including predicting the movement of PCBs through the food chain and their accumulation in target species. The fundamental objective of the modeling study is to demonstrate that mass balance has been achieved for the key constituents being modeled, in this case water, solids, and PCBs. Additional objectives of this modeling study are to:

1. Quantify future spatial and temporal distribution of PCBs (both dissolved and particulate forms) within the water column and bed sediment.

2. Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment.

3. Quantify the historical and relevant contributions of various PCB sources to bioaccumulation in targeted species.

4. Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of "clean" sediment (i.e., natural recovery).

5. Estimate the time required for PCB concentrations in fish tissue to be reduced to levels that no longer pose either a human health or ecological risk based on various remediation and restoration scenarios, including allowing for natural recovery.

6. Quantify the relative risk(s) of extreme storm event(s) contributing to the resuspension of sequestered sediment and the redistribution of PCB-laden sediment within the area of study.

A scope of work for the models is presented in Appendix A.1, and more detail on the specifics of the modeling effort is provided in the draft Modeling Framework Design document (AQUA TERRA, 02-0188), currently being finalized, and in the modeling QAPP, which is under development. In addition, a cooperative effort between EPA, GE, and their consultants has been established to review and provide input to the modeling. Regular meetings and conference calls have been and will be held between EPA and GE to discuss the overall modeling direction, assumptions, current data, data needs, and other information to ensure the modeling objectives are met.

Specific activities that will be undertaken to support the data needs for the hydrodynamic model include surface water sampling and storm event sampling, measurement of channel geometry cross sections, and flow monitoring as described in the following subsections. In addition, historical meteorological, water quality, and hydrodynamic data will be assembled to support the modeling effort. This will include but not be limited to discharge data (e.g., POTWs), information on dams in the watershed, and storm drainage systems.

Meteorological data will include the following parameters, which will be provided monthly to EPA by GE from their meteorological station located on the GE facility:

- Precipitation
- Temperature
- Wind speed/direction
- Barometric pressure

- Pan evaporation
- Solar radiation
- Relative humidity
- Snow depth (will be measured by WESTON in accordance with National Oceanic and Atmospheric Administration Guidelines for Snow Measurement).

5.3.1 Surface Water

WESTON will collect surface water samples monthly for water quality analyses, as well as during storm events for water quality analyses and suspended sediment analyses. These surface water quality data will support the data collection needs for the hydrodynamic and water quality modeling as well as for the risk assessments. Data are needed to describe the ambient water quality in the Housatonic River to meet the risk assessment and modeling objectives.

Individuals may be exposed to PCBs and other contaminants in the surface water of the Housatonic River during a variety of recreational activities discussed in Subsection 5.2.1.2.1. Exposure may result from both incidental ingestion of water as well as dermal contact. Although the Housatonic River is designated by the MADEP as a Class B Inland Water (99-0063) of the Commonwealth, none of the Housatonic River is classified as a drinking water source (99-0113).

WESTON will collect monthly water quality samples at 17 locations along the Housatonic River and tributaries starting in August 1998 through September 1999, at locations shown in Figure 5.3-1. Fourteen of the locations are on the main branch or the East Branch of the Housatonic River. Six of these sampling locations (i.e., those on Reach 5) will be used to support the risk assessments. Two locations are on tributaries to the river, and the remaining location is the West Branch of the Housatonic River. The proposed sampling dates are shown in Table 5.3-1. The sampling locations are numbered consecutively moving in an upstream direction (except for the Pittsfield POTW) and are as follows:

- Lenoxdale Bridge (Location SW000001)
- Upstream of Woods Pond Dam (SW000002)
- Woods Pond headwaters (SW000003)
- New Lenox Road Bridge (SW000004)
- The Pittsfield Wastewater Treatment Plant discharge mixing zone (SW000017)
- Adjacent to Joseph Drive (SW000005)

Table 5.3-1

Proposed Surface Water Sampling Schedule
Housatonic River, Massachusetts

Month	Proposed Sample Dates
July	7/31-8/3-4 1998
August	8/31-9/1
September	9/24-25
October	10/26-27
November	11/23-24
December	12/17-18
January	1/18-1/19 1999
February	2/23-24
March	3/22-23
April	4/19-20
May	5/26-27
June	6/23-24
July	7/26-27
August	8/25-26
September	9/23-24

- Holmes Road Bridge (SW000006)
- West Branch Housatonic River (above confluence with East Branch; SW000007)
- Pomeroy Avenue Bridge (SW000008)
- Elm Street Bridge (SW000009)
- Lyman Street Bridge (SW000010)
- Footbridge adjacent to Newell Street Parking Lot (SW000011)
- Newell Street Bridge (SW000012)
- Goodrich Pond Tributary (SW000013)
- Unkamet Brook (SW000014)
- Hubbard Avenue Bridge (SW000015)
- Crane Paper Company (Dalton, MA; SW000016)

Samples will be collected only from the Goodrich Pond tributary (outflow stream) when there is adequate flow. The water samples will be analyzed for the following parameters:

- Total suspended solids
- Total dissolved solids
- Filtered and unfiltered PCBs (total, Aroclors, and congeners)
- Five-day biochemical oxygen demand (BOD_5)
- Phosphorus (ortho- and total-P)
- Appendix IX parameters (filtered and unfiltered metals)
- Calcium
- Magnesium
- Alkalinity
- Hardness
- Chlorophyll-a
- Total Kjeldahl nitrogen
- Ammonia nitrogen
- Nitrite nitrogen
- Nitrate nitrogen
- Total organic carbon and dissolved organic carbon (particulate organic carbon by difference)
- Cyanide
- Sulfide

Samples will also be analyzed for field parameters including pH, temperature, dissolved oxygen (DO), turbidity, and specific conductance using field instruments.

PCB congeners will be analyzed starting in February or March 1999. High-volume (i.e., approximately 17-liter) samples will likely be used for the filtered water samples for congener analysis. Sampling, filtration, and analysis methods will be based on those developed for the Hudson River (99-0148). High-resolution GC/MS analyses may be used with smaller sample volumes as necessary.

The modeling effort will also require a characterization of the trophic status of Woods Pond. Woods Pond is a eutrophic water body that exhibits typical symptoms of a shallow nutrient-enriched pond including algae blooms and extensive macrophyte growth. Additional water quality measurements will be collected in Woods Pond to better qualify the degree of eutrophication. This study will include a water column profile of the deep basin at the eastern side of the pond for the following parameters:

- pH
- Temperature
- DO
- Specific conductance
- Turbidity

The water column profile will be examined to determine if vertical stratification occurs. If there is evidence of stratification, additional profiles may be determined to evaluate spring turnover. The degree of eutrophication can be estimated based on the phosphorus concentration of a water body following spring turnover (in dimictic ponds/lakes). Therefore, the water sample collected from Woods Pond following this event may be used to estimate the eutrophic status based on the phosphorus content according to established indices (e.g., 99-0137). In addition, the biomass estimates from the macrophyte study (see Subsection 5.5.1.1 and Appendix A.5) will also provide an indication on the status of the pond.

5.3.2 Stormflow Sampling

The objective of this task is to provide suspended solids information (i.e., load and quality), PCB, and water quality data for the modeling effort. Data collected will be used to assist in the determination of resuspension and redistribution of PCB-laden sediment within the study area, as well as determining the effects of storms on water quality and hydrodynamics. A comprehensive description of the technical approach and sampling methodology for the stormflow sampling is provided in Appendix A.3.

Samples of water and suspended solids will be collected from three primary locations during storm events with the objective of harvesting suspended solids from the water column as shown in Figure 5.3-1. In addition, water samples will be collected from five secondary locations to measure suspended solids, resulting in eight sample locations. The primary sampling locations will be:

- Pomeroy Avenue Bridge (ST000004)
- New Lenox Road Bridge (ST000007)
- Woods Pond Dam (footbridge upstream of the dam; ST000009)

The secondary locations will be:

- Hubbard Avenue Bridge (Coltsville; ST000002)
- Unkamet Brook (ST000003)
- West Branch Housatonic River (ST000005)
- Sackett Brook (ST000006)
- Roaring Brook (ST000008)

Water samples from the primary locations will be analyzed for the following compounds:

- Ammonia-nitrogen
- Nitrite-nitrogen
- Nitrate-nitrogen
- Total Kjeldahl nitrogen
- Organic-phosphorus
- Ortho-phosphorus
- Total phosphorus
- Chlorophyll-a
- Biochemical oxygen demand (5-day)
- Chemical oxygen demand
- Total organic carbon
- Dissolved organic carbon
- Particulate organic carbon
- Total suspended solids
- Polychlorinated biphenyls (PCBs) (total, Aroclors, and congeners)
- Dissolved PCBs (total, Aroclors, and congeners)
- Alkalinity
- Hardness
- Turbidity (field-measurement)
- Temperature (field measurement)
- pH (field measurement)
- Dissolved oxygen (field measurement)
- Specific conductivity

Water samples from the secondary locations will be analyzed for the same parameters as the primary locations except for PCB, alkalinity, and hardness analyses. PCB analyses may be conducted at selected secondary locations based on the results of the ongoing sampling program.

Additional parameters to be analyzed will be selected in conjunction with the modeling team. Collection of additional volumes of water at the secondary locations for laser or sieve analysis of grain sizes will also be considered.

Suspended sediment samples will be analyzed for the following parameters:

1. Grain size fractions for the four size categories:
   - 5-10 µm
   - 10 – 62 µm
   - >62 – 250 µm
   - >250 µm
2. Total PCBs for each of the size fractions listed above except the >250 µm fraction. (The >250 µm fraction may also be analyzed for PCBs if preliminary data suggest this component is important for PCB transport.)
3. TOC (for each size fraction listed above).

Samples will be collected using a high-volume pump for the primary locations and peristaltic pumps for the secondary locations. Manually collected samples (total suspended solids) will also be used to confirm that the high-volume pump is collecting representative samples.

5.3.3 Flow Monitoring

Flow will be measured at approximately seven locations along the Housatonic River under a variety of flow conditions. Flow measurements are proposed to be taken at low flow (September), moderate flow (January), and high flow (March/April). Historical and current hydrograph information will be reviewed to determine the optimum time to take the measurements. The objectives of the flow monitoring are to establish a stage-discharge relationship (rating curve) at the seven locations and to perform a flow-balance of the Housatonic River in the 12-mile stretch of river between the GE facility and Woods Pond Dam. Staff gages may be installed at the eight locations listed below.

The flow-measurement locations will be:

- Pomeroy Avenue Bridge
- Holmes Road Bridge
- New Lenox Road Bridge
- Woods Pond Footbridge

- West Branch Housatonic River
- Unkamet Brook
- Sackett Brook
- Roaring Brook

Additional staff gages will be installed and flow measurements will be collected as needed to support the storm sampling task. If the preliminary flow monitoring data and the current modeling approach indicate the need, the flow monitoring program will be modified to meet the objectives.

5.3.4 Channel Geometry Measurement

Floodplain and channel cross sections will be surveyed at locations between the GE facility and Woods Pond Dam. The preliminary cross-section locations are shown in Figure 5.3-2. The cross sections will provide the channel geometry needed to support the modeling study. In addition, sediment, riverbank, and floodplain soil samples may be collected from these transects as described in Subsections 5.2.1, 5.2.2, and 5.2.3. Channel measurements will include water depth, sediment depth, and distance to top of bank at each transect. Approximately 250 additional cross sections over the 10-mile-long Reach 5 may be measured if necessary to support advanced modeling approaches.

5.3.5 Supplemental Field Measurements

Additional field measurements will be added to provide supplemental information for the modeling study. These needs will be identified after the initial evaluation of chemical and physical measurements associated with the site characterization, stormflow, and surface water studies. Further information on these studies will be provided in the Modeling Framework Design (MFD) document (02-0188). The activities may include:

1. A series of toe pins that may be placed in selected river banks to evaluate possible erosion and bank collapses, particularly in areas of the river subject to erosional forces. The exposure of the pins and changes in their elevation would be monitored to assess the contributions to the river sediment and the change in channel morphology.

2. Detailed floodplain elevation profiles may also be determined in selected areas to better evaluate wetland community maps in preparation of a floodplain topographic map. This would allow a more accurate assessment of sediment transport processes.

3. Additional velocity measurements using an Acoustic Doppler Current Profiler (ADCP) in selected areas to better calibrate the hydrodynamic model.

4. Additional stormflow monitoring may be initiated in selected areas using pressure transducers and automated sampling for basic parameters such as TSS. The monitoring may also include the use of sediment bedload traps to evaluate the magnitude and relationships of the stormflows with the sediment transport.

5. Sediment flume studies may be conducted to evaluate the erosion potential of the sediments under various flow conditions.

5.4 AIR SAMPLING

The purpose of the air sampling program is to provide data for the evaluation of potential risks to human health through inhalation for all of the scenarios under consideration in the risk assessment. If the air sampling program results in concentrations below acceptable risk-based concentrations, the air pathway will be eliminated from quantitative evaluation in the risk assessment.

Air sampling was previously conducted by GE (04-0004) in a number of areas around the site, including a station at the headwaters of Woods Pond. This effort included eight sampling events between May and August 1995. Results of the air sampling at Woods Pond showed very low ambient levels of PCBs in the Woods Pond area. The mean PCB/Aroclor concentration reported was 0.0033 $\mu g/m^3$. Further upstream at Fred Garner Park (Reach 4, just above Reach 5), the mean Aroclor concentration was slightly higher at 0.0055 $\mu g/m^3$. Results from the locations at Silver Lake on the GE site in Pittsfield were still higher at 0.015 to 0.017 $\mu g/m^3$.

As an initial screening step, the EPA Region III risk-based concentrations (RBCs) (99-0139) for PCBs were compared with the concentrations at the Woods Pond site. The RBC for the applicable PCB Aroclor concentration is 0.0031 $\mu g/m^3$. This concentration assumes continuous inhalation exposure (365 days/year for 30 years) and is based on a lifetime cancer risk of 1E-06. While the Woods Pond mean concentration is slightly above the 1E-06 lifetime cancer risk level, it is likely that a mean concentration over the course of an entire year would be lower. The PCB concentrations measured in the report (04-0004) were found during the warmer months. Because of the tendency for PCBs to volatilize as a function of increased temperature, these concentrations are likely to be higher than an annual average air concentration.

To confirm this assumption, air sampling is planned at two locations in the study area over four seasons as shown in Table 5.4-1. One of the locations will be across from the Decker Canoe Launch on the DeVos property and the other will be at an access area off October Mountain Road. The program will include sampling for both particulate and volatile PCB/Aroclors that could be associated with contaminated soils, sediments, and surface waters. The method will consist of high-volume air sampling through an inlet filter to capture the particulate fraction, coupled with a polyurethane foam cartridge to adsorb the volatile fraction. A detailed description of the air sampling methods is provided in Appendix A.4. Data collected during the first two seasons will be evaluated and, based on the results, the remaining collection program may be terminated or modified.

5.5 BIOLOGICAL INVESTIGATIONS

The following subsections provide a brief overview of the biological investigations that are proposed in support of the baseline human health and ecological risk assessments, and the modeling effort. Each investigation summary provides a brief study justification, study objectives, and a summary of the methodology that will be used. For most investigations, a work plan or protocol is referenced that provides detailed study plans. Further detail on the study designs, use of the data, and data quality objectives can be found in these individual protocols and in Sections 6 and 7, the human health and ecological risk assessment work plans. In general, tissue samples collected as part of the following biological investigations will be analyzed for PCBs (total, Aroclors, congeners, and homologs), lipids, and percent moisture. A subset of each tissue type will also be analyzed for dioxins/furans and select OC pesticides. The lipid analysis conducted will follow SOP No. 9727 (WESTON, 00-0458), which uses methylene chloride as the extractant. The methods being used are summarized in the project QAPP.

In this section the investigations are discussed in the following order:

- Investigations to support the AQUATOX model (Subsection 5.5.1).
- Investigations to support ecological characterization (Subsection 5.5.2).
- Investigations to support ecological risk assessment (Subsection 5.5.3).
- Investigations to support human health risk assessment (Subsection 5.5.4)

Table 5.4-1

Air Sampling

AIR No. Samples	Same sample design for all scenarios 40
Sample Location	Air samplers located across from Decker Canoe Launch and an access area off October Mountain Road
Sampling Rationale	Data collected from 2 locations, 5 consecutive days, 4 seasons
Chemical Analyses	Aroclors (particulate and vapor phases)

External Reference Areas—Reference areas located within the Housatonic River watershed were used for several of the biological studies. Descriptions of the Housatonic River watershed and those reference areas located outside the primary study area are included below.

The Housatonic River lies in Berkshire County in an area underlain by large areas of limestone and dolomite, which are geologically speaking relatively soft, slightly soluble and easily eroded. The limestone, dolomite, and marble outcrops neutralize the generally acidic soils of the watershed (Bickford and Dymon, 99-0353), particularly in river floodplains where calcareous soils and bedrock groundwater seepage supply nutrients (Weatherbee, 99-0354). The unique geochemistry of the Housatonic River watershed results in soil and surface water conditions that enhance the productivity of the landscape and the development of diverse habitat conditions. These unique qualities are believed to account for the high biological diversity found in the region—portions of Berkshire County have the second highest density of state-listed rare plant and animal species in Massachusetts (Barbour et. al., 99-0352). Moreover, the Housatonic Drainage is known for its exceptional aquatic resources and fishing opportunities (99-0353). Because of the geochemical character and the resulting habitat dissimilarity of the study area to other potential reference areas outside the watershed, reference areas within the same watershed were selected.

To identify potential reference areas, USGS topographical maps, medium intensity soil maps, aerial photos, and windshield surveys were used to identify places with similar natural community features as those present in the study area—open water habitat, emergent marsh, scrub-shrub wetland, and forested wetland. Areas with similar features, which were located adjacent to land with a minimum of several hundred acres of undeveloped forested and active or former agricultural land, were considered potential reference area sites. Additionally, similar land management patterns were searched for, primarily Wildlife Management Areas (WMAs), which exist in the study area. Potential areas identified using maps and windshield surveys were visited on foot to determine if they provided habitat for species that are the subject of the proposed ecological studies, including leopard frogs, largemouth bass and other warmwater fish, mallards and wood ducks, hawks and owls, tree swallows, and mink and river otter. Potential habitat was identified using the best professional judgment of wildlife biologists, published and unpublished reports on species use, and personal contacts with the regional Massachusetts Fish and Wildlife biologists.

Selected reference areas include the Three-Mile Pond WMA, Hinsdale Flats WMA (Muddy Pond), and Washington Mountain Lake. Three-Mile Pond WMA, approximately 15.6 miles south of the study area, consists of a shallow pond dominated by submerged aquatic vegetation with pockets of emergent and scrub-shrub wetlands around the periphery of the pond. Surrounding the pond is a mixture of upland habitats including old field, and deciduous and mixed deciduous/coniferous forest. This habitat contains similar water levels, similar amounts of submerged aquatic vegetation, emergent marsh, and surrounding undeveloped habitat, as that of the lower portions of the study area near and upstream of Woods Pond. Three-Mile Pond WMA is known to contain leopard frogs, mallards and wood ducks, tree swallows, largemouth bass, and other warmwater fish. It also contains habitat for mink and otter and for hawks and owls.

Muddy Pond and its outlet in Hinsdale, approximately 7.2 miles east-northeast of the study area, is the headwaters of the East Branch of the Housatonic River. This area contains similar wetland habitats and surrounding upland habitat as both the study area and the two other reference areas.

Washington Mountain Lake is located approximately 2 miles east of the study area in the middle of October Mountain State Forest. The lake now contains palustrine open water, emergent marsh, and scrub-shrub habitat similar to that found to the west along the Housatonic River. Mixed forests containing trees of similar size as those found in the study area surround the lake. Washington Mountain Lake is known to contain leopard frogs, mallards and wood ducks, and tree swallows. It also contains suitable habitat for hawks and owls, and mink and river otter.

5.5.1 Supplemental Biological Investigations To Support the AQUATOX Model

The objectives of the AQUATOX model are presented in Subsection 4.2.1. The Lower Reaches of the Housatonic River have physical properties conducive to the propagation of vegetative and planktonic communities that contribute significantly to the nature of the aquatic ecosystem. The sampling of these ecological components at the base of the food chain (macrophytes, filamentous algae, periphyton, and plankton/detritus) will provide two key pieces of information for the fate and effects model (AQUATOX) being developed for the river: biomass per unit area (standing crop) during a period when significant biomass is present in the Housatonic River study area; and contaminant concentrations in these ecological components. These single sampling event studies are not intended to provide information on the seasonal and year-to-year variation nor are they intended to fully characterize these assemblages; however, voucher samples will be collected to identify dominant taxa. Additional sampling periods would be required to measure the time changes in the study area or an alternative approach developed to extrapolate to other seasons and years. Alternative approaches are being investigated.

The AQUATOX model domain includes the Housatonic River from the confluence of the East and West Branches downstream to Woods Pond; therefore, the focus of the data collection will be in this area. The four major aquatic habitats that occur in the area will be sampled: shallow, swift stream; deep, slow river channel; backwater; and pond. The deep, slow river channel habitat has been further partitioned into two study segments to address the interactions of the adjacent backwaters associated with Woods Pond. Additionally, two areas (consisting largely of shallow, swift stream habitat) have been identified for sampling to define boundary conditions at the upstream end of the study area.

Field reconnaissance and previous studies have demonstrated that certain reaches lack sufficient appropriate physical conditions to support some of the aquatic biota communities. Macrophytes and filamentous algae may not occur as significant community components in all reaches, particularly in the upper portion of the study area. Where a lack of suitable habitat occurs, no samples will be collected and the absence of suitable habitat will be documented in the field log.

The selection of the specific sampling areas will be based on wetland vegetation community maps prepared by TechLaw, Inc. (00-0309) and field reconnaissance. For each sampled reach, three sample stations will be selected for each aquatic biota community designated for sampling. In addition, within each reach the occurrence of the communities of interest will be mapped to provide estimates of areal distribution.

The communities within the major aquatic habitat types in the study area have different sampling requirements. The collection techniques are described below and are consistent with EPA Rapid Bioassessment Protocols (EPA, 99-0247), U.S. Geological Survey Aquatic Biota Collection and Water Quality Assessment Protocols (USGS, 99-0250; Porter et al., 99-0256; Shelton and Capel, 99-0253), and APHA Standard Methods for the Examination of Water and Wastewater (99-0325). The SOPs for all sampling discussed in this section are provided in Appendix A.5.

5.5.1.1 Macrophyte Sampling

Macrophytes (submerged aquatic vegetation) are a key component of many aquatic ecosystems. Macrophytes are widely distributed in the study area of the Housatonic River, and serve as a food source, substrate for invertebrates, algae and other biota (commonly referred to as epiphytes), and habitat for fish, reptiles, and amphibians. Macrophytes can accumulate contaminants from the surrounding aquatic environment and the potential exists for the transfer of these contaminants to organisms that feed on macrophytes. Understanding the levels of contaminants associated with macrophytes and the total contribution to the aquatic system being assessed provides insight into the effects of contaminants on the system.

Portions of the Housatonic River study area support significant populations of macrophytes. These are primarily the areas mapped as riverine aquatic bed (RAB) by TechLaw, Inc. (00-0309), which includes Woods Pond and backwater areas. Macrophytes will be collected in these reaches of the Housatonic River study area to evaluate biomass and chemical residues. Sample locations will be selected following qualitative surveys of the macrophyte distribution in the study area. There will be three sample locations within each reach for macrophyte collection and analysis.

Three samples of each macrophyte community will be collected from each study area and analyzed individually for biomass; a composite sample will be collected and analyzed for tissue residue. Chemical analysis of composite samples will be for PCBs (total, Aroclors, congeners, and homologs); a subset of the samples will also be analyzed for dioxins/furans and organochlorine pesticides. Biomass samples will be analyzed for wet weight, dry weight, TOC, and ash-free dry matter.

Within each sampled reach, the distribution of macrophyte communities will be estimated to allow for a determination of total biomass (standing crop). Voucher samples of macrophytes will be collected for identification by a qualified botanist.

5.5.1.2 Filamentous Algae

Filamentous algae are defined as algae that grow in single-cell strands. Filamentous algae may serve as a food source, a substrate for invertebrates and other biota, and may concentrate aquatic contaminants. In some areas, filamentous algae form large mats that cover the surface of water bodies and comprise an important component of the ecosystem. For these reasons, they are potentially useful indicators of the effects of pollution on aquatic ecosystems. Contaminant levels in filamentous algae may also be used to determine potential food chain uptake by consumers such as zooplankton, fish, or waterfowl.

In reaches of the Housatonic River where filamentous algae are considered a significant component of the aquatic ecosystem, samples will be collected to assess biomass and chemical contaminants. Sample locations will be selected following qualitative surveys of the filamentous algae distribution in the study area. There will be three sample locations within each reach selected for collection and analysis.

Three samples of filamentous algae will be collected from each study area and analyzed individually for biomass; a single composite sample will be analyzed for tissue residue. Chemical analysis of all samples will be for PCBs (total, Aroclors, congeners, and homologs); a subset of samples will also be analyzed for dioxins/furans and organochlorine pesticides. Biomass samples will be analyzed for chlorophyll a and phaeophytin, wet and dry weight, TOC, and ash-free dry matter.

Within each sampled reach, the distribution of filamentous algae will be estimated to allow for a determination of total biomass (standing crop). Voucher samples will be collected and preserved for taxonomic identification.

5.5.1.3 Periphyton

Periphyton, also commonly known as aufwuchs (Ruttner, 99-0248), is a collective term used to describe a diverse assemblage of organisms that are firmly attached to, but do not penetrate, submerged substrate (plant and mineral) in aquatic habitats. The periphyton community is complex and includes a wide range of algae, bacteria, fungi, protozoans, rotifers, and small macroinvertebrates. This diverse community is involved in many key processes in the aquatic food web, including primary productivity, decomposition, and nutrient cycling. Periphyton can serve as a critical base to the food web in certain aquatic habitats (Smith, 99-0249). Preliminary reconnaissance has confirmed that the major aquatic habitats occurring in the Housatonic River potentially support a substantial biomass of periphyton.

Cobble and gravel riffle, soft bottom, and aquatic macrophyte bed locations containing periphyton communities will be selected for sampling. Three samples of periphyton communities will be collected from each study area and analyzed individually for biomass; a composite sample will be analyzed for tissue residue. Chemical analysis of all samples will be for PCBs (total, Aroclors, congeners, and homologs); a subset of samples will be analyzed for dioxins/furans and organochlorine pesticides. For periphyton biomass samples collected from cobble riffles and macrophytes, each sample will be analyzed for chlorophyll a, phaeophytin a, dry matter, ash-free dry matter, and TOC. For periphyton collected from soft bottom and gravel substrates, samples will be analyzed only for chlorophyll a and phaeophytin.

Within each sampled reach, the distribution of periphyton will be estimated to allow for a determination of total biomass (standing crop). Voucher samples will be collected and preserved for taxonomic identification.

5.5.1.4 Plankton/Detritus

The water column in freshwater habitats is a dynamic system wherein nutrients and chemicals are in a constant state of flux among the various compartments of the aquatic ecosystem. Two key components of this system are the plankton and detritus compartments. Both may occupy important positions in the base of the Housatonic River food web and influence the extent to which PCBs and related chemicals bioaccumulate in upper trophic level biota inhabiting or frequenting the Housatonic River ecosystem.

Plankton is a term used to describe a diverse assemblage of microscopic aquatic plants and animals that occur free-floating and suspended in surface waters and have limited or no resistance to current. Phytoplankton are the microscopic unicellular, colonial, or filamentous plants/algae that serve as major primary producers in open freshwater systems. Also in suspension are microscopic animals (zooplankton) that graze upon the phytoplankton. Detritus is the organic matter (complex substances and particulate matter) that arises from nonliving and decomposing organisms. Dissolved and particulate organic detritus may have an important role in controlling the direct and dietary uptake of PCBs by aquatic organisms. Together, this assemblage comprises the base of the freshwater aquatic food web and can serve as a key energy and contaminant source to higher trophic level organisms (Thomann et al., 99-0254; Swackhammer and Skogland, 99-0326; Sijm et al., 99-0257).

Three samples of the plankton (phytoplankton and zooplankton) and detritus community from each reach will be collected and analyzed for biomass; composite phytoplankton and zooplankton samples from each reach will be analyzed for tissue residue. Chemical analysis of all samples will be for PCBs (total, Aroclors, congeners, and homologs); a subset of samples will be analyzed for dioxins/furans and organochlorine pesticides. Biomass plankton samples will be analyzed for chlorophyll a and phaeophytin, wet and dry weight, TOC, and ash-free dry matter. Detritus biomass samples will be analyzed for total (TOM) and dissolved (DOM) organic matter, which will be used to quantify labile and refractile content.

5.5.2 Investigations To Support Ecological Characterization

5.5.2.1 Rare Plants and Natural Communities Survey

Surveys for Priority Sites of Rare Species and Exemplary Natural Communities, as defined by the Massachusetts Natural Heritage and Endangered Species Program, were initiated under a previous work assignment and are being continued to determine the presence of rare plants and natural communities within the study area. The primary objectives of this field survey are to determine the presence and location of any rare species or exemplary communities within the study area that could be directly impacted by site-related PCB contamination. This information has been used in the problem formulation of the ecological risk assessment and will be incorporated into specific portions of the ecological risk assessment, and will provide a basis for evaluating the impacts of potential remedial actions.

Landscape analysis has been and will be performed to provide a macroscopic view of the history and ecology of the study area. This process enables identification of habitats with the potential for containing a feature of concern (e.g., rare plants, animals, or natural communities). A landscape analysis involves several steps, including literature reviews, aerial photo interpretation, and field surveys. If extant rare plant or natural communities are found during the field survey, data regarding location, population size, and evidence of reproduction are gathered. Photographs will be taken, and voucher specimens collected if sufficient numbers of plants are present, and it is not likely that collection will harm the population of the species at the site.

A detailed protocol for the rare plants and natural communities survey is presented in Appendix A.6.

5.5.2.2 Dragonfly Survey

Four dragonfly species listed as being of Special Concern by the Massachusetts Natural Heritage and Endangered Species Program (MNHESP)—skillet clubtail (*Gomphus ventricosus*), brook snaketail (*Omphiogomphus aspersus*), ringed emerald (*Somatochlora cingulata*), and slender emerald (*Somatochlora elongata*)—were historically found in Berkshire County. These species could occur in the study area based on the availability of existing habitat. No state-listed threatened or endangered dragonfly species are known to occur in Berkshire County in habitats that occur in the study area.

The objective of the dragonfly survey is to determine the species that occur or may occur within the study area, with a special emphasis on rare species. The protection of these species may be a location-specific ARAR.

A literature review will be performed and local and regional experts will be consulted to determine the historic distribution of dragonflies in the Housatonic River drainage system. In addition to the literature search and expert consultation, exuvia and adult dragonflies will be collected and identified. (Exuvia is the exoskeleton of the larval dragonfly that is shed when the larvae leave the water and transform into the adult form.)

A detailed protocol on the exuvia and adult dragonfly collection is presented in Appendix A.7. The following discussion presents a brief overview of exuvia and adult dragonfly collection.

Exuvia collection will be conducted from mid-May through August. Each survey will span a 2- to 5-day period, and be repeated five times during the field season. Surveys will be conducted on foot or by canoe along the shore, and cover the majority of the 12-mile study area. Exuvia will be collected from vegetation, rocks, logs, and exposed substrates along transects approximately 200 m long by 2 m wide. Specimens will be shipped to a contracted lab for identification.

Adult dragonflies will be collected via aerial netting. Netted individuals will be euthanized in a jar, then mounted as reference specimens. Specimens will be shipped to a contracted lab for identification. Voucher specimen collection will be limited to two specimens of each common species and one of the listed species, if found.

5.5.2.3 Freshwater Mussel Survey

Freshwater mussels are bivalve mollusks (Class *Pelecypoda*) that belong to the order *Unionoida*. Species of *Unionoida* produce larvae (glochidia) that are parasitic on fish or amphibian hosts. Metamorphosis into adult mussels occurs while attached to the host. Adult freshwater mussels are infaunal filter feeders, living in or on the sediment substrate, and are known to rarely move (99-0048). Given their sedentary adult life history behavior and filter feeding habits, freshwater mussels are intimately associated with local sediments and could be directly or indirectly impacted by PCBs in sediments through several mechanisms including: (1) adverse toxicological effects as a result of exposure and accumulation, (2) loss of food supplies, and (3) loss of fish and amphibian intermediate hosts.

The objectives of this study are to: (1) determine the historical distribution of mussels in the Housatonic River drainage; (2) determine the current distribution of mussels within and upstream of the study area; (3) evaluate the condition of any mussels when located; (4) identify potential mussel hosts; (5) identify wildlife species that are potential mussel predators; and (6) document habitat characteristics at each site where mussels are found. The protection of any threatened or endangered species may be a location-specific ARAR. The extent to which PCB contamination may contribute to any adverse effect observed in the community will be evaluated along lines of evidence provided from other studies, e.g., macroinvertebrate toxicity testing, benthic community analysis, and in situ mussel bioaccumulation and condition study.

In general, surveying activities will be restricted to water depths of 3 ft or less. Habitat characteristics where mussels are found will be recorded for future comparisons with uninhabited areas. A detailed study plan of the activities associated with the mussel inventory is provided in Appendix A.8.

Although the presence or absence of mussels in the study area, in and of itself, cannot be directly tied to the potential effects of PCBs, an inference to the general condition of the river may be made from the status of the mussel community in comparison with suitable reference areas.

5.5.2.4 Reptile and Amphibian Use Surveys

Floodplains within the Housatonic River drainage adjacent to and downgradient from the GE Pittsfield Facility provide habitat for a variety of reptiles and amphibians (herpetiles). Approximately 40 different species of herpetiles may occur within this area (see Appendix A.9), several of which are listed as State-Endangered, Threatened, Special Concern, or Watch List (99-0046). Breeding amphibians and several reptile species (predominantly turtles) use temporary and permanent pools within the Housatonic River drainage for courtship, egg laying, and foraging. In addition, the floodplain area (for this assessment, the confluence to Woods Pond) adjacent to the river provides suitable habitat for many of the herpetiles expected in this area. Because previous reports have documented the presence of PCBs in floodplain soils and river sediment, the potential exists for the bioaccumulation of PCBs in herpetile tissues and PCB-related toxicity effects resulting from numerous potential exposure pathways.

The task was begun under a previous work assignment. The objectives of this task are to (1) provide a qualitative estimate of amphibian and reptile species richness in the study area per habitat type for use in the problem formulation of the ecological risk assessment, and as part of the ecological characterization of the study area; and (2) semiquantitatively sample larval amphibians in breeding habitats that have different sediment PCB concentrations, including collection of specific growth metrics; and (3) submit amphibian carcasses that result from incidental mortality for chemical analysis. Should incidental mortality occur during sampling, these individuals will be collected for PCBs (total, Aroclors, congeners, and homologs) lipids, and moisture analyses. A subset of these samples will also be analyzed for dioxins/furans and select OC pesticides if sufficient tissue mass is available.

The detailed protocol of the methods that will be used to conduct amphibian and reptile use surveys is provided in Appendix A.9. A summary of this protocol is presented in the following narrative.

During the 1998 survey effort, temporary pools located within the study area were mapped and relevant habitat characteristics recorded. Visual encounters and acoustic surveys were conducted throughout the floodplain area, and qualitative dipnetting of temporary and permanent pools (99-0045) was included as part of the visual encounter survey. Aquatic funnel trapping was used to assess amphibian presence and abundance in 15 to 20 pools, which were selected to represent a range of average PCB concentrations in surficial sediments. Pit trap arrays and funnel traps, used in conjunction with the small mammal survey effort (see Appendix A.25), were used to provide additional information on the herpetile community.

The amphibian community condition may be assessed using endpoints that include species richness per habitat type; species abundance; gross pathology; and body, tail, and total length measurements. Length measurements will be collected for up to 25 individuals/species/site. All data collected will be recorded on field data sheets. Location information and trap array components will be specifically referenced using GPS.

5.5.2.5 Avian Field Surveys

Riverine, adjacent floodplain wetlands, and associated uplands within the Housatonic River drainage adjacent to and downgradient from the GE Pittsfield Facility contain habitat suitable for use by a number of avian species, which if present would nest, breed, and feed in the study area. Because previous reports have documented the presence of PCBs in floodplain soils and river sediment, the potential exists for the bioaccumulation of PCBs in avian tissues and PCB-related toxicity effects resulting from numerous potential exposure pathways.

The objectives of the following surveys are to identify the species of birds that occur in the study area. This information has been used in the problem formulation of the ecological risk assessment to identify species in the study area that most likely could come in contact with PCB-contaminated sediment or potential PCB-contaminated prey items (i.e., kingfisher). In addition, species in the study area of management concern (e.g., rare, threatened, or endangered) to the

U.S. Fish and Wildlife Service or the Massachusetts Division of Fisheries and Wildlife may be a site-specific ARAR. This study was initiated under a previous work assignment.

The protocols for the raptor, waterfowl, forest, and marsh and wading bird surveys of the Housatonic River drainage are presented in Appendices A.10 and A.11. A summary of the protocols is presented in the following narrative.

Technical literature and available recent surveys of the area have been reviewed to determine the historic distribution of raptors in the Housatonic River drainage. Playback point counts will be used to survey raptors within the study area and in two reference areas. Transects will be established along the river or waterbody (for reference area) and adjacent roads with point counts being taken at 300-m intervals. Approximately 10 minutes will be spent at each point, with calls being broadcast, at various angles, for 10 seconds followed by 30 seconds of silence for each call. All raptors observed will be identified and recorded along with type of observation. Raptor surveys will be conducted between one-half hour before sunrise to sunset, whereas owl surveys will be conducted one-half hour after sunset to sunrise. Transects will be visited two to three times during breeding season, at least once during mating season, and once during the nesting-fledgling period.

Technical literature and available recent surveys of the area have been reviewed to determine the historic distribution of forest birds in the Housatonic River drainage. Two types of data were collected during the forest bird survey, (1) miscellaneous observations while performing other surveys; and (2) observations while performing point counts. Point counts were conducted at designated survey stations. Each point count consisted of a 20-minute sampling period during which each bird seen or heard was identified and recorded.

Technical literature and available recent surveys of the area have been reviewed to determine the historic distribution of marsh and wading birds in the Housatonic River drainage. Marsh and wading bird survey routes were chosen based on habitat description and based on reconnaissance surveys of the study area. Each survey route was visited two to three times from late May through July, between 30 minutes before and 4 hours after sunrise. Calls for several species were broadcast at each survey station. Approximately 50 seconds of calls per species were broadcast interspersed with 10 seconds of silence. All marsh and wading birds seen or heard were identified and recorded.

5.5.2.6 River Otter, Mink, and Bat Surveys

As previously discussed, mammals living and foraging within the floodplain of the study area may be adversely affected by the PCB contamination. The objectives of this study are to (1) determine if mink (*Mustela vision*) and river otter (*Lutra canadensis*) are present in the study area for use in the problem formulation of the ecological risk assessment, and to determine if follow-on studies are necessary for these sensitive receptors, and (2) to determine which species of bats are present in the study area and what habitats they are using for feeding, and, potentially, roosting for purposes of the ecological characterization. These objectives will be achieved through track surveys, scat analysis, scent stations for mink and otter, and echo location surveys for bats.

The protocol for the study of river otter, mink, and bats associated with the Housatonic River study area is presented in Appendix A.12. A summary of the protocol is presented in the following narrative.

Mammal snow track counts will be conducted in various habitat types. Several 500-m-long transects will be established so that each habitat type (forested and shrub swamp, emergent marsh, forested upland, and agricultural field) is represented. Transects in the study and reference areas will be walked a minimum of two times after fresh snowfall.

Scent stations will be used to detect the presence or absence of mink and otter. Transects will be set up parallel to the river. Each transect will be 600 m long and contain 10 scent stations at 60-m intervals. Fine sand will be placed around each scent post in an approximate 0.5-m radius to facilitate track observation. Transects will be visited for 3 days following setup, weather permitting.

Bat species will be surveyed using echolocation. Three 1-km transects will be set up parallel to the river. Surveys will be conducted starting 15 minutes after sunset and performed for 120 minutes. Transects will be walked or paddled during which echolocation noise of bats will be monitored.

5.5.3 Investigations To Support Ecological Risk Assessment

5.5.3.1 Benthic Macroinvertebrate Community Evaluation

The benthic macroinvertebrate community in streams, rivers, and ponds plays a key role in ecosystem functions, such as nutrient cycling and organic matter processing, and is an important food source for instream consumers, as well as for some bird and mammal species. Benthic macroinvertebrates are relatively sedentary organisms that inhabit or depend on bottom sediments or other substratum (e.g., rocks, vegetation) for their various life functions. Therefore, they are sensitive to both long-term and short-term changes in habitat, sediment, and water quality, and, because they spend most of their lives in a single location, can serve as effective indicators of environmental conditions in that location.

The benthic macroinvertebrate community structure and function has been used extensively to evaluate the quality of water resources and characterize causes and sources of impacts in lotic (flowing water) and lentic (standing water) freshwater ecosystems (99-0049). Individual organisms respond to both biotic and abiotic environmental variables. Biotic variables may include competition, predation, and food availability, while abiotic variables may include substrate size, temperature, dissolved oxygen, flow characteristics, and habitat quality. Adverse habitat modifications can include the addition of toxic chemicals and alterations to the physical habitat.

A focused assessment of the benthic macroinvertebrate community in selected habitats is an important component of the ERA for the Lower Housatonic River. Information developed from this study will have four primary applications in the ecological risk assessment:

- Provide data on community characteristics for comparison with a range of measured concentrations of PCBs, other chemicals in sediments, and the potential impact of the WWTP effluent.

- Provide data for one component (the others being toxicological data and sediment chemistry) of a Sediment Quality Triad evaluation at the six locations at which in situ toxicology testing is being conducted.
- Provide data on contaminant body burdens in macroinvertebrate taxa for use in the AQUATOX model.
- Provide supporting supplementary information on contaminant body burdens in major benthic taxa for potential integration into the ongoing studies of tree swallows in the study area.

A detailed protocol for the benthic community study is presented in Appendix A.13. The following discussion presents a brief overview of the data collection and data analysis that will be used.

The infaunal macroinvertebrate community will be sampled at 13 stations, four of which will be located in areas of known background levels of PCBs and will be considered reference locations. The remaining nine stations will be located throughout Reach 5 of the river (i.e., between the confluence and Woods Pond) and will be considered target locations. Two of the reference locations and four of the target locations will be co-located with the locations at which the in situ toxicology testing will be conducted, thus providing (in combination with the sediment chemistry data) the basic information necessary to conduct a Sediment Quality Triad analysis. The remaining five target locations will be selected to provide additional locations at which the investigation of benthic community structure in sediments containing levels of PCBs other than those included in the in situ toxicology study may be conducted. An additional goal is to investigate benthic communities in comparable habitats upstream and downstream of the WWTP effluent, and to determine tissue residue concentrations for use in the tree swallow study.

Twelve replicate samples for taxonomic analysis will be collected from depositional habitats at each location with a Petite Ponar grab sampler. These samples will be sieved through a 0.5-mm sieve prior to analysis. Subsamples will be removed from each grab for analysis of PCB concentration, TOC, and grain-size distribution. Additional macroinvertebrate samples for tissue residue analysis will be collected at each location using a kick-net. If sufficient material is collected, these samples will be separated into community functional groups prior to analysis. All tissue residue samples will be analyzed for PCBs (total, Aroclor, congeners, and homologs), total lipids, and percent moisture; if sufficient material is collected, additional analyses will be conducted for dioxins/furans and OC pesticides.

The 12 replicate samples will be processed for taxonomy and enumeration using stereo and compound microscopes as necessary. All organisms picked from the sample will be identified to the lowest practical identification level (LPIL), which is expected to be genus in most cases. All specimens will be retained as a voucher collection.

Data will be analyzed to investigate significant differences in community structure and summarize community parameters among locations. Parameters to be investigated will include species richness and density, diversity, and evenness. Analyses will be conducted, in general, following standard ANOVA procedures and/or nonparametric analogs. Additional examinations of similarities between and among groups of stations will be conducted using multivariate classification (cluster) analysis. A protocol for the benthic macroinvertebrate community evaluation is provided in Appendix A.13.

5.5.3.2 Sediment Macroinvertebrate Toxicity, Bioaccumulation, and Stressor Identification Testing

The relationship of benthic organisms with the sediment substrate, and interstitial and overlying waters for much of their life cycle, increases the likelihood for adverse effects to be observed when in the presence of contaminated sediment. As previously discussed (see Subsection 5.5.3.1), benthic organisms fulfill a variety of ecological functions within an aquatic ecosystem. Bulk sediment toxicity tests using benthic macroinvertebrates are often the optimal assessment tool in determining sediment toxicity (99-0050). A substantial database exists on the responses of macroinvertebrates to various nutrient, chemical, and physiochemical perturbations. Also, a variety of standardized testing methods have been developed for species that play a major role in the function of many aquatic ecosystems, such as amphipods, midges, polychaetes, mayflies, oligochaetes, and cladocerans.

Bulk sediment toxicity testing is the only currently available approach that directly measures the biological effects of all classes of chemicals, including the combined interactive effects of chemical, biological, and physicochemical conditions found in field sediments (99-0052). The assessment endpoints that will be evaluated using sediment toxicity testing are survival, growth, and reproduction of benthic invertebrates. In addition, when combined with sediment chemistry (which will be collected at each location) and benthic community structure, sediment toxicity testing completes the Sediment Quality Triad, one of the most widely accepted approaches for evaluating pollution-induced degradation (99-0050). The primary objectives of this study are to (1) evaluate sediment macroinvertebrate toxicity in the laboratory and in situ; (2) determine the bioaccumulation potential of PCBs in the Housatonic River sediments; and (3) identify which stressors (if any) may be contributing to adverse effects that are observed.

A detailed discussion of the sediment toxicity testing approach that will be used for this project is provided in Appendix A.14. The following discussion presents a brief overview of the protocol. The sediment macroinvertebrate toxicity study will consist of the following three tasks: (1) chronic sediment toxicity tests using *Hyalella azteca* and *Chironomus tentans*; (2) in situ exposure of *Daphnia magna*, *C. tentans*, *H. azteca*, and *Lumbriculus variegatus* (2- to 10-day) to determine effects and/or contaminant uptake from overlying water and bedded sediment; and (3) a toxicity identification evaluation (TIE) conducted in the laboratory using *Ceriodaphnia dubia*. Note that the TIE evaluation will only be conducted if significant adverse effects are observed during the chronic toxicity testing or the in situ toxicity testing.

Sediment and surface water analyses required for this study are discussed in Subsections 5.2 and 5.3.

5.5.3.3 In Situ Freshwater Mussel Bioaccumulation and Condition Study

In an effort to evaluate the potential effects of PCB contamination on the mussel populations existing or that existed historically in the Lower Housatonic River study area, an in situ monitoring study of transplanted mussels, eastern floater (*Elliptio complanata*), will be conducted. The objectives of this study include the following:

- Determine the bioaccumulation potential of PCBs and other select chemicals in mussels potentially resident to the Lower Housatonic River study area.
- Develop inferences, to the extent possible, to the effect of chemical stressors, and PCBs in particular, on mussel populations that exist or that are potentially resident in the Lower Housatonic River study area.

As many as 900 mussels will be collected from a reference area in the Connecticut River that is expected to be free of chemical contamination and known to contain substantial beds of eastern floater. The study will use mussels from approximately the same size range, e.g., 60- to 80-mm shell length. A subset of mussels collected from the reference area (Connecticut River), as well as sediment from the bed from which the mussels are harvested, will be submitted to the laboratory for chemical analyses.

Approximately 150 mussels will be deployed at each of five stations in the Housatonic River and one station in the Connecticut River. The general locations of the five monitoring stations in the Housatonic River include:

- Upstream of the influence of the GE facility in the east Branch of the Housatonic River near Dalton.
- Downstream of the GE facility in the vicinity of Holmes Road.
- Between Holmes Road and New Lenox Road.
- In the Housatonic River immediately above Woods Pond.
- Downstream of Woods Pond in Great Barrington.

In addition to the monitoring locations to which the mussels are transplanted in the Housatonic River, the Connecticut River (from which the resident mussels are collected) will also serve as a reference monitoring location. Sample testing and sample design will be replicated at that location.

Mussels will be collected for tissue analysis at the midpoint (42 days) and the end of the study (84 days). All tissue samples will be analyzed for PCBs (total, Aroclors, congeners, and homologs), lipids, and moisture content. A subset of the tissue samples will also be submitted for dioxins/furans and select OC pesticides analyses. In addition, mussel tissue will be monitored for glycogen content. In this study, glycogen is being used to monitor the physiological condition of the mussels. During the retrieval of the mussels at the study's midpoint and end, mortality and general mussel condition (e.g., gaping) will also be recorded.

The glycogen content endpoint, rather than the more commonly used endpoints of survival or growth, is proposed for this study for a number of reasons. Although survival will be monitored during the study, survival is typically an all-or-nothing response and may be insensitive to environmental change. Growth rates, another traditional measure of condition, also are problematic due to slow growth rates of adult mussels, measurement error, and chipping of the shell margins. Changes in glycogen are a sensitive indicator of the physiological condition of freshwater mussels and are useful at both the individual and populations levels. Although this study will not, in itself, definitively demonstrate that any observed differences in mussel condition are caused by PCB contamination, the exposure locations will be carefully selected to isolate sediment PCB concentration as the important environmental variable, and the data will be evaluated in concert with other data available from the program, thereby increasing the likelihood that any observed differences are due to differences in sediment PCB concentrations.

A detailed discussion of the approach that will be used to conduct the transplanted mussel study is presented in Appendix A.15.

5.5.3.4 Crayfish Tissue Analysis

Because of their life history characteristics, crayfish may be useful indicators of the potential impacts of PCB contamination on the aquatic food web of the Housatonic River. Crayfish live in stream and lake habitats, are in direct contact with sediment and surface water for most of their lives, and feed on decaying organic matter. In addition, they have a limited home range, and are consumed by several species of fish, birds, and mammals. The tissue residue analyses from this effort will be used in food chain modeling in the ecological risk assessment.

Crayfish will be collected using baited traps, hand nets, or seine nets at each of six locations (four locations in Reach 5 plus two reference locations) in the study area to evaluate bioaccumulation and potential subsequent food chain transfer to upper trophic level species such as largemouth bass and wading birds. Deployment of traps may be modified due to field conditions and trapping success. Tissue samples will be analyzed for PCBs (total, Aroclors, congeners, and homologs), moisture, and lipids; a subset of these samples will also be analyzed for dioxins/furans and select OC pesticides. The protocol for crayfish collection and handling is provided in Appendix A.16.

5.5.3.5 Bullfrog Tissue Analysis

Bullfrogs (*Rana catesbeiana*) are proposed for collection and analysis to meet two major objectives. The first objective is to determine the whole-body frog tissue concentrations for use in ecological risk exposure models and potentially for incorporation in the AQUATOX model. The second objective is to support a possible qualitative evaluation of the potential risk to human health from consumption of bullfrog leg muscle tissue. The complete protocol for sampling and analysis of bullfrog tissue is provided in Appendix A.17.

To support the human health and ecological risk assessments, PCBs (total, Aroclors, congeners, and homologs), moisture, and lipid analyses of bullfrog tissue will be performed; a subset of these samples will also be analyzed for dioxins/furans and select OC pesticides.

A total of 40 bullfrogs will be collected from locations representing a range of sediment PCB concentrations and areas of bullfrog habitat. Four sampling areas (two within the study area and two reference locations) were chosen by conducting a field reconnaissance to identify areas of appropriate bullfrog habitat, followed by a review of available contaminant data to identify areas indicative of a range of sediment PCB concentrations. These areas are (1) Woods Pond, (2) backwater areas within 1 mile north of Woods Pond, (3) Three-Mile Pond, and (4) Muddy Pond. Ten frogs will be collected from each location. The complete protocol for sampling and analysis of bullfrog tissue is provided in Appendix A.17.

5.5.3.6 Amphibian Vernal Pool Reproductive Success Study

As stated previously, the floodplains within the Housatonic River drainage provide habitat for a variety of amphibians. Because previous reports have documented the presence of PCBs in the floodplain soils and river sediment, the potential exists for the bioaccumulation of PCBs in amphibian tissues and PCB-related toxicity effects resulting from numerous potential exposure pathways.

The objective of this task is to determine if PCB contamination is potentially having an adverse effect on amphibian reproduction in vernal pools. Amphibian carcasses that result from incidental mortality will be submitted for chemical analysis.

The detailed protocol of the methods that will be used to conduct the amphibian vernal pool reproductive success study is provided in Appendix A.18. A summary of this protocol is presented in the following narrative.

Four or five pools exhibiting a range of PCB concentrations will be studied. Relative abundance of amphibians entering and leaving vernal pools will be assessed using drift fences and pitfall traps. In addition, acoustic surveys and funnel traps will be used to evaluate vernal pool occupation by endemic amphibians. General growth matrices and gross pathology will be assessed for a subset of individuals captured. Egg laying, hatching success, and larval development will also be assessed at each pool. Unhatched eggs, developing larvae, and dead individuals will be submitted for tissue analyses. Tissue samples will be analyzed for PCBs (total, Aroclors, congeners, and homologs), lipids, and moisture. If sufficient tissue mass is available, a subset of samples will be analyzed for dioxins/furans and select OC pesticides.

Amphibian reproductive success will be assessed using amphibians entering vernal pools by determining adult breeding behavior and condition; egg laying; hatching success; larval growth and development; metamorphosis; and emigration.

Pools will be selected based on soil PCB concentration, the presence of target species (spotted salamanders and wood frogs), and similarity in physical and hydrologic characteristics.

5.5.3.7 Amphibian Toxicity Testing

Amphibian toxicity testing, using northern leopard frogs *(Rana pipiens)*, will be conducted to determine if the PCB contamination in the Housatonic River downstream of the GE facility is adversely affecting amphibians in the study area. Specifically, survival, reproduction, and development are the assessment endpoints evaluated. Measurement endpoints include hatching success, post-hatch survival, fertilization rate, egg and sperm viability, sperm count and morphology, number of eggs per adult female, gravidity, morphological development, early embryogenesis, oocyte maturity, and mortality. The amphibian toxicity tests will use eggs and semen taken from resident frogs collected over a range of PCB concentrations in site sediments, and from one or more reference areas. Tissues collected during the toxicity testing will be analyzed for PCBs (total, Aroclors, congeners, and homologs) and lipids. A subset will also be analyzed for dioxin/furans and select OC pesticides.

The protocol for the amphibian toxicity testing is presented in Appendix A.19. The following discussion presents a brief overview of the protocol.

Male and female frogs will be collected from the target and reference areas and transported to the study laboratory. Sperm counts, morphology, and overall viability will be assessed. In addition, the gravidity of the females will be recorded and gravid females will be hormonally induced to superovulate egg masses, which will then be fertilized in vitro. The number of eggs produced per female will be counted volumetrically and rates of necrosis and developmental stage determined. The eggs will be monitored in the laboratory for fertilization, morphology, and coloration, while the embryos will be monitored for mortality, hatching success (including time to hatch), and morphological abnormalities. Deformities, particularly those that could directly affect juvenile survival and thus affect population levels, will be specifically documented by type of terata induced and the number responding. Exposure studies in the laboratory will be conducted throughout metamorphosis of progeny cultured in the lab. The rate of metamorphosis, which will include an evaluation of the rate and morphology of limb development, rate and morphology of tail resorption, and development of secondary morphological characteristics, including mature skin, will be evaluated. In addition, a portion of each egg mass, as well as the ovaries of females from which egg masses are obtained, testes from the males, whole bodies of developing embryos and larvae, and whole bodies of mature male and female frogs will undergo total PCB content and congener-specific analysis to allow for the potential determination of a dose-response relationship between observed effects and PCBs.

5.5.3.8 Fish Tissue Sampling and Processing

Because of PCB contamination in fish, a fish consumption advisory has been in effect in the Housatonic River for approximately 80 miles downstream of the facility since approximately 1988. To determine if the PCB contamination from the GE facility is adversely affecting fish in the study area and accumulating in fish tissue at concentrations detrimental to human and ecological consumers, fish tissue sampling was conducted for tissue residue analysis under a previous work assignment. Fish tissue concentrations will be used to determine the potential risks to individuals who may be catching and consuming fish illegally, as well as to determine risk to recreational anglers in the absence of administrative or institutional controls. Ecological measurement endpoints supported by fish tissue sampling efforts are the comparison of tissue concentrations to Maximum Allowable Tissue Concentrations (MATCs) from literature and reference area concentrations, and incorporation in ecological exposure models for piscivores.

Table 5.5-1 provides a summary of the sampling and analytical program for fish tissue sampling. The table shows the specific areas where fish were collected, the species and type of sample collected, the types and number of laboratory analyses, and the total number of samples.

The protocol for the fish tissue sampling and processing is presented in Appendix A.20. A summary of the protocol is presented below.

Various life stages of fish were collected from seven locations—five downstream of the GE facility and two from reference areas. Forage size and adult fish were collected for each species (largemouth bass and other centrarchids, yellow perch, brown bullhead, and goldfish and other cyprinids).

Once fish were collected, they were retained in live wells containing location-specific water until sample processing was initiated. Fish were sacrificed, and metrics were recorded for each fish included in a sample, including total length, total weight, sex, age, and fillet and offal weight as appropriate. Fish not retained for analysis were released unharmed to their respective locations.

5.5.3.9 Fish Health and Toxicity Testing

In addition to fish tissue sampling, fish health and toxicity testing, using eggs and fish tissue extracts from fish collected in the study area, will be conducted to determine if the PCB contamination in the Housatonic River downstream of the GE facility is adversely affecting fish in the study area. The study proposed is divided into two phases: Phase I - Laboratory Rearing of Eggs from Field-Collected Fish; and Phase II - Laboratory Egg Injection Studies with Contaminant Extracts. The primary objectives are to determine the embryotoxic effects of PCBs found in fish from selected areas of the Housatonic River and to determine the validity of the embryo toxicity model for PCB-related effects in fish embryos collected from various locations

Table 5.5-1

Fish Collection and Analysis Summary

FISH SPECIES	3-Mile Pond (H9)	Upper H. River (H0)	Shallow River (H3) (RM 03)	H. River Deep (H3) (RM 7 -11)	Woods Pond (H4)	Rising Pond (H5)	Goodrich Pond (H7)
LARGEMOUTH BASS *(1)*							
Fillet/Offal **(2)**	15/21 (10)	1	3	15 (10)	14 (10)	11 (10)	8
Whole Body (<12)	10/15 (5)	19 (14)	5	10 (5)	11(5)	14 (5)	1
Composite	4	1	2	5	5	5	5
YELLOW PERCH							
Fillet/Offal	17 (15)	19 (15)	25 (15)	25 (15)	25 (15)	6	18 (15)
Whole Body (<12)	***0/12 (0)***	0	0	0	0	0	0
Composite	2	5	5	5	5	5	5
BROWN BULLHEAD							
Fillet/Offal	6	5	1	17 (15)	25 (15)	7	2
Composite	0	9	0	(2 fish)	0	0	0
PUMPKINSEED (Whole Bdy)	***0/6 (0)***						
Fillet/Offal	12	0	1	25/28 (15)	25/27 (15)	13	9 (7)
Composite	5	10	0	5	5	5	3
GOLDFISH							
Lg. Size	0	0	0	18 (15)	25/26 (15)	0	7
Sm. Size	0	0	0	0	0	0	0
CYPRINIDS							
Golden Shiner	6	2	0	6	5	0	5
Common Shiner	0	1	0	0	0	0	0
Fallfish	0	2	5	0	0	0	0
Bluntnose minnow	0	2	0	0	0	0	0
BLUEGILL							
Fillet/Offal			1				15 (10)
Composite							4
SMALLMOUTH BASS							
Whole Body			2				

Table 5.5-1

Fish Collection and Analysis Summary

FISH SPECIES	3-Mile Pond (H9)	Upper H. River (H0)	Shallow River (H3) (RM 03)	H. River Deep (H3) (RM 7 -11)	Woods Pond (H4)	Rising Pond (H5)	Goodrich Pond (H7)
YELLOW BULLHEAD							
Fillet/Offal							3
	PCBs/Total/D/F	PCBs/Total/D/F	PCBs/Total/D/F	PCBs/Total/D/F	PCBs/Total/D/F	PCBs/Total/D/F	PCBs/Total/D/F
TOTAL SAMPLES *(3)*	137/162/108	101/101/88	81/81/61	214/219/152	234/239/150	103/103/92	137/137/117
					GRAND TOTAL SAMPLES		**1007/1042/768**

(1) For the Upper River (H0) no bass over 12" were collected; one composite consists of 2 fish.

(2) Where three numbers are listed, the order is: PCB analyses (includes Aroclor and congener/homolog analyses), total number of samples collected, and number of dioxin/furan/OC pesticides analyses in ( ). One number indicates all analyses will be run.

(3) Total samples includes counting fillet and offal as separate samples. Numbers listed are samples for PCB analysis/ total number of samples collected/ and samples for dioxin/furan/OC pesticide analyses, respectively.

of the river. Measurement endpoints proposed for the testing include fertilization rates, embryo viability, time to hatch, gross pathology, histopathology, cytochrome P4501A induction, and fry growth. Endpoints for both phases will be the same.

The protocol for the fish health and toxicity testing is provided in Appendix A.21. A summary of the protocol is presented in the following narrative.

In Phase I of the study, largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*) collected from the Housatonic River will be evaluated to determine whether exposure of adults to PCBs in river water and sediments might adversely affect the survival and development of their offspring. The specific objectives of Phase I are to determine differences in rates of stage-specific mortality, pathologies associated with PCB toxicity, and growth of surviving swim-up fry in progeny of largemouth bass and bluegill collected from three reaches of the Housatonic River and a reference location.

Adult fish will be collected from Three-Mile Pond (the reference location), Woods Pond, Rising Pond, and the deepwater reach below the confluence of the Housatonic River with Roaring Brook and transported to the U.S. Geological Survey Columbia Environmental Research Center (CERC) in Columbia, MO, for study. The fish will be maintained at CERC in artificial ponds and allowed to spawn naturally. The eggs will be collected, then transferred to the laboratory to be hatched and reared under controlled conditions.

The Phase I embryo and fish toxicity evaluation for largemouth bass and bluegill will have three components:

1. An evaluation of mortality rates from hatch to swim-up in each species. In addition to monitoring the survival of the developing embryos and early fry, this study will also determine the frequency of occurrence of gross PCB-induced pathologies in the embryos and fry.

2. A growth and mortality study of surviving largemouth bass and bluegill swim-up fry. Fry weight and length at 15 days post swim-up will be the measurement endpoints for this component of the study.

3. Rearing a separate batch of eggs collected from each study replicate under conditions duplicating those followed in the investigations described above. Samples of freshly collected eggs; fry at hatch, at swim-up, and at the end of the growth study will be

submitted for histological examination and biochemical analysis. Additionally, samples of egg, fry, and adult brood fish tissues will be archived for future chemical, biochemical, and histological analyses.

Phase II of this study, Laboratory Egg Injection with Contaminant Extracts, will consist of controlled laboratory exposures of fish eggs and developing embryos to an extract of fish collected from the Housatonic River. Dose-response relationships using graded doses of extract will be developed and compared with individual chemical responses using the same exposure procedures.

5.5.3.10 Soil Invertebrate Tissue Analysis

Being in nearly constant contact with the soil, soil invertebrates are continually exposed to soil contamination. In addition, soil invertebrates account for the majority of animal biomass in soil, and are preyed upon by a number of secondary consumers. The quantitation of earthworm tissue stressor burdens will be the focus of this investigation.

Earthworms are important in agricultural, forest, pasture, and natural herbaceous soils where they play a significant role in the development of soil fertility and structure by enhancing permeability, aeration, and decomposition processes (99-0053). Because earthworms survive by ingesting soils and extracting metabolizable nutrients, they can also bioaccumulate chemicals from the soil and, in turn, transfer these chemicals to predators, such as birds, shrews, amphibians, and moles. As previously discussed, PCB-contaminated sediments have been deposited throughout the Housatonic River floodplain. Exposure to soil invertebrates, particularly earthworms, and subsequent trophic transfer may be responsible for adverse impacts to soil invertebrate predators in this area.

The primary objective of this task is to determine contaminant concentrations in earthworm tissue. Tissue concentrations will be incorporated in the ecological risk assessment to evaluate contaminant exposure to carnivorous birds and mammals through food chain modeling. Earthworms will be collected at several areas throughout the study area floodplain where habitat conditions are suitable for earthworm-ingesting receptors (e.g., American robin and shrews), and at locations with a range of PCB concentrations in soil including locations where PCB concentrations are at or below detection limits. These locations are currently planned to coincide with identified small mammal trapping areas.

Approximately 13 samples of earthworms (10 individual worms and/or composites depending upon earthworm size) and of other soil invertebrates (composite) will be collected at each of three locations. Soil invertebrates will be collected using pitfall traps, or if necessary, by hand. Composite tissue samples will be submitted for PCBs (total, Aroclors, congeners, and homologs), lipid, and moisture analyses. A subset of these samples also will be submitted for dioxins/furan and select OC pesticide analyses.

A detailed study plan of the activities associated with the soil invertebrate tissue analysis is provided in Appendix A.22.

5.5.3.11 Duck Collection and Tissue Analysis

Based on survey work conducted in the spring and summer of 1998, mallards (*Anas platyrhynchos*) and wood duck (*Aix sponsa*) are known to breed and raise their young in the portion of the study area between New Lenox Road and Woods Pond (TechLaw, 05-0062). Both mallards and wood ducks are considered omnivorous species; however, during the breeding and nesting period, both species feed primarily on aquatic insects, if available (99-0047). As a result of their dietary habits and the bioaccumulative potential of PCBs, mallards and wood ducks nesting in the study area and their offspring may be accumulating PCBs in their tissue at levels that may adversely affect the ducks themselves, as well as predators (e.g., humans) that use them as a food source.

The objectives of this task, which was conducted under a prior work assignment, were to collect resident mallards and wood ducks from the study area and appropriate reference areas before the fall migration began (late August through mid-September 1998), and to submit tissue samples for analyses of PCBs (total and Aroclors), PCB congeners and homologs, dioxins/furans, select OC pesticides, percent lipids, and percent moisture. Table 5.5-2 summarizes the results of the sampling program. Forty-five ducks were collected and submitted for breast and liver analyses for a total of 90 separate analyses. Five duplicate breast samples were also analyzed. Tissue

Table 5.5-2

Waterfowl Collection and Analysis* Summary
Lower Housatonic River

Species	Location	
	Housatonic River or Woods Pond	Three-Mile Pond
***Wood Duck* (40 Total)**		
Female		
Immature	6	3
Adult	3	5
Male		
Immature	9	7
Adult	2	5
***Mallard* (5 Total)**		
Female		
Immature	1	0
Adult	0	0
Male		
Immature	4	0
Adult	0	0

*All samples analyzed for PCBs (total and Aroclors), PCB congeners and homologs, dioxins/furans, OC pesticides, percent lipids, and percent moisture.

residue concentrations will be used directly in the human health risk assessment and will be compared between study area and reference samples.

The detailed protocol for duck collection and processing is presented in Appendix A.23. The following discussion presents a brief overview of waterfowl collection and sample processing procedures.

Waterfowl were collected from late August through mid-September 1998. Ducks were collected by hand-netting from air-boats and using floating box and walk-in clover bait traps. Species, age, sex, weight, and other relevant metrics were recorded for each sample before target tissues were removed and shipped for analysis. Any gross pathological abnormalities, if observed, were recorded on field data sheets prior to the completion of sample processing. If analyses indicate that PCBs are accumulating in waterfowl, additional surveys may be conducted (see Appendix A.10). These surveys may involve monitoring nesting, egg-laying, hatching rates, fledgling rates, juvenile feeding, and the collection of tissue for analysis of PCBs in young-of-the-year ducks.

5.5.3.12 Tree Swallow Study

Insectivorous birds, such as tree swallows, nesting along and foraging within the study area may be adversely affected by PCB contamination, primarily through their exposure from ingesting newly emerging aquatic invertebrates. The primary objectives of the tree swallow study are to determine PCB exposure and if there are any adverse effects and at what PCB concentrations for tree swallows nesting along the Housatonic River near Pittsfield, MA.

The protocol for the tree swallow study of the Housatonic River is presented in Appendix A.24. A summary of the protocol is presented in the following narrative.

Nest boxes have been erected within three separate reaches of the river, as well as three reference sites. The number of eggs and young were monitored, and pippers and nestlings were collected as appropriate, based on the number of swallows nesting at each site and the number of young produced. The collected tree swallows were euthanized, and the stomach contents were removed and pooled for analysis separate from the carcasses. Carcasses and pooled food samples will be analyzed for the standard organochlorine chemical screening, including total PCBs and PCB congeners. In addition to the standard organochlorine chemical screen, pooled pipper and nestling samples will be analyzed for dioxins/furans and trace elements. The Mayfield method (99-0054) will be used to quantify reproductive success. In 1999, nesting swallows were ligatured to obtain additional food samples for dietary analysis.

In general, procedures used during the 1998 and 1999 study seasons will be followed for the 2000 season.

5.5.3.13 Small Mammal Use and Tissue Analysis

Mammals living and foraging within the floodplain of the study area may be adversely affected by the PCB contamination. The primary objective of the mammal use study is to identify the mammals using the riverine, wetland, and upland habitats found within the study area as a component of the ecological characterization. Secondary objectives are to determine (1) the concentrations of PCBs and related compounds in the tissues of small mammals captured over a range of PCB soil concentrations for use in food chain modeling, and (2) if there is the potential for PCBs to influence small mammal reproduction. To achieve this end, qualitative surveys of mammals throughout the Housatonic River drainage, with a particular emphasis on the study area, will be conducted.

Tissue concentrations of PCBs (total, Aroclors, congeners, and homologs), moisture content, and percent lipids will be quantitatively analyzed in small mammals for use in dietary intake models. A subset of the small mammal tissue samples will also be submitted for dioxins/furans and select OC pesticide analysis.

The protocol for the mammal use study of the Housatonic River drainage is presented in Appendix A.25. A summary of the protocol is presented in the following narrative.

Technical literature and available recent mammal surveys of the area will be reviewed to determine the historic distribution of mammals in the Housatonic River drainage. After the literature is reviewed, field surveys, including direct observations and small mammal trapping, will be conducted.

Several potential small mammal trap sites were identified in the floodplain based on habitat characteristics. At each potential trap site, soil samples will be collected and analyzed for total PCB concentrations. After soil samples are analyzed, three sites will be chosen for trapping. One of the sites chosen for sampling will be a reference site with PCB levels below detection limits, while the other sites chosen will contain PCBs in sampled soils over a range of concentrations. At each trap site, 100 baited traps will be placed in an "X" pattern when possible (see Figure 5.2-14). Traps will be run for 5 days for a total of approximately 500 trap nights per site. Captured animals will be weighed, measured (body length, tail length, hind limb length, ear length, and testes length and width), sexed, and aged. The number of placental scars and embryos will be counted for captured females.

5.5.3.14 Mink Toxicity Testing

Field surveys have failed to observe mink and otter at expected frequencies, either directly or by sign, in suitable habitat along the more highly contaminated sections of the river, while viable population inhabit nearby reference areas. Based upon this information, mink toxicity testing will be conducted to determine if contaminants in the Housatonic River downstream of the GE facility are bioaccumulating and adversely affecting upper trophic level mammalian piscivores. Mink were selected as the experimental species in part because they are semiaquatic piscivores indigenous to the area and are sensitive to the target contaminants. In addition, there is a scarcity of both mink and otter in suitable habitat within the study area (00-0309) that historically supported populations of piscivores.

Specific assessment endpoints to be evaluated from this study are general condition, survival, growth, and reproduction. Measurement endpoints supported by the mink toxicity study include body weight, feed composition, length of gestation, reproductive success, survival, histopathology, biochemical analyses measuring exposure (including cytochrome P-450 levels), and organ weights. The mink toxicity test will use diets with various percentages of PCB-contaminated fish from the Housatonic River and uncontaminated ocean fish as a control. Tissues collected in support of (i.e., fish tissue) and resulting from the toxicity testing (i.e., liver tissue) will be analyzed for OC pesticides, total PCBs, PCB congeners, and dioxins/furans.

The protocol for the mink toxicity testing is presented in Appendix A.26. The following discussion presents a brief overview of the protocol.

Fish will be collected from the Housatonic River in areas of mink habitat. The fish will be ground and blended into a homogeneous mixture. Three grab samples (300 to 500 g each) will be collected and analyzed as noted above. The results of these analyses will be used to determine the proportion of fish incorporated into the experimental diets. There will be five dietary levels of PCBs (0.25, 0.50, 1.0, 2.0, and 4.0 ppm) plus a control. Twelve first-year (virgin) female mink will be assigned to each dietary treatment. Male mink will be untreated and used for breeding only. Animals will be fed test diets daily for approximately 150 days total, with exposure beginning approximately 8 weeks prior to the start of breeding and continuing through gestation, parturition, lactation, and weaning. After weaning, the adult females and 6 kits from each treatment group will be necropsied and 12 kits from each treatment group will be maintained on their respective diets for approximately an additional 5 months.

Observations to be made during the experiment include determination of body weights and feed consumption during pre-breeding; body weight of kits; necropsy of morbid (except for unweaned kits) or euthanized individuals; organ weights (brain, liver, kidneys, spleen, heart, thyroid gland, and adrenal glands); histological examination of organs; and analysis of liver samples for cytochrome P450; CYP1A and CYP2B activity, assays for ethoxyresorufin *O*-deethylase (EROD), ethoxycoumarin *O*-deethylase (ECOD), pentoxyresorufin *O*-deethylase (PROD), benzyloxyresorufin *O*-deethylase (BROD), and protein content.

5.5.4 Investigations To Support Human Health Risk Assessment

5.5.4.1 Agricultural Land Use/Practice Investigation

There is concern for potential PCB exposure to humans through the consumption of milk and other dairy products from cows raised on farms with land in the floodplain. Dairy cows can be exposed through the consumption of corn silage or other feed crops grown in contaminated soil. They can also be exposed through grazing on land with PCB contamination through incidental ingestion of soil.

Exposure to humans from consumption of dairy products will be evaluated in an iterative process in the risk assessment. The first step will be to determine whether any of the farmland in the floodplain that could be used for growing crops for dairy cow consumption or for grazing of dairy cows is contaminated with PCBs through the floodplain soil sampling program described in earlier sections. If there is a potential concern identified through this initial assessment, the next step will involve more in-depth evaluations based on the farming practices in the area. This could include using existing data to model uptake of PCBs into silage or other feed crops, analyzing crops used for feed grown in the floodplain for PCB levels, using soil data to model uptake in cows during grazing activities, or analyzing milk samples from area farms. The final approach will be identified during the risk assessment process; therefore, specific types and numbers of samples cannot be identified at this time.

5.5.4.2 Crop/Vegetable Sampling

5.5.4.2.1 Corn Sampling

To assess the possible uptake of PCBs in corn and the potential transfer to humans or dairy cows and ultimately consumers of dairy products, corn samples will be collected from cornfields extending into the floodplain where PCB contamination of soils is confirmed in the floodplain sampling program.

Corn samples will be taken from cornstalks located in agricultural areas within the floodplain that have elevated PCB concentrations. Samples will also be taken in the same general area but outside the floodplain to serve as reference locations. Total weight and ear weight will be determined for each stalk. The stalk (including leaves) and the ear will be included in the analyses.

In addition, at each of the areas where the corn samples are collected, three soil samples (0 to 1 ft) will be collected and submitted for analysis. All samples, including corn and soils, will be analyzed for PCBs (total and Aroclor) concentrations. If floodplain soil sampling shows no significant concentrations of PCBs in cropland areas (where corn is grown), corn sampling will not be conducted. The specific number and location of samples will be identified during the risk assessment process.

5.5.4.2.2 Vegetable Sampling

To determine the possible uptake of PCBs in vegetables grown in floodplain soils contaminated with PCBs, a sampling program will be developed. This program will support the human health risk assessment in providing data for the evaluation of homegrown vegetable consumption. This sampling program will be dependent upon identifying areas where vegetable crops are being grown for human consumption within the study area. If areas are identified, the protocols that will be followed will be similar to those identified above for corn sampling.

6. HUMAN HEALTH RISK ASSESSMENT WORK PLAN

6.1 INTRODUCTION

6.1.1 Purpose and Approach

The baseline human health risk assessment (BHHRA) represents an integral component of the supplemental investigation of the Lower River and serves multiple functions. The BHHRA provides:

- An evaluation of the potential human health risks under baseline conditions (i.e., no action) of current and future site use.
- A basis for determining whether remedial actions are necessary.
- A basis for setting remediation goals for contaminants of concern.
- A basis for comparing various remedial alternatives.

The approach to evaluating potential human health risks is divided into two separate phases. Phase 1 consists of the development of screening risk-based concentrations (SRBCs) for exposures to PCBs in soil and sediment for all applicable exposure scenarios. Based on a comparison of representative media contaminant concentrations with these SRBCs, decisions will be made on which specific areas may require a more comprehensive analysis. Phase 2 is the more comprehensive analysis that will be conducted for those areas and exposure scenarios that were not eliminated during the Phase 1 screening. Those areas that require a more comprehensive analysis will be evaluated in Phase 2 using approaches described in standard EPA risk assessment guidance documents.

Subsection 6.2 of the Work Plan presents a detailed treatment of the Phase 1 screening approach for calculating and applying the SRBCs. This screening step is necessary because of the large area under evaluation. It is anticipated that a significant number of discrete areas can be eliminated from further consideration based on very low or undetectable site-specific PCB concentrations, thereby allowing a greater focus on those areas with elevated PCB levels. The Phase 1 evaluation is illustrated in Figure 6.1-1. Briefly, PCB data collected from appropriate media at sites along the Lower River will be compared with medium-specific SRBCs that have been developed based on information about current and future land uses (i.e., residential, recreational, agricultural, and commercial/industrial). These SRBCs incorporate conservative estimates of potential exposure so that areas with PCB concentrations below the SRBCs can be eliminated from further consideration in the risk assessment. The initial screening analysis involves the comparison of the maximum PCB concentration detected in a given medium with a medium-specific SRBC appropriate for the specific land use. Based on the results of the initial screening, this analysis may be followed by a comparison of the PCB exposure point concentration (EPC), such as the 95% upper confidence limit of the mean (95% UCL), with the SRBC.

Subsection 6.3 discusses Phase 2, which is the comprehensive BHHRA process, as illustrated in Figure 6.1-2. A summary of each key component is provided below:

- **Hazard Identification (Subsection 6.3.2)—**This subsection describes data usability, data validation and the guidelines for data reduction for risk assessment purposes; identifies the methods for selecting contaminants of potential concern (COPCs); and outlines the data evaluation approach.
- **Dose-Response Assessment (Subsection 6.3.3)—**This subsection identifies toxicological criteria and how they will be used for the quantitation of both carcinogenic risk and noncancer health effects. The criteria, sources, and the rationale for their use are presented.
- **Exposure Assessment (Subsection 6.3.4)—**A discussion of the exposure setting and local land and water uses is provided in this subsection. A conceptual site model is presented that outlines sources of contamination, affected media, and current and future exposure scenarios and their associated exposure pathways. Methods for estimating the contaminant EPCs are also presented.
- **Risk Characterization (Subsection 6.3.5)—**The methods that will be used to estimate carcinogenic risks and noncancer health effects are presented.
- **Uncertainty Analysis (Subsection 6.3.6)—**This subsection briefly describes the rationale that will be used to present the level of uncertainty and its impact on the risk results. Probabilistic approaches will be considered for further evaluating contaminants and pathways that may result in potentially unacceptable levels of risk.

6.1.2 Risk Assessment Guidance

The BHHRA methodology has been developed by EPA primarily for activities conducted under the CERCLA and RCRA programs. Risk assessment guidance documents and information sources that will be used include, but are not limited to, those presented in Table 6.1-1.

Table 6.1-1

Risk Assessment Guidance Documents

A. EPA Risk Assessment Guidance
The human health risk assessment of the Lower River will take into account the guidance, procedures, assumptions, methods, and formats contained in:
EPA-Region I Waste Management Division Risk Updates.
Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors (EPA OSWER Directive 9285.6-03, 25 March, 1991).
Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (RAGS HHEM) ▪ (Part A) Interim Final, (EPA 540/1-89/002, December 1989) ▪ Development of Risk-Based Preliminary Remediation Goals (Part B) (EPA Publication 9285.7-01B, December 1991, PB92963333) ▪ Risk Evaluation of Remedial Alternatives (Part C), (EPA Publication 9285.7-01C, December 1991, PB92-963334) ▪ Part D, Standardized Planning Reporting, and Review of Superfund Risk Assessments. Interim (EPA 540-R-97-033). OSWER 9285.7-01D) January 1998
Calculating the Concentration Term: Supplemental Guidance to RAGS (EPA Publication 9285.7-081, May 1992).
Guidance for Data Usability in Risk Assessment, Part A (EPA Publication 9285.7-09A, April 1992, PB92-963356).
Dermal Exposure: Principles and Applications (EPA/600/8-91/011B, January 1992).
Risk Assessment Guidance for Superfund Volume I. Human Health Evaluation Manual, Supplemental Guidance. Dermal Risk Assessment Interim Guidance, 6 November 1998. Peer Consultation Workshop Draft. OERR.
Air/Superfund National Technical Guidance Study Series, Volumes I, II, III, and IV (EPA 450/1-89-001, 002, 003, 004, July 1989).
Guidelines for Exposure Assessment (57FR22888 – 57 FR22938, 29 May 1992).
Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children, EPA, OERR, Publication Number 9285.7-15-1, PB93-963510, available through NTIS (703/487-4650).
Exposure Factors Handbook , Volumes I, II, and III. (EPA/600/P-95/002Fa). August 1997.
Land Use in the CERCLA Remedy Selection Process (EPA, OSWER Publication 9355.7-04, 25 May 1995, PB95-963234).
Guidance on Risk Characterization for Risk Managers and Risk Assessors, Memorandum from F. Henry Habicht, EPA Deputy Administrator, to Assistant Administrators and Regional Administrators. Office of the Administrator, Washington, DC (U.S. EPA, 1992).

Table 6.1-1

Risk Assessment Guidance Documents
(Continued)

EPA Risk Characterization Program. Memorandum from Administrator Carol M. Browner to Assistant Administrators, Associate Administrators, Regional Administrators, General Counsel and Inspector General on March 21, 1995. Office of the Administrator, Washington, DC. (U.S. EPA, 1995).
Proposed Guidelines for Carcinogen Risk Assessment. Office of Research and Development, Washington, DC. EPA/600P-92/003C. (U.S. EPA, 1996).
Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis. Office of Research and Development, Washington, DC. EPA Publication Number EPA/630/R-96/012. February 1997 (U.S. EPA, 1997).
Integrated Risk Information System (IRIS).
PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures.
B. DEP Guidance
DEP. 1995. *Guidance for Disposal Site Risk Characterization, in Support of the Massachusetts Contingency Plan*, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup and Office of Research and Standards, Interim Final Policy, BWSC/ORS-95-141, July 1995.

Supplementary risk assessment guidance documents will be cited in the individual sections of this Work Plan and the risk assessment as appropriate.

6.2 PHASE 1—SITE SCREENING APPROACH

6.2.1 Objectives and Rationale

The primary objective of the Phase 1 evaluation is to identify areas along the Lower Housatonic River that may not require a BHHRA. To accomplish this objective, a conservative screening method has been developed allowing for the elimination of areas along the Lower River that would not be expected to pose a significant health risk. The general approach is presented in Figure 6.1-1. The following subsections provide a detailed description of the steps involved in the Phase 1 site screening approach:

- Data Evaluation (Subsection 6.2.2)
- Dose-Response Assessment (Subsection 6.2.3)
- Exposure Assessment (Subsection 6.2.4)
- SRBC Calculations and Results (Subsection 6.2.5)
- Site Screening Methodology (Subsection 6.2.6)

It should be noted that this screening evaluation will be based on current land use. The risk assessment will identify properties/areas that are eliminated based on this screening process. This will provide a database that can be used to evaluate any future changes to land use classifications.

6.2.2 Data Evaluation

PCB samples collected along the Lower River from floodplain soil, riverbank soil, and sediment will be grouped according to land use designations. These land uses represent specific current and/or future residential and commercial properties, recreational areas, and other land classifications within which sample data will be grouped for comparison with SRBCs. These data will be summarized statistically to obtain the maximum detected PCB concentration and, if necessary, the 95% UCL in each medium at each site according to the methodology presented in the "Data Evaluation" discussion for the BHHRA (see Subsection 6.3.2.4). These summarized data will be compared with medium-specific SRBCs as described later in this subsection.

6.2.3 Dose-Response Assessment

Cancer-based and noncancer-based SRBCs have been developed for use in the Phase 1 Assessment. Cancer-based SRBCs were developed from the current oral cancer slope factor (CSF) for PCBs of 2 $(mg/kg\text{-}day)^{-1}$ (EPA, 99-0011). A CSF for dermal carcinogenicity of PCBs has not been issued by the agencies. To evaluate exposure to PCBs through this route, a gastrointestinal (GI) absorption factor for PCBs of 100% was applied to the oral CSF (99-0002) resulting in a CSF equivalent to the oral CSF of 2 $(mg/kg\text{-}day)^{-1}$.

Noncancer SRBCs have been based on the chronic oral reference dose (RfD) for Aroclor 1254 of 2E-05 mg/kg-day (99-0011). The dermal RfD was assumed to be equivalent to the oral RfD, assuming 100% GI tract absorption. It was assumed for screening that all exposure scenarios were of a chronic duration.

6.2.4 Exposure Assessment

Various activities are known to occur on the Lower River that may result in potential human exposure to PCB-contaminated floodplain soil, riverbank soil, and sediment. Exposure to surface water of the Housatonic River may also result from these activities; however, due to the constantly changing nature of exposure to surface water in a river, surface water exposure will not be included in the screening procedure. Exposure to surface water will be evaluated in Phase 2. For screening, the types of potential exposures resulting from such activities have been condensed into four major categories:

- **Residential Exposure.** Residents may be exposed to floodplain soil, riverbank soil, and sediment during activities on their properties along the Lower River.
- **Recreational Exposure.** Recreational visitors may be exposed to floodplain soil, riverbank soil, and sediment through activities related to hunting, fishing, canoeing, wading, hiking, picnicking, etc.
- **Agricultural Exposure.** Farmers tilling, planting, maintaining, or harvesting crops may be exposed to PCB-contaminated floodplain soil.
- **Commercial/Industrial Exposure**
  - **Utility Worker Exposure.** A number of areas within the floodplain along the Lower River have easements for utilities. Utility workers can be exposed to

floodplain and riverbank soils during activities such as maintenance or installation of new equipment.

- **Groundskeeper Exposure.** Commercial or private groundskeepers may be involved in such activities as lawn or garden maintenance in floodplain soil along the Lower River.

For the Phase 1 site screening process, conservative exposure assumptions were developed for these potential activities in calculating SRBCs. These exposure assumptions were coupled with the dose-response information described in the previous subsection to develop SRBCs for use in the screening process.

Guidance for SRBC development was obtained from the *Human Health Evaluation Manual, Part B: Development of Risk-based Preliminary Remediation Goals* (EPA, 99-0090) and EPA *Region 9 PRGs* (99-0057). The algorithms were modified according to site-specific information, updated toxicity (99-0011) and exposure information (EPA, 99-0007), and professional judgment. The SRBC algorithms and exposure inputs are presented by exposure scenario in the following subsections.

6.2.5 Calculation of Screening Risk-Based Concentrations (SRBCs)

Models for calculating medium-specific SRBCs and the results of these calculations are presented in this subsection. SRBCs have been calculated for floodplain soil, riverbank soil, and sediment. Within an exposure scenario, the approach was to develop a conservative or health-protective SRBC. To accomplish this objective, the following steps were taken:

- Age-adjusted lifetime cancer risks for a 30-year exposure duration were evaluated for the child-adult.
- Noncancer effects were evaluated separately for a young child and an adult.
- The SRBCs were based on direct contact exposure (incidental ingestion and dermal absorption).
- The SRBCs were selected based on the most conservative assessment (cancer or noncancer).
- High-end media concentrations (maximum or 95% UCL) will be used for comparison to the SRBCs.

SRBCs for the resident and recreational users have been developed based on "low-contact" or "high-contact" exposures (see Subsections 6.2.5.1 and 6.2.5.2).

Each SRBC is based on an integration of soil or sediment ingestion and dermal contact pathways. The method for this integration is discussed in Subsection 6.2.5.5. Listed below is a summary of the site classifications and the respective receptors and media for which SRBCs have been developed:

- **Residential—**Child, adult; floodplain soil.
- **Residential, Low Contact—**Child, adult; riverbank soil, sediment.
- **Residential, High Contact—**Child, adult; riverbank soil, sediment.
- **Recreational, Low Contact—**Child, adult; floodplain soil, riverbank soil, sediment.
- **Recreational, High Contact—**Child, adult; floodplain soil, riverbank soil, sediment.
- **Agricultural—**Child, adult; floodplain soil.
- **Commercial/Industrial—Utility Worker—**Adult; floodplain soil, riverbank soil.
- **Commercial/Industrial—Groundskeeper—**Adult; floodplain soil.

The target cancer risk associated with the SRBCs is at the low end of the EPA acceptable risk range for cancer ($5x10^{-6}$ or less). The target hazard quotient for noncancer effects is at the level below which no adverse health effects are expected to occur (Hazard Quotient = 1). As described below, the SRBCs were developed using conservative exposure assumptions and will be compared initially with maximum detected PCB concentrations. These SRBCs will be useful in focusing the Phase 2 evaluation on those areas where there is a potential for unacceptable risks to occur under current or future land use.

6.2.5.1 Residential Sites

A maximum floodplain soil PCB concentration of 2 mg/kg has been identified as the level at which a residential property is to be referred to GE for more detailed evaluation if the area of contamination on the property has been specifically identified as actual/potential lawn area (as identified in the Consent Decree, 00-0388). The 2 mg/kg level will also be used as the screening concentration for residential floodplain property not specifically identified in the Consent Decree (00-0388) as actual/potential lawn area. Therefore, the SRBC for contaminated floodplain soils for any residential property on any portion of the Lower Housatonic River will default to a value of 2 mg/kg. The models for calculating age-adjusted cancer-based SRBCs for riverbank soil and sediment associated with residential and recreational use are presented in Table 6.2-1. The age-adjusted factors for soil ingestion and dermal contact are presented in Tables 6.2-2 and 6.2-3, respectively. Child and adult noncancer algorithms for direct contact with soil and sediment are presented in Table 6.2-4.

Riverbank soil and sediment for each current or reasonably foreseeable future residential site will be designated as “low” or “high” contact depending on site-specific information about its use or potential use. High-contact exposure in areas of residential use is differentiated from low-contact exposure by accessibility and exposure frequency (EF). For high-contact residential riverbank soil, the 2 mg/kg concentration that was developed in the Consent Decree (00-0388) will be used as the SRBC. For sediment, high-contact exposure equates to 84 days per year (i.e., 3 days of exposure per week for 7 months of the year).

For low-contact riverbank soil and low- and high-contact sediment, SRBCs have been calculated based on conservative assumptions. Low-contact residential exposure to riverbank soil and sediment has been defined as 2 days of exposure per week for 7 months of the year (i.e., 56 days per year). For each of these media, soil ingestion and dermal contact exposures have been evaluated. SRBCs were then calculated by integrating the two exposure pathways.

It has been assumed that both a child and an adult can visit those portions of a residential property that may be used for recreational or other purposes. The child is assumed to be 1 to 6 years old (with an exposure duration [ED] of 6 years); the adult is assumed to have an ED of 30 years. Standard body weights (BW) of 15 kg and 70 kg will be used for the child and adult, respectively. Carcinogenic averaging time (ATc) for the adult is assumed to be 25,550 days (i.e., 70 years *x* 365 days per year).

The soil and sediment ingestion rates (IRS) have been assumed as 200 mg per day (child) and 100 mg/day (adult). For dermal contact, the child is assumed to have an exposed skin surface area (SA) of 2,900 cm^2 per day (equating to the 50^{th} percentile values for head, forearms, hands,

Table 6.2-1

Models for Age-Adjusted Cancer SRBCs for Soil/Sediment Exposure Residential* and Recreational Uses - High and Low Contact

Lower Housatonic River
Pittsfield, MA

Soil/Sediment Ingestion

$$\text{SRBC (mg/kg)} = \frac{TR \times AT_c}{EF \times IFS_{adj} \times CSF_o \times CF}$$

Dermal Contact with Soil/Sediment

$$\text{SRBC (mg/kg)} = \frac{TR \times AT_c}{EF \times SFS_{adj} \times ABS_d \times CSF_d \times CF}$$

Parameter	Definition	Value
TR	Target cancer risk.	5.00E-06
AT_c	Averaging time – carcinogens (days).	25,550
EF_{hc}	Exposure frequency – high contact (days/year).	84
EF_{lc}	Exposure frequency – low contact (days/year).	56
IFS_{adj}	Age-adjusted soil/sediment ingestion factor (mg-year/kg-day). See Table 6.2-2.	114
CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$.	2.0
$SFS_{soil\text{-}adj}$	Age-adjusted soil contact factor (mg-year/kg-day). See Table 6.2-3.	252
$SFS_{sed\text{-}adj}$	Age-adjusted sediment contact factor (mg-year/kg-day). See Table 6.2-3.	934
ABS_d	Skin absorption factor (unitless).	0.14
CSF_d	Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$.	2.0
CF	Conversion factor (kg/mg).	1.00E-06

*Low-contact soil values were used to estimate riverbank soil SRBCs for residential exposures for limited accessibility. For riverbank soil where accessibility is potentially high, a 2 mg/kg SRBC will be used.

Table 6.2-2

Age-Adjusted Soil/Sediment Ingestion Factor
Residential and Recreational Uses

Lower Housatonic River
Pittsfield, MA

$$IFS_{adj}\ (mg\text{-}yr/kg\text{-}day) = \frac{ED_c \times IRS_c}{BW_c} + \frac{ED_a \times IRS_a}{BW_a}$$

Parameter	Definition	Value
IFS_{adj}	Age-adjusted soil/sediment ingestion factor (mg-year/kg-day).	114
ED_c	Exposure duration – child (years).	6
ED_a	Exposure duration – adult (years).	24
IRS_c	Soil/sediment ingestion rate – child (mg/day).	200
IRS_a	Soil/sediment ingestion rate – adult (mg/day).	100
BW_c	Body weight – child (kg).	15
BW_a	Body weight – adult (kg).	70

Table 6.2-3

Age-Adjusted Soil/Sediment Contact Factor
Residential and Recreational Uses

Lower Housatonic River
Pittsfield, MA

$$SFS_{adj}\ (mg-yr/kg-day) = \frac{ED_c \ x \ AF_c \ x \ SA_c}{BW_c} + \frac{ED_a \ x \ AF_a \ x \ SA_a}{BW_a}$$

Parameter	Definition	Value
$SFS_{soil-adj}$	Age-adjusted soil contact factor (mg-year/kg-day).	252
$SFS_{sed-adj}$	Age-adjusted sediment contact factor (mg-year/kg-day).	934
ED_c	Exposure duration – child (years).	6
ED_a	Exposure duration – adult (years).	24
AF_{soil-c}	Soil adherence factor (head, forearms, hands, lower legs, and feet) – child playing (wet soil) (50th percentile) (mg/cm^2).	0.2
AF_{soil-a}	Soil adherence factor (head, forearms, hands, lower legs, and feet) – adult soccer player (50th percentile) (mg/cm^2).	0.01
AF_{sed-c}	Sediment adherence factor (head, forearms, hands, lower legs, and feet) – reed gatherers (50th percentile) (mg/cm^2).	0.3
AF_{sed-a}	Sediment adherence factor (head, forearms, hands, lower legs, and feet) – reed gatherers (50th percentile) (mg/cm^2).	0.3
SA_c	Surface area exposed (head, forearms, hands, lower legs, and feet) – child (cm^2/day).	2,900
SA_a	Surface area exposed (head, forearms, hands, lower legs, and feet) – adult (cm^2/day).	5,700
BW_c	Body weight – child (kg).	15
BW_a	Body weight – adult (kg).	70

Table 6.2-4

Models for Noncancer SRBCs for Riverbank Soil/Sediment Exposure Residential* and Recreational Uses - High and Low Contact

Lower Housatonic River
Pittsfield, MA

Soil/Sediment Ingestion

$$\text{SRBC (mg/kg)} = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times IRS \times 1/RfD_o \times CF}$$

Dermal Contact with Soil/Sediment

$$\text{SRBC (mg/kg)} = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times AF \times SA \times ABS_d \times 1/RfD_d \times CF}$$

Parameter	Definition	Value
THQ	Target hazard quotient.	1.0
$AT_{nc\text{-}child}$	Averaging time – noncancer (days) - child.	2,190
$AT_{nc\text{-}adult}$	Averaging time – noncancer (days) - adult.	10,950
BW_c	Body weight (kg) - child.	15
BW_a	Body weight (kg) - adult.	70
EF_{hc}	Exposure frequency – high contact (days/year).	84
EF_{lc}	Exposure frequency – low contact (days/year).	56
ED_c	Exposure duration (years) - child.	6
ED_a	Exposure duration (years) - adult.	30
IRS_c	Soil/sediment ingestion rate (mg/day) - child.	200
IRS_a	Soil/sediment ingestion rate (mg/day) - adult.	100
RfD_o	Oral reference dose (mg/kg-day).	2.0E-05
$AF_{soil\text{-}c}$	Soil adherence factor (head, forearms, hands, lower legs, and feet) – child playing (wet soil) (50^{th} percentile) (mg/cm^2).	0.2
$AF_{soil\text{-}a}$	Soil adherence factor (head, forearms, hands, lower legs, and feet) – adult soccer player (50^{th} percentile) (mg/cm^2).	0.01
$AF_{sed\text{-}c}$	Sediment adherence factor (head, forearms, hands, lower legs, and feet) – reed gatherers (50^{th} percentile) (mg/cm^2).	0.3
$AF_{sed\text{-}a}$	Sediment adherence factor (head, forearms, hands, lower legs, and feet) – reed gatherers (50^{th} percentile) (mg/cm^2).	0.3

Table 6.2-4

Models for Noncancer SRBCs for Riverbank Soil/Sediment Exposure Residential* and Recreational Uses - High and Low Contact

Lower Housatonic River
Pittsfield, MA
(Continued)

SA_c	Surface area exposed (head, forearms, hands, lower legs, and feet) – child (cm^2/day).	2,900
SA_a	Surface area exposed (head, forearms, hands, lower legs, and feet) – adult (cm^2/day).	5,700
ABS_d	Skin absorption factor (unitless).	0.14
RfD_d	Dermal reference dose (mg/kg-day).	2.0E-05
CF	Conversion factor (kg/mg).	1.00E-06

*Low-contact soil values were used to estimate riverbank soil SRBCs for residential exposures for limited accessibility. For riverbank soil where accessibility is potentially high, a 2 mg/kg SRBC will be used.

lower legs, and feet) (EPA, 99-0123). The 50^{th} percentile surface area-weighted soil adherence factor (AF) has been estimated as 0.2 mg per cm^2 for a child playing in wet soil (99-0123). For the adult, the skin SA will be assumed to be 5,700 cm^2 per day (equating to the 50^{th} percentile values for head, forearms, hands, lower legs, and feet) (99-0123). The 50^{th} percentile surface area-weighted AF for the adult has been estimated as 0.01 (adult soccer player) (99-0123). The 50^{th} percentile surface area-weighted sediment AF for both the child and adult has been estimated as 0.3 (reed gatherers) (99-0123). A dermal absorption factor of 0.14 has been used for PCBs for both high- and low-contact calculations (99-0123).

Table 6.2-4 presents the riverbank soil and sediment ingestion and dermal contact SRBC models for noncancer-based residential (low contact) and recreational exposures (high and low contact). Exposure assumptions are the same as those used for the cancer-based SRBCs, with the exception that the averaging time (ATn) has been adjusted for the actual duration (ED x 365 days per year), and the route-specific RfD has been incorporated in the equation.

6.2.5.2 Recreational Sites

The models for calculating cancer-based and noncancer-based SRBCs for sites associated with recreational use are similar to those used for the residential scenario, with the exception of floodplain soil. Recreational SRBCs for floodplain soil have been developed in a manner similar to that for residential riverbank soil and sediment. The soil/sediment models for recreational use are presented in Tables 6.2-1 and 6.2-4, as they are similar to the residential models. Differences in exposure inputs have been noted in the table. Algorithms for both ingestion and dermal contact are presented.

For recreational areas, SRBCs for floodplain soil and riverbank soil and sediment have been calculated for each age group as “high-contact” and “low-contact. Designation of “low” or “high” contact depends on site-specific information about its use. High-contact exposure in areas of recreational use is differentiated from low-contact exposure by the accessibility and the likely degree of exposure frequency. For floodplain and riverbank soil and sediment, high-contact exposure equates to 84 days per year (i.e., 3 full days of exposure per week for 7 months of the year). Low-contact exposure has been defined as 2 days of exposure per week for 7 months of the year (i.e., 56 days per year). These frequencies have been judged to represent an upper range of the likely exposure frequencies during the late spring, summer, and early fall periods.

It has been assumed that both a child and an adult visit recreational areas. The child is assumed to be 1 to 6 years old, i.e., exposure duration (ED) of 6 years, and the adult is assumed to have an ED of 30 years. Standard body weights (BW) of 15 kg and 70 kg will be used for the child and adult, respectively. Carcinogenic averaging time (ATc) for the adult is assumed to be 25,550 days (i.e., 70 years *x* 365 days per year).

The soil and sediment ingestion rates (IRS) are identical and are assumed to be 200 mg per day for the child and 100 mg/day for the adult. For dermal contact, the child is assumed to have an exposed skin surface area (SA) of 2,900 cm^2 per day (equating to the 50^{th} percentile values for head, forearms, hands, lower legs, and feet) (EPA 99-0123). The 50^{th} percentile surface area-weighted soil adherence factor (AF) has been estimated as 0.2 mg per cm^2 for a child playing in wet soil (99-0123). For the adult, the skin SA will be assumed to be 5,700 cm^2 per day (equating to the 50^{th} percentile values for head, forearms, hands, lower legs, and feet) (99-0123). The 50^{th} percentile surface area-weighted soil AF for the adult has been estimated as 0.01 (adult soccer player) (99-0123). The 50^{th} percentile surface area-weighted sediment AF for both the child and adult has been estimated as 0.3 (reed gatherers) (99-0123). A dermal absorption factor of 0.14 has been used for PCBs for both high- and low-contact calculations (EPA, 99-0127).

Table 6.2-4 presents the soil/sediment ingestion and dermal contact SRBC models for noncancer-based residential (low contact) and recreational exposures (high and low contact). Exposure assumptions are the same as those used for the cancer-based SRBCs, except the averaging time (ATn) has been adjusted for the actual duration (ED x 365 days per year), and the route-specific RfD has been incorporated in the equation in place of the CSF.

6.2.5.3 Agricultural Sites

Agricultural areas will be initially screened on the basis of soil ingestion and dermal contact with floodplain soil. This initial screening does not include the potential for exposure through other pathways such as dust inhalation, vegetable ingestion, and dairy product consumption from cows raised on silage grown in floodplain soil or grazed in the floodplains. These pathways will be evaluated separately as part of the comprehensive BHHRA.

The 2 mg/kg floodplain soil concentration that will be applied in the residential scenario will also be applied in the agricultural scenario. This provides an acceptable SRBC for incidental soil ingestion and dermal contact with soil. In addition, for those agricultural areas that might, at some point in the future, be developed into residential properties, the residential SRBC (2 mg/kg) is an appropriate value.

6.2.5.4 Commercial/Industrial

There are two categories of commercial/industrial use that will be evaluated in the risk assessment – the utility worker and the commercial groundskeeper. Any commercial/industrial land uses that have a significant potential for current or future use as a recreational or residential area will also be screened for those additional land uses. This will be based on a site-specific evaluation.

6.2.5.4.1 Utility Worker Sites

The models for calculating cancer-based and noncancer-based SRBCs for the utility worker are presented in Table 6.2-5. Soil ingestion and dermal contact exposures from riverbank and floodplain soils have been considered. The utility worker is assumed to be involved in easement repair in contaminated areas of floodplain and riverbank soils for 5 days per year for 25 years (99-0336). The utility worker is assumed to weigh 70 kg. Because of the likely heavy exposure to soils, a soil ingestion rate (IRS) of 200 mg/day will be assumed. Exposed body parts will be assumed to be the head, forearms, and hands (3,300 cm^2 per day; 50^{th} percentile) and the surface area-weighted adherence factor (AF) is assumed to be 0.8 mg/cm^2 (95^{th} percentile-utility worker) (99-0123).

Table 6.2-5

Models for Cancer and Noncancer Floodplain and Riverbank Soil SRBCs for the Utility Worker

Lower Housatonic River
Pittsfield, MA

Soil Ingestion

Cancer

$$SRBC\ (mg/kg) = \frac{TR \times AT_c \times BW}{EF \times ED \times IRS \times CSF_o \times CF}$$

Noncancer

$$SRBC\ (mg/kg) = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times IRS \times 1/RfD_o \times CF}$$

Dermal Contact with Soil

Cancer

$$SRBC\ (mg/kg) = \frac{TR \times AT_c \times BW}{EF \times ED \times AF \times SA \times ABS_d \times CSF_d \times CF}$$

Noncancer

$$SRBC\ (mg/kg) = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times AF \times SA \times ABS_d \times 1/RfD_d \times CF}$$

Parameter	Definition	Value
TR	Target cancer risk.	1.6E-06
THQ	Target hazard quotient.	1.0
AT_c	Averaging time – carcinogens (days).	25,550
AT_{nc}	Averaging time – noncancer (days).	9,125
BW	Body weight (kg).	70
EF	Exposure frequency (days/year).	5
ED	Exposure duration (years).	25

Table 6.2-5

Models for Cancer and Noncancer Floodplain and Riverbank Soil SRBCs for the Utility Worker

Lower Housatonic River
Pittsfield, MA
(Continued)

IRS	Soil ingestion rate (mg/day).	200
CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$.	2.0
RfD_o	Oral reference dose (mg/kg-day).	2.0E-05
AF	Adherence factor (head, forearms, and hands) – (95^{th} percentile) (mg/cm^2).	0.8
SA	Surface area exposed (head, forearms, and hands) – gardener (50^{th} percentile) (cm^2/day).	3,300
ABS_d	Skin absorption factor (unitless).	0.14
CSF_d	Dermal cancer slope factor $(mg/kg\text{-}day)^{-1}$.	2.0
RfD_d	Dermal reference dose (mg/kg-day).	2.0E-05
CF	Conversion factor (kg/mg).	1.00E-06

6.2.5.4.2 Groundskeeper Sites

The models for calculating cancer-based and noncancer-based SRBCs for sites where a commercial groundskeeper may be exposed are presented in Table 6.2-6. Soil ingestion and dermal contact exposures from floodplain soil only will be considered, as a typical groundskeeper's activity is unlikely to result in significant exposures to riverbank soil or sediment. The groundskeeper is assumed to be an adult with a body weight (BW) of 70 kg and an exposure duration (ED) of 25 years. The groundskeeper is assumed to mow grass and perform other related activities in the floodplain area for 28 days per year during the late spring, summer, and early fall. Assuming this activity occurs over a 7-month period, this would equate to an exposure frequency (EF) of 4 days per month (approximately 1 day per week) of exposure. The soil ingestion rate (IRS) is assumed to be 50 mg of soil per day. Exposed body parts are assumed to be the head, forearms, and hands (50^{th} percentile SA estimated as 3,300 cm^2 per day), and the surface area-weighted adherence factor (AF) is estimated as 0.1 mg/cm^2 (50^{th} percentile for a commercial groundskeeper) (99-0123).

6.2.5.5 Integrated SRBCs

SRBCs were estimated initially for each exposure pathway within a scenario and age group. This approach was taken to determine the contribution of each pathway to the final integrated SRBC. For purposes of the site-screening comparison process, an integrated medium-specific SRBC was developed inclusive of all calculated exposure pathways for a given exposure scenario.

Table 6.2-7 presents the equation for calculating the integrated medium-specific SRBC through all applicable exposure pathways (Rosenblatt et al., 99-0097). The integrated SRBCs have been derived from the respective SRBCs for ingestion and dermal contact calculated for the applicable scenarios.

6.2.5.6 SRBC Results

Medium-specific SRBCs for PCBs were developed based on both cancer risk and noncancer health effects. Table 6.2-8 summarizes the calculated SRBCs by exposure scenario, age group,

Table 6.2-6

Models for Cancer and Noncancer Floodplain Soil SRBCs for the Commercial Groundskeeper

Lower Housatonic River
Pittsfield, MA

Soil Ingestion

Cancer

$$\text{SRBC (mg/kg)} = \frac{TR \times AT_c \times BW}{EF \times ED \times IRS \times CSF_o \times CF}$$

Noncancer

$$\text{SRBC (mg/kg)} = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times IRS \times 1/RfD_o \times CF}$$

Dermal Contact with Soil

Cancer

$$\text{SRBC (mg/kg)} = \frac{TR \times AT_c \times BW}{EF \times ED \times AF \times SA \times ABS_d \times CSF_d \times CF}$$

Noncancer

$$\text{SRBC (mg/kg)} = \frac{THQ \times AT_{nc} \times BW}{EF \times ED \times AF \times SA \times ABS_d \times 1/RfD_d \times CF}$$

Parameter	Definition	Value
TR	Target cancer risk.	1.1E-06
THQ	Target hazard quotient.	1.0
AT_c	Averaging time – carcinogens (days).	25,550
AT_{nc}	Averaging time - noncancer (days).	9,125
BW	Body weight (kg).	70
EF	Exposure frequency (days/year).	28
ED	Exposure duration (years).	25
IRS	Soil ingestion rate (mg/day).	50
CSF_o	Oral cancer slope factor $(mg/kg\text{-}day)^{-1}$.	2.0

Table 6.2-6

Models for Cancer and Noncancer Floodplain Soil SRBCs for the Commercial Groundskeeper

Lower Housatonic River
Pittsfield, MA
(Continued)

RfD_o	Oral reference dose (mg/kg-day).	2.0E-05
AF	Adherence factor (head, forearms, and hands) – gardener (50th percentile) (mg/cm^2).	0.1
SA	Surface area exposed (head, forearms, and hands) – gardener (50th percentile) (cm^2/day).	3,300
ABS_d	Skin absorption factor (unitless).	0.14
CSF_d	Dermal cancer slope factor (mg/kg-day)$^{-1}$.	2.0
RfD_d	Dermal reference dose (mg/kg-day).	2.0E-05
CF	Conversion factor (kg/mg).	1.00E-06

Table 6.2-7

Model for Medium-Specific Integrated SRBCs* through Combined Oral and Dermal Exposure Pathways

Lower Housatonic River
Pittsfield, MA

$$\mathrm{RBC}_{\mathrm{int}} = [(\mathrm{RBC}_{\mathrm{ing}})^{-1} + (RBC_{der})^{-1}]^{-1}$$
Where: RBC_{int} = Medium-specific integrated risk-based concentration for all pathways combined. RBC_{ing} = Medium-specific risk-based concentration for ingestion. RBC_{der} = Medium-specific risk-based concentration for dermal contact.
Method of Rosenblatt et al. (1982) (99-0097)

*Medium-specific integrated SRBCs were calculated for floodplain soil, riverbank soil, and sediment.

Table 6.2-8

Summary of SRBCs
Lower Housatonic River
Pittsfield, MA

Scenario/Receptor	Screening Risk-Based Concentration (SRBC)		
	Floodplain Soil (mg/kg)	Riverbank Soil (mg/kg)	Sediment (mg/kg)
Resident – Low Contact			
Child - Noncancer	2	7	6
Child/Adult Age-Adjusted - Cancer	2	8	5
Adult - Noncancer	2	85	27
Resident – High Contact			
Child - Noncancer	2	2	4
Child/Adult Age-Adjusted - Cancer	2	2	3
Adult - Noncancer	2	2	18
Recreational – Low Contact			
Child - Noncancer	7	7	6
Child/Adult Age-Adjusted - Cancer	8	8	5
Adult - Noncancer	85	85	27
Recreational – High Contact			
Child - Noncancer	5	5	4
Child/Adult Age-Adjusted - Cancer	5	5	3
Adult - Noncancer	56	56	18
Agricultural			
Adult - Cancer	2	NA	NA
Commercial/Industrial – Utility Worker			
Adult - Cancer	20	20	NA
Adult - Noncancer	221	221	NA
Commercial/Industrial – Groundskeeper			
Adult - Cancer	20	NA	NA
Adult - Noncancer	250	NA	NA

toxicity type (cancer or noncancer), and medium. For screening, the lowest of each medium-specific SRBC will be used to compare site PCB levels.

6.2.6 Site Screening Methodology

Site uses along the Lower River have been designated as residential, recreational, agricultural, or commercial/ industrial. The most conservative of the SRBCs for each scenario and medium will be compared with site-related PCB concentrations. In the case that a specific area could be used for more than one land use, the more conservative SRBC will be used in the screening analyses.

If the EPC for PCBs in any medium at a given site exceeds its medium-specific SRBC, the entire site will be considered for further evaluation through a BHHRA.

6.2.6.1 Residential Exposure

6.2.6.1.1 Floodplain Soil

Figure 6.2-1A illustrates the site screening procedure for residential floodplain soil. The PCB SRBC for residential floodplain soil is 2 mg/kg, as noted in the Consent Decree (00-0388). If the maximum detected soil concentration at a residential property is less than or equal to 2 mg/kg, no further analysis is necessary (i.e., a BHHRA is not necessary). If the maximum value exceeds the 2 mg/kg benchmark, the site will be referred to GE for further analysis if the exceedance is in an area identified in the Consent Decree (00-0388) as actual/potential lawn area. If the maximum value exceeds 2 mg/kg, and the site is not in the specified actual/potential lawn area, an EPC (i.e., the 95% UCL or the maximum detected value, whichever is lower) will be calculated, which may involve the collection of additional samples. If the EPC is greater than 2 mg/kg, the site will be considered for additional analysis.

6.2.6.1.2 Riverbank Soil

The site screening approach for riverbank soil associated with a residential property is illustrated in Figure 6.2-1B. Each residential property will be classified according to its likelihood for riverbank soil exposure as either low- or high-contact. These classifications will be based on the accessibility of the riverbank soil area, i.e., qualitative judgments of the likelihood that the riverbank area of a residential property has physical features consistent with a child (or adult) contacting riverbank soil on a regular basis. If the riverbank soil is a high-contact area, the SRBC will be the 2-mg/kg concentration used for floodplains. If it is deemed to be a low-contact area, the low-contact SRBC will be used.

If the maximum detected riverbank soil PCB level is less than the appropriate high- or low-contact SRBC, then no further evaluation will be necessary. If the maximum detected concentration of PCBs in the riverbank soil exceeds the appropriate SRBC, the EPC (i.e., the 95% UCL or the maximum detected concentration, whichever is lower) will be calculated for individual property riverbanks (additional samples may be required). If a likely riverbank contact location overlaps several properties, riverbank samples from several contiguous properties may be grouped to estimate an EPC. If the EPC is less than the selected SRBC, no further analysis will be necessary. If the EPC is greater than the SRBC, additional evaluation (i.e., a BHHRA) will be considered.

6.2.6.1.3 Sediment

The screening approach for sediment associated with a residential property is also shown in Figure 6.2-1B. If the maximum detected PCB concentration in the sediment of a given residential property is less than its SRBC, no further evaluation will be required. If it exceeds the SRBC, the EPC (i.e., the 95% UCL or the maximum detected value, whichever is lower) will be calculated for the individual property sediments (additional samples may be required). If a likely sediment contact location overlaps several properties, sediment samples from contiguous residential properties may be grouped to estimate an EPC. If the EPC is less than the SRBC, no further analysis of sediment exposure is necessary. If greater, then the need for a BHHRA will be considered.

6.2.6.2 Recreational Exposure

6.2.6.2.1 Floodplain Soil

Floodplain soil in recreational areas will be evaluated as illustrated in Figure 6.2-2A. Following determination of whether the recreational site represents a high-contact or low-contact area, the appropriate SRBC value for high or low contact will be compared with the maximum detected PCB concentration. If the maximum detected concentration is less than its SRBC, no further evaluation will be required. If it exceeds the SRBC, a 95% UCL of the mean PCB concentration (defined as the EPC) will be developed. If the EPC is less than the SRBC, no further analysis of floodplain soils is necessary. If the EPC exceeds the SRBC, additional evaluation will be considered (i.e., BHHRA).

6.2.6.2.2 Riverbank Soil and Sediment

Once the determination of low or high contact has been made for an area, the appropriate SRBC will be compared with the maximum detected riverbank soil and sediment samples (Figure 6.2-2B). If the maximum values are less than their respective SRBCs, then no further analysis of the site is required. If the maximum values exceed the SRBC, additional samples will be collected and a 95% UCL calculated. If the 95% UCL of the soil and sediment values are less than the respective SRBCs, no further evaluation is necessary. If the SRBCs are exceeded, then additional evaluation (i.e., BHHRA) of the site will be considered.

6.2.6.3 Agricultural Exposure

Figure 6.2-3 illustrates the screening procedure that will be used for floodplain soil associated with agricultural uses. The maximum PCB concentration detected in floodplain soil will be compared with an SRBC of 2 mg/kg. If the maximum concentration is less than the SRBC, no further evaluation of the site will be required for direct contact exposures. If the maximum concentration is greater than the SRBC, additional PCB samples will be taken to estimate an EPC (i.e., 95% UCL of the mean). If the EPC is less than the 2 mg/kg SRBC, no further evaluation is required. If greater, then the need for a BHHRA will be considered.

6.2.6.4 Commercial/Industrial - Utility Worker Exposure

Figure 6.2-4A illustrates the screening approach that will be taken with the utility worker for floodplain and riverbank soils. A single SRBC has been developed for the utility worker, which will be compared with the maximum detected PCB concentration for riverbank and floodplain soil along utility right-of-way areas. If the maximum PCB concentration is less than the calculated SRBC, no further evaluation of the site soil will be required. If the maximum concentration exceeds the SRBC, then a 95% UCL will be developed for comparison with the SRBC. If the 95% UCL exceeds the SRBC, the need for a BHHRA will be considered.

6.2.6.5 Commercial/Industrial - Groundskeeper Exposure

Figure 6.2-4B illustrates the procedure for evaluating floodplain soil designated as a potential exposure area for a groundskeeper. Each potential area will be evaluated separately. If the maximum detected floodplain soil level of PCBs is less than the calculated SRBC, the site requires no further evaluation. If greater than the SRBC, additional PCB samples will be taken to estimate an EPC (i.e., 95% UCL of the mean). If the EPC is less than the SRBC, no further evaluation is required. If the EPC is greater than the SRBC, then the need for a BHHRA will be considered.

6.3 PHASE 2—BHHRA APPROACH

6.3.1 Introduction

For those areas remaining after completion of the Phase 1 screening process, a comprehensive BHHRA will be performed, as identified in Subsection 6.1.2 and Figure 6.1-1. The following subsections describe each key component of the risk assessment process:

- Hazard Identification (Subsection 6.3.2).
- Dose-Response Assessment (Subsection 6.3.3).
- Exposure Assessment (Subsection 6.3.4).
- Risk Characterization (Subsection 6.3.5).
- Uncertainty Analysis (Subsection 6.3.6).

6.3.2 Hazard Identification

The following subsections describe the methods that will be used for data reduction, evaluation, and selection of contaminants of potential concern (COPCs). The BHHRA for the Lower River will be based on validated data collected as part of EPA's current site characterization efforts, described in Section 5, as well as any previously collected data that meet established data quality objectives (Subsection 4.3).

6.3.2.1 Data Usability and Data Validation

EPA Region 1 discusses data usability issues that should be considered in the risk assessment process in its Risk Update 3 (99-0005). Data usability is defined as the process of ensuring that the quality of the data meets the intended uses and satisfies the data quality objectives (DQOs) established for sampling and analysis. Data usability involves assessing both the analytical quality, sampling methodology, and field errors that may be inherent in the data. Factors evaluated include the level of validation (data validation tier) and data quality indicators such as completeness, comparability, precision and accuracy, and analytical detection limits.

EPA Region I recommends that all data used in the human health risk assessment process be validated to Tier II or Tier III. In a Tier II validation, quality control (QC) checks are conducted and analytical procedures are assessed, and the data are qualified accordingly. In a Tier III validation, in addition to meeting the Tier II requirements, the raw data are examined to check for calculation errors, compound misidentification, and transcription errors. A Data Validation report is produced by the validator for both Tier II and Tier III validations.

Data quality objectives and risk assessment data needs are discussed in detail in Section 4 of this Work Plan.

6.3.2.2 Guidelines for Data Reduction

The following guidelines for data reduction will be used to produce the data summaries for each medium in each area. These approaches are consistent with *Risk Assessment Guidance for Superfund (RAGS), Volume 1*, *Human Health Evaluation Manual (Part A)* (EPA, 99-0002).

- If a chemical is not positively identified in any sample from a given medium, because it is reported as a nondetect or because of blank contamination, it will not be addressed for that medium.

- All chemical data with "J" qualifiers will be assumed to be positive identifications within any medium. "J" indicates that the numerical value is an estimated concentration (e.g., is reported below the minimum confident sample quantitation limit).

- All U-qualified data represent nondetected samples for the parameter evaluated. As discussed in Subsection 7.2.1, EPA is currently evaluating several approaches for dealing with nondetect (i.e., censored data) and how these approaches may impact the development of exposure concentrations.

- If a sample duplicate is collected and analyzed, the average of the two reported concentrations will be used for subsequent calculations unless there is a greater than 30% difference in surface water concentrations or a greater than 50% difference in soil, sediment, or tissue concentrations, in which case the higher of the two concentrations will be used.

- The arithmetic mean, based on detected concentrations and nondetected concentrations at half of the detection limits, will be calculated for the chemicals identified in each medium.

6.3.2.3 Selection of Non-PCB Contaminants of Potential Concern (COPCs)

The selection of COPCs is complicated by the size of the area under consideration. There are so many individual sites and areas within the approximately 46 miles from the confluence to the Massachusetts-Connecticut border that it is necessary to establish an initial contaminant screening step to focus the sampling efforts. This will be accomplished by using a set of criteria designed to determine the need for additional sampling at sites or areas that exceed the SRBCs. This process is described in Subsection 6.2. Thus, for sites or areas that have PCB concentrations greater than the SRBCs and are therefore included in the BHHRA phase, media concentrations of other contaminants will be initially compared with the following criteria, among others, to determine the need for additional sampling in that area:

- Background concentrations established for the area.
- The 1-ppb TEQ concentration for dioxins/furans.
- Massachusetts Department of Environmental Protection (MADEP) Method 1 Soil Standards.

If these or other applicable criteria are exceeded, additional characterization sampling at that site or area will be conducted. If they are not exceeded, additional samples will not be required, and the BHHRA will be performed using the available analytical data.

The analytical data will be screened for the selection of COPCs by comparing maximum detected concentrations with contaminant-specific risk-based concentrations. This approach will be applied as referenced by EPA Region 1 in its guidance documentation (99-0005). A target cancer risk of 1E-06 and a target hazard quotient of 0.1 will be used. The principal criterion for selection of a COPC will be an exceedance of the medium-specific Preliminary Remediation Goal (PRG) by the maximum concentration of the contaminant. This comparison will not, however, provide the sole basis for inclusion of a contaminant as a COPC. The agency recognizes that the PRGs proposed for use in this screening evaluation may not include some exposure pathways that are relevant to the evaluation of risk, principally food chain transport. Consequently, those contaminants that are known to bioaccumulate in biological tissues, but which may be otherwise excluded in a comparison with PRGs, will be evaluated for their possible selection as a COPC.

6.3.2.4 Data Evaluation

The objectives of the data evaluation are to summarize the data by medium and exposure scenario and to evaluate the usability of the data for the risk assessment.

As previously noted, RAGS Part D guidance (EPA, 99-0010) will be used to develop Standard Tables as interim deliverables for this portion of the risk assessment. Standard Table 2, "*Occurrence, Distribution and Selection of COCs*" and the information supporting this table will be provided.

Summary tables will be prepared for each site, by medium and exposure scenario, that present the following information for site-related data:

- List of contaminants detected at the site.
- Frequency of detection.
- Range of detected concentrations.
- Range of sample quantitation limits.
- Arithmetic mean concentration of non-transformed data.

- Standard deviation of the mean.
- Distribution of data (normal, lognormal, neither).
- 95% UCL of the arithmetic mean.
- Exposure point concentration (EPC).

Site data will be evaluated initially by the Shapiro-Wilk *W*-test to determine whether data are normally or lognormally distributed, after which the appropriate summary statistics will be calculated. Arithmetic means will include the positive identifications (i.e., detects) plus the nondetects at one-half the sample quantitation limit. The 95% UCL of the mean for COPCs will be calculated in accordance with EPA guidelines presented in *Supplemental Guidance to RAGS: Calculating the Concentration Term* (99-0003). The appropriate formula (dependent on the type of distribution) will be used to estimate the 95% UCL of the mean. Shown below are the formulas:

Lognormal Distribution

$$UCL = e^{\left(\bar{x} + 0.5s^2 + sH/\sqrt{n-1}\right)}$$

Where:

UCL	=	95% upper confidence limit of the arithmetic mean
e	=	constant (base of the natural log, equal to 2.718)
$\bar{x}$	=	arithmetic mean of the log-transformed data
s	=	standard deviation of the log-transformed data
H	=	H-statistic, determined by the standard deviation and sample size
n	=	sample size for contaminant in the designated media set

Normal Distribution

$$UCL = \bar{x} + t\,(s/\sqrt{n})$$

Where:

UCL	=	95% upper confidence limit of the arithmetic mean
$\bar{x}$	=	arithmetic mean of the untransformed data
s	=	standard deviation of the untransformed data
t	=	Student-*t* statistic
n	=	number of samples

Exposure algorithms will be presented in RAGS Part D format.

6.3.3 Dose-Response Assessment

6.3.3.1 Introduction

The primary purpose of the dose-response assessment is to identify the toxicity values (i.e., cancer slope factors [CSFs] and reference doses [RfDs]) that will be used in the evaluation of potential human cancer risks and noncancer health effects. These toxicity values will be:

- Applied to the estimated doses (chronic daily intakes) in order to calculate potential cancer risks and noncancer health effects in the risk characterization step.
- Used in the development of SRBCs (discussed earlier in Subsection 6.2.5).

Exposure to all chemicals potentially can produce adverse noncancer health effects, whereas the potential for causing cancer is limited to those agents classified as carcinogens. Therefore, RfD values will be used where available for all chemicals, whereas CSFs will be used only for carcinogens. Because the major contaminants of concern are PCBs, the dose-response assessment includes the evaluation of PCB congeners, including dioxin-like PCBs.

EPA databases and documents will be the primary sources of cancer and noncancer toxicity values. Toxicity values obtained from the *Integrated Risk Information System* (IRIS) (99-0011) will be preferentially used, because these values have undergone extensive scientific peer review (i.e., they have been "verified"). If a toxicity value is not published in IRIS, provisional values may be obtained from the *Health Effects Assessment Summary Tables* (HEAST) (99-0006). Finally, EPA's National Center for Environmental Assessment (NCEA) may be contacted at EPA's direction for a provisional value if none is available in IRIS or HEAST.

The following subsections describe the approach to calculating toxicity criteria. Subsection 6.3.3.2 describes the approach to evaluating cancer effects, and Subsection 6.3.3.3 describes the approach to evaluating noncancer health effects.

6.3.3.2 Carcinogenic Effects

6.3.3.2.1 Weight-of-Evidence Categorization

The *Proposed Guidelines for Carcinogen Risk Assessment* (EPA, 99-0106) recommend a different scheme for weighting evidence of carcinogenicity than has been traditionally used in risk assessments (99-0002). Previous risk assessment guidance assigned a weight-of-evidence classification to each evaluated chemical as follows: Group A (human carcinogen), Group B (probable human carcinogen), Group C (possible human carcinogen), Group D (not classifiable), or Group E (no evidence of carcinogenicity) (EPA, 99-0128). PCBs are classified as B2 carcinogens (inadequate human data and sufficient animal data) under this classification scheme. The proposed guidelines recommend replacing these classifications with descriptions of "known likely," "cannot be determined," or "not likely." However, since most chemicals are still classified by the old system in the IRIS database, the older system has been retained in this risk assessment.

6.3.3.2.2 Cancer Potency

The oral, inhalation, and dermal CSFs used in this risk assessment are expressed as risk per unit dose, in units of incremental cancer risk per milligram of chemical per kilogram of body weight per day $(mg/kg\text{-}day)^{-1}$. Cancer potency is directly proportional to the CSF value. The values for inhalation cancer potency are sometimes expressed as an inhalation unit risk factor (URF) and in units of incremental cancer risk micrograms of chemical per cubic meter of air $(\mu g/m^3)^{-1}$. The inhalation unit risks can be converted to inhalation slope factors, in accordance with EPA guidance (99-0006).

Although EPA has developed oral and inhalation CSFs for a number of carcinogens, dermal CSFs have not been derived for any chemical. EPA has published guidance for calculating dermal slope factors for chemicals that have an oral slope factor available. In accordance with this guidance (99-0002), a dermal CSF will be derived for PCBs and other chemicals by dividing their oral slope factor with an appropriate gastrointestinal (GI) absorption factor. EPA recommends the use of a 100% GI absorption factor for PCBs and most organic chemicals (99-0123); if a GI absorption factor cannot be obtained from this guidance, EPA Region I will be consulted. This method results in the conversion of the oral CSF that represents the carcinogenic potency of the administered dose, to a dermal CSF that represents the carcinogenic potency of the absorbed dose. The conversion is necessary to calculate risk through the dermal pathway since the dermal doses will be calculated in the exposure assessment as absorbed doses. The oral and inhalation doses, by contrast, are calculated as administered doses, and are evaluated using CSFs based on the administered dose. Converting oral CSFs to the dermal route introduces some degree of uncertainty into risk results for the dermal pathway.

Oral, dermal, and inhalation CSFs will be presented in the risk assessment in RAGS Part D Table 6.1 and 6.2 formats (99-0010).

6.3.3.2.3 Polychlorinated Biphenyls

Evidence suggests that following the release of PCB mixtures (i.e., Aroclors) into the environment, significant alteration of the mixture properties may occur as a result of medium partitioning, transformation, and bioaccumulation over time. Environmental concentrations of individual PCB congeners may differ substantially from those present in the original Aroclor mixture at various times after its initial release (EPA, 99-0031). Depending on the environmental conditions, these transport and transformation processes may increase or decrease the toxicity of the mixture considerably.

Recent evidence suggests that the chlorine content and/or three-dimensional structure of a PCB congener may result in differing exposure potential and toxicity to an individual (99-0031). The manufacturing process of commercial PCB mixtures (i.e., Aroclors) results in the creation of approximately 175 of the possible 209 PCB congeners. Their qualitative and quantitative patterns differ in the various Aroclor preparations (ATSDR, 99-0017). The lower chlorinated congeners (i.e., mono-, di-, tri- and tetra-) are most subject to volatilization and biodegradation, whereas the higher chlorinated congeners are more persistent in the environment and biological tissues, and have a marked potential for bioaccumulation in the food chain and in humans. Additionally, there is evidence that bioaccumulated PCBs may have a greater carcinogenic potential than inferred from animal toxicity studies of the Aroclors (Cogliano, 99-0241). Finally, lot-to-lot variations in the quantities of these congeners in the commercial preparations may contribute to variations in the environmental concentrations.

The toxicity data considered adequate for assessing the carcinogenic potency of PCB mixtures in humans has come from animal toxicity studies of commercial Aroclors (EPA, 99-0031, 99-0011; and Safe, 99-0060). Conventional treatment of PCBs in the past has been to determine the total Aroclor concentration in a given medium, calculate the lifetime (i.e., carcinogenic) daily dose, and then multiply the calculated exposure dose by the route-specific CSFs for the Aroclors. EPA's recent approach for assessing the cancer risk from environmental PCBs uses the toxicity studies of these commercial mixtures to develop a range of cancer potency estimates based on site-specific exposure potential, congener analysis, and fate and transport properties.

It has been demonstrated that some PCB congeners may have dioxin-like activity (99-0060, 99-0031). Because the commercial Aroclor mixtures may contain some dioxin-like congeners at varying levels, it is believed that these may contribute in part to the carcinogenic potential of Aroclor mixtures in animal studies.

EPA believes that congener analysis is a useful supplement to total PCB measurements (99-0031). Congener analysis will be conducted on all fish and duck tissue samples and on a percentage of soil and sediment samples. The Aroclor analysis of soil and sediment samples will be compared to the congener data to assess the relationship between Aroclor and congener data.

Table 6.3-1 presents the range of CSFs that have been developed by EPA for PCB mixtures (i.e., Aroclors) based on their relative persistence and potential routes of exposure (99-0031). The choice of CSF is dependent on a variety of factors relating to the type of exposure, the medium, the distribution of congeners, and receptor age. For high risk and persistence, the recommended slope factors range from a central value of 1.0 $(mg/kg\text{-}d)^{-1}$ to an upper-bound value of 2.0 $(mg/kg\text{-}d)^{-1}$. These CSFs should be used for food chain exposures, ingestion and dermal contact with soils and sediments, dust inhalation, and early life exposures. For low risk and persistence, the CSFs range from 0.3 to 0.4 $(mg/kg\text{-}d)^{-1}$ and should be used for drinking water ingestion and inhalation of evaporated congeners. If congener analysis shows that greater than 99.5% of the mixture in a given medium is composed of PCB congeners with four or fewer chlorine groups, and no dioxin-like PCBs are present, the CSF range recommended is from 0.04 to 0.07 $(mg/kg\text{-}d)^{-1}$.

Several notes are made relative to the use of PCB CSFs in this risk assessment:

- For the central tendency (CT) risk estimates for PCBs, the central slope factors will be used (Table 6.3-1).

- For estimating RME risk, the upper range of the slope factors within each risk/persistence classification will be used.

- Surface water ingestion will be evaluated for several scenarios. In recreational scenarios (e.g., swimming), ingestion of surface water will include soluble PCBs as well as PCBs adsorbed to suspended particulate matter. The upper bound slope factor of (2.0 mg/kg-d)$^{-1}$ will be conservatively used for this pathway assuming that a significant fraction of unfiltered surface water will contain PCBs in the particulate form. If data analysis indicates the contrary, a lower slope factor will be considered (0.4 mg/kg-d)$^{-1}$.

- For child (1 to 6 yr) exposures, a value of 2.0 (mg/kg-d)$^{-1}$ will be used for all exposure pathways and scenarios. For the older child and adult, the appropriate CSF from Table 6.3-1 will be used.

6.3.3.2.4 Toxicity Equivalency Factors for Dioxins and Furans

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) (dioxins and furans, respectively) are commonly found as complex mixtures when detected in environmental media and biological tissues, or when measured as environmental releases from specific sources. In this manner, humans are likely to be exposed to variable distributions of individual dioxin and furan compounds, referred to as “congeners,” that vary by source and pathway of exposure. This complicates the human health risk assessment of exposures to variable mixtures of dioxin-like compounds. In order to address this problem, the concept of toxic equivalency factors (TEFs) has been developed and introduced to facilitate exposure to these chemical mixtures (EPA, 99-0068).

TEFs compare the potential toxicity of each dioxin-like compound comprising the mixture to the well-studied toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), believed to be the most toxic member of the group. To accomplish this, scientists have reviewed the toxicological databases along with considerations of chemical structure, persistence, and resistance to metabolism, and have agreed to ascribe specific TEFs for each dioxin-like congener. To apply this TEF concept, the TEF of each congener present in a mixture is multiplied by the respective

Table 6.3-1

Tiers of Cancer Slope Estimates for Environmental Mixtures of Polychlorinated Biphenyls (PCBs)

Central Slope $(mg/kg\text{-}d)^{-1}$	Upper-Bound Slope $(mg/kg\text{-}d)^{-1}$	Criteria for Use
High Risk and Persistence		
1.0	2.0	Food chain exposure
		Sediment or soil ingestion
		Dust or aerosol inhalation
		Dermal exposure, if an absorption factor has been applied to reduce the external dose
		Presence of dioxin-like, tumor-promoting, or persistent congeners in other media
		Early-life exposure (all pathways and mixtures)
Low Risk and Persistence		
0.3	0.4	Ingestion of water-soluble congeners
		Inhalation of evaporated congeners
		Dermal exposure, if no absorption factor has been applied to reduce the external dose
Lowest Risk and Persistence		
0.04	0.07	Congener or isomer analyses verify that congeners with more than 4 chlorines comprise less than 0.5% of total PCBs

Source: EPA, 99-0031.

mass congener concentration and the products are summed to represent the 2,3,7,8-TCDD toxic equivalence (TEQ) of the mixture, as determined by the equation:

$$TEQ = \sum_{n1}(PCDD_i \text{ x } TEF_i) + \sum_{n2}(PCDF_i \text{ x } TEF_i) + \sum_{n3}(PCB_i \text{ x } TEF_i)$$

Where:

TEQ = Toxic equivalent concentration
PCDD = Polychlorinated dibenzo-p-dioxin
PCDF = Polychlorinated dibenzofuran
PCB = Dioxin-like polychlorinated biphenyl
TEF = Toxic equivalency factor

(Source: 99-0275)

The TEF approach adopted by the World Health Organization (WHO) (99-0275) will be used. Table 6.3-2 summarizes these TEFs.

Each carcinogenic congener may have distinct physical-chemical properties and may therefore distribute and/or accumulate in different media to different degrees during transport over time. The medium-specific TEQ concentration of each congener will be evaluated through the exposure dose calculation step to yield the TEQ doses by the ingestion, dermal, and inhalation routes for each exposure pathway. TEQ concentrations will then be added to yield the total 2, 3, 7, 8-TCDD TEQ. The provisional CSF for oral and inhalation carcinogenicity of 2,3,7,8-TCDD in HEAST is 1.5E+05 $(mg/kg\text{-}d)^{-1}$ (99-0006).

6.3.3.2.5 Dioxin-Like Polychlorinated Biphenyls

A small subset of PCB congeners may elicit biochemical and toxic responses similar to dioxins and furans. The WHO has derived dioxin TEFs for 12 of these dioxin-like PCBs. These congeners and their TEF values are shown in Table 6.3-3.

Table 6.3-2

Toxicity Equivalency Factors (TEFs) for Dioxins and Furans

Compound	TEF
Chlorodibenzo-p-dioxins (CDDs)	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD 1,2,3,6,7,8-HxCDD 1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
Chlorodibenzofurans (CDFs)	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF 2,3,4,7,8-PeCDF	0.05 0.5
1,2,3,4,7,8-HxCDF 1,2,3,6,7,8-HxCDF 1,2,3,7,8,9-HxCDF 2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF 1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001

Source: Van den Berg et al., 99-0275.

Table 6.3-3

WHO Interim TEFs for Human Intake of Dioxin-Like PCBs

Congener	TEF
77: 3,4,3’,4’-TeCB	0.0001
81: 3,4,4’5-TeCB	0.0001
126: 3,4,5,3’,4’-PeCB	0.1
169: 3,4,5,3’,4’,5’-HxCB	0.01
105: 2,3,4,3’,4’-PeCB	0.0001
114: 2,3,4,5,4’-PeCB	0.0005
118: 2,4,5,3’,4’-PeCB	0.0001
123: 3,4,5,2’,4’-PeCB	0.0001
156: 2,3,4,5,3’,4’-HxCB	0.0005
157: 2,3,4,3’,4’,5’-HxCB	0.0005
167: 2,4,5,3’,4’,5’-HxCB	0.00001
189: 2,3,4,5,3’,4’,5’-HpCB	0.0001

Source: EPA, 99-0068.

The approach used for estimating dioxin risks will be used for estimating risks associated with the dioxin-like PCB congeners. Each carcinogenic congener may have distinct physical-chemical properties and may therefore distribute and/or accumulate in different media to different degrees. Therefore, the medium TEQ concentration of dioxin-like PCBs will be evaluated through the exposure dose calculation step to yield the TEQ doses by the ingestion, dermal, and inhalation routes for each exposure pathway. The total dioxin-like TEQ dose will be multiplied by the 2,3,7,8-TCDD slope factor to yield PCB dioxin-like risk.

6.3.3.3 Noncancer Health Effects

6.3.3.3.1 Derivation of Reference Doses (RfDs)

The toxicity values used to estimate the potential for adverse noncancer health effects are termed reference doses (RfDs). The RfDs represent chemical toxicity, other than cancer, such as gross or microscopic organ damage, physiological effects (reproductive dysfunction, immunotoxicity, or biochemical effects, e.g., altered enzyme systems). It is assumed when deriving RfDs that a threshold dose exists below which there is no potential for toxicity (99-0002). Below this threshold, other factors such as the body's protective mechanisms (i.e. metabolism, elimination) can limit the chemical's toxic effect, preventing the expression of toxicity. An RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (99-0002). The RfD value is inversely proportional to the toxic potency of the chemical.

EPA has proposed RfDs for two different exposure periods. Where toxicity data are adequate, subchronic RfDs have been developed for some chemicals to evaluate exposure periods in humans of 2 weeks to 7 years (99-0002). Chronic RfDs have been developed to evaluate human exposures of greater than 7 years. This risk assessment will conservatively use chronic RfDs for all age groups as a general rule. The reason for this is that the shortest exposure duration assumed for the various scenarios proposed is 6 years. Given the uncertainty inherent in the RfD development process, and the fact that the lowest exposure durations used in this risk assessment are typically in the upper range of the subchronic exposure period, it seems reasonable to default to the chronic exposure period. An exception to this general rule may be if the exposure is intermittent, resulting in a significantly reduced total exposure period. In this case, the use of a subchronic RfD (e.g., Aroclor 1254) will be considered.

RfDs are expressed as a dose in units of milligrams of chemical per kilogram of body weight per day (mg/kg-day). When deriving RfDs for the inhalation exposure route, EPA often expresses the value as a reference concentration (RfC) in units of milligrams of chemical per cubic meter of air (mg/m^3). Because exposure doses for all pathways, including the inhalation pathway, are calculated in this risk assessment in units of mg/kg-day, RfCs will be converted to inhalation RfDs, in accordance with EPA guidance (99-0006), by multiplying the RfC by 20 cubic meters of air per day (m^3/d), and dividing it by 70 kg (adult body weight) for adult exposure. The RfCs for inhalation exposure to children will be modified accordingly.

EPA has not published dermal RfDs for any chemicals, but has provided guidance (99-0002) for deriving dermal values if an oral RfD is available. In accordance with this guidance, dermal RfDs will be derived for most chemicals by multiplying the oral RfD by an appropriate gastrointestinal (GI) absorption factor. Chemical-specific GI absorption factors will be obtained from recent dermal risk assessment guidance (99-0123). If a GI absorption value is not available from this document, EPA Region I will be consulted.

If an RFD cannot be obtained or derived for a chemical by the procedures described previously, the potential noncancer health effects posed by that chemical through the applicable exposure routes will not be evaluated quantitatively, unless a value is recommended by EPA Region I. Converting oral RfDs to the dermal route introduces a degree of uncertainty into noncancer health effects results for the dermal pathway.

Reference doses for oral, dermal, and inhalation pathways will be presented in the risk assessment in RAGS Part D Tables 5.1 and 5.2 formats, respectively (99-0010).

6.3.3.3.2 Noncancer Effects of Polychlorinated Biphenyls

Two Aroclor mixtures (1016 and 1254) have verified oral chronic RfD values (99-0011). These are:

- Aroclor 1016—7E-05 mg/kg-d
- Aroclor 1254—2E-05 mg/kg-d

The RfD for Aroclor 1254 will be preferentially used to assess oral and dermal risk for total PCBs unless the congener/homolog data suggest that Aroclor 1016 is more appropriate. There is a provisional subchronic RfD for Aroclor 1254 (5E-05 mg/kg-d; 99-0006). As discussed in Subsection 6.3.3.3.1, subchronic RfDs will not be considered for use unless it is judged that intermittent exposure will significantly reduce the total exposure period below the 7-year chronic duration period.

6.3.4 Exposure Assessment

6.3.4.1 *Introduction*

The objective of the exposure assessment is to estimate the nature, extent, and magnitude of potential exposure of humans to contaminants of concern that are present in the media associated with the Lower River, considering both current and future uses. The exposure assessment involves several steps. These are:

- Evaluating the exposure setting (Subsection 6.3.4.2), including describing local land and water uses and identifying potentially exposed human populations.
- Developing the conceptual site model (Subsection 6.3.4.3), including sources, release mechanisms, transport and receiving media, exposure media, exposure scenarios, exposure routes, and potentially exposed populations.
- Calculating chemical exposure point concentrations (EPC) (Subsection 6.3.4.4) for each of the exposure scenario and route.
- Identifying the exposure models and assumptions (Subsection 6.3.4.5) with which to calculate the exposure doses.

This subsection of the Work Plan describes the approaches to be used in each step and provides an overview of the site-specific information that has been obtained to date.

Recent EPA guidance (RAGS Part D; 99-0010) recommends the evaluation of both the reasonable maximum exposure (RME) and the central tendency exposure (CTE). The RME is the highest exposure that is expected to occur at a site and would be representative of a “high-end” risk (99-0002). According to EPA (99-0088), “The high-end risk description is a plausible estimate of the individual risk for those persons at the upper end of the risk distribution. The intent of this description is to convey an estimate of risk in the upper range of the distribution, but to avoid estimates which are beyond the true distribution.” The RME approach uses exposure assumptions that represent the high end of the exposure parameter distributions to arrive at an upperbound risk estimate. The CTE is the central tendency (i.e., average) exposure, which uses average exposure assumptions to yield an average risk to the individual (99-0088).

6.3.4.2 Exposure Setting

Many areas along the Lower River are currently heavily forested and support a broad range of uses including residential, recreational, agricultural, and commercial/industrial. A detailed description of the site environmental setting is presented in Section 2 of this Work Plan. A series of land use maps from the confluence to Woods Pond is provided in Appendix B. The maps illustrate environmentally important areas in the Lower Housatonic River including current land uses and the 10-year floodplain boundaries. Figures 5.2-6 through 5.2-13 are maps that show current recreational areas of concern along the Lower River in Reaches 5 and 6. Figure 5.2-15 illustrates the location of various current utility easements along Reach 5. These various maps contain site-specific information used in developing the subsections below.

Land use maps will also be developed for the reaches below Woods Pond (Reaches 7, 8, and 9) to assist in the evaluation of this large area. In the approximately 17 miles between Woods Pond and Rising Pond (Reach 7), there is a wide variety of land uses. A portion of the broad floodplain in Reach 7 is currently agricultural. Other current uses include residential developments, wooded and open areas, commercial/industrial properties, and recreational areas. Current land uses around Rising Pond (Reach 8) include residential, industrial, and forested. From Rising Pond to the Massachusetts-Connecticut Border (Reach 9), the area is increasingly rural and currently dominated by agricultural, wetland, forested areas, and open land, with smaller areas in recreational and other land uses. If necessary, additional land uses and activities may also be evaluated below the Connecticut border.

6.3.4.2.1 Local Land Uses

Existing homes and unoccupied residentially zoned properties are generally concentrated in the upper reaches of the Housatonic River near Pittsfield. The number of existing homes and unoccupied residentially zoned properties in the floodplain areas of Reach 5 decreases progressing to the south toward Connecticut. Based on the Reach 5 and 6 land use maps (Appendix B), there are an estimated 40 residentially zoned properties (both occupied and nondeveloped) wholly or partly within the 10-year floodplain. A significant portion of the residentially zoned properties appears to abut the river shoreline based on a review of the land use maps. Specific property information such as access to the river and the presence of riverbanks will be confirmed by site surveys. In addition to activities in floodplain soil, such as gardening, yardwork, and playing, activities such as swimming, wading, and fishing may occur near riverbanks where residential properties abut the river.

Figure 5.2-6 shows the locations of specific current recreational areas that have been identified along Reaches 5 and 6. Specific recreational areas in Reaches 5 and 6 that will be evaluated in this risk assessment include:

- Paintball Area (Figure 5.2-7)

- Canoe Meadows (Figure 5.2-8)
- John Decker Canoe Launch (Figure 5.2-9)
- Lenox Sportmans Club (Figure 5.2-10)
- October Mountain Road Access Areas (Figure 5.2-11)
- Duck Blind Areas (Figure 5.2-12)
- Woods Pond Boat Launch (Figure 5.2-13)
- DeVos Farm (Figure 5.2-16)

These areas support activities such as boating, hunting, fishing, trapping, hiking, picnicking, swimming, and wading, among others. Other recreational areas within Reaches 5 and 6 and below Woods Pond that may serve as recreational locations will also be evaluated.

Agricultural areas also exist throughout the study area. Crops known to be grown in these areas include corn and other vegetables such as squash. There are no indications of subsistence farming activities in the area. A more detailed evaluation of farming activities in the floodplains will be made prior to performing the risk assessment.

Areas zoned commercial and industrial along the Lower River within the 10-year floodplain are illustrated in Appendix B (Figures 3 through 9) for Reaches 5 and 6. Similar areas exist in Reaches 7 through 9. The number of active commercial and industrial facilities will be investigated further prior to performing the risk assessment. Additionally, there are a number of public utility easements along the Lower River (Figure 5.2-15) identified in Reach 5. These easements are associated with the following utilities:

- Western Massachusetts Electric Company (two easements: one near river confluence and one in mid to lower Reach 5).
- TENNECO Gas Transmission Company (Upper Reach 5).
- Sewer Authority (Upper Reach 5).
- AT&T (Reach 5).

6.3.4.2.2 Local Water Uses

Based on available information, it is unlikely that groundwater in the Lower River region used for residential purposes has been impacted by contaminant sources from the GE facility. Therefore, drinking water ingestion and other indoor exposures to groundwater represent incomplete exposure pathways in terms of current and future uses and will not be evaluated in the risk assessment.

The surface water in the Lower River has been designated as Class B (i.e., "suitable as a source of public water supply with treatment where designated"). According to MADEP, Reaches 5 and 6 of the Housatonic River are not currently designated as a public water supply source. Therefore, this represents an incomplete exposure pathway for current and future drinking water uses of the river. Incidental ingestion of and dermal contact with river water might occur during boating, fishing, or swimming activities. These types of exposures are evaluated in the recreational and residential scenarios.

6.3.4.2.3 Identification of Potentially Exposed Human Populations

Based on the current and future land and water uses, the potential types of activities, and the potential transport of contamination to various media in the Lower River, several human populations are identified for evaluation in this risk assessment:

- Adult and child residents.
- Adult and child recreational users including hikers, canoers, swimmers, waders, picnickers, hunters, and anglers.
  - Adult hunters and their children - for consumption of game only.
  - Adult anglers and their children - for consumption of fish only.
- Adult farmers and their children.
- Outdoor utility workers and groundskeepers.

6.3.4.3 Conceptual Site Model

A conceptual site model describes the chemical sources, release mechanisms, transport and receiving media, exposure media, exposure routes, and potentially exposed populations. One objective of the conceptual site model is to identify complete and incomplete exposure pathways. A complete exposure pathway has all of the above-listed components, whereas an incomplete pathway is missing one or more. Figure 4-1 illustrates the proposed conceptual site model for the Lower River. The following text describes each component in detail.

6.3.4.3.1 Sources of Contamination, Release and Transport Mechanisms, and Receiving Media

Sources of contamination to the Housatonic River are located on or near property currently or formerly operated by GE. These potential contaminant sources include the following:

- Former oxbows of the Housatonic River that have been filled with hazardous materials.
- Nonaqueous phase liquids (NAPLs) and soil contaminated with hazardous substances, including PCBs, VOCs, metals, and SVOCs as a result of spills from a number of aboveground storage tanks (ASTs), underground storage tanks (USTs), and process pipelines currently or formerly located on GE property.
- Unkamet Brook Landfill and contaminated soils and sediments on the banks or in Unkamet Brook.
- PCB-contaminated soil used as fill material.
- Former waste stabilization basin.
- Silver Lake.
- Stormwater and wastewater discharges.
- Contaminated groundwater discharge to the river.
- Contaminated soil and sediment on the banks or in the river itself.

Surface water runoff from source areas, flooding of source areas by the Housatonic River, migration of nonaqueous phase liquids (NAPLs), direct discharge of PCBs from the Building 68 tank implosion, and groundwater discharge to the upper reaches of the Housatonic River have contributed to the sediment contamination in the Housatonic River. Migration and redistribution of contaminated sediment within the Housatonic River have further resulted in contamination detected in the floodplain downstream from the site.

There are five main potential source areas in the vicinity of the facility, including East Street Area 1, East Street Area 2, Unkamet Brook, Newell Street Parking Lot, and Lyman Street

Parking Lot (Figure 1-1). These areas are associated with various USTs, ASTs and their associated piping, several other underground pipes, outfalls, and tunnels that could act as potential sources/pathways of migration for contaminants. Many sanitary sewer pipelines, stormwater drainage lines, and french drains enter the river. Other sources in these areas include surface, subsurface, and riverbank soils through which erosion, surface water flow, or groundwater discharge could impact the Housatonic River. There are also fill areas, such as Oxbow H, that have been filled with contaminated soil that could potentially impact the river. Groundwater plumes (LNAPL, DNAPL, and other dissolved contaminants) may also impact the river. Unkamet Brook contains PCB-contaminated sediment that has migrated to the Housatonic River. There are also several landfills that contain contaminated soil and debris. Finally, some PCBs may have volatilized or become airborne as dust particles through wind erosion or soil disturbances. This latter pathway is shown as a dotted line in the conceptual site model as it may represent an insignificant contribution to the total PCB release.

6.3.4.3.2 Secondary Release and Transport Mechanisms

The contaminant release and transport processes affecting the fate and effect of PCBs within the Housatonic River and its floodplain are interrelated and complex.

The following discrete, but interrelated PCB transport pathways have been identified:

- Erosion and downstream transport of contaminated bank soils. Bank contamination has occurred as a consequence of historical cut and fill operations that used fill material contaminated with PCBs, as well as PCB spills and LNAPL seeps.
- Sediment contamination via runoff carrying suspended soil particles contaminated with PCBs.
- Sediment contamination via discharge of contaminated groundwater plumes, with subsequent contaminant adsorption.
- Surface water contamination from direct discharge of contaminated groundwater as well as flux of soluble PCBs from contaminated sediments, and suspension of contaminated sediment particles.
- Floodplain soil and riverbank soil contamination via deposition of suspended river sediment during flood events.
- Erosion of contaminated floodplain soil (surface and subsurface) during flood events, and subsequent deposition as contaminated river sediment.

- Bioaccumulation and cycling of PCBs within the terrestrial and aquatic food chains exposed to contaminated soil, surface water, and sediment, via diffusion across the epidermis or gill membrane of aquatic species, ingestion of contaminated food items, or sediment/soil/surface water directly.

6.3.4.3.3 Primary Exposure Media

Surface Water, Sediment, and Soil

Based on the review of land and water uses, Figure 4-1 shows the following primary exposure media that may be of potential concern to humans in the Lower River:

- Surface waters.
- Sediments.
- Riverbank soils.
- Floodplain soils.

Historical sample results have indicated that some or all of these media are contaminated with PCBs and other chemicals (00-0274).

Groundwater

Groundwater sampling results have indicated little to no contamination with PCBs or other chemicals in the Lower River. Therefore, this medium is not believed to be a significant current or future direct exposure pathway and will not be evaluated in the risk assessment.

Air

Air sampling conducted previously in the area during warmer months showed low concentrations of PCBs (BBL, 04-0004). Therefore, it is unlikely that the air pathway will contribute any significant exposure to humans. Additional sampling and a screening-level risk assessment is planned to confirm this assumption (see Subsection 5.4). However, depending on site-specific conditions, fugitive dust emissions and inhalation exposures to farmers may need to be evaluated.

6.3.4.3.4 Secondary Exposure Media – Biota

Ducks, fish, and other species are commonly hunted or caught in the Lower River and wetlands and then consumed by humans. These species may contain significant levels of chemicals, especially those that bioaccumulate and biomagnify (such as PCBs), as a result of ingestion of sediments, surface water, aquatic or terrestrial vegetation, or lower tropic organisms that have been contaminated. Local residents and farmers may also grow vegetables and silage in areas of the floodplain that have been contaminated by PCBs. In addition, the local harvesting of fiddlehead ferns from the floodplains may also contribute to chemical exposure.

6.3.4.3.5 Exposure Scenarios and Routes of Exposure

Based on land and water uses, the types of activities common in the area, and the known transport of contamination to various media, four primary exposure scenarios are proposed for evaluation. These include residential, recreational, agricultural, and commercial/industrial. The subpopulations, age groups, exposure routes and pathways, and site-specific considerations are presented below. The conceptual site model (Figure 4-1) illustrates these pathways and scenarios.

Residential Scenario

A portion of the area within the 10-year floodplain of the Housatonic River between the GE facility and Woods Pond Dam is currently zoned for residential use (Appendix B). Residential density varies along the Lower River. In the upper portion of Reach 5, for example, houses are spaced closely together. Several residences in this area have some portion of their property lying within the 10-year floodplain, and some of the properties were noted to have vegetable gardens located within the floodplain. Additionally, some of these properties abut the river. At downstream locations closer to Woods Pond, residential properties are fewer in number and less densely spaced. Residential use also occurs downstream of Woods Pond in Reaches 7 and 9.

Any existing residential property that has floodplain soil levels of PCBs greater than 2 mg/kg in actual/potential lawn areas as identified in the Consent Decree (00-0388) will be identified and referred to GE for further evaluation. The details of this evaluation and the criteria for moving into the remediation phase are presented in the Consent Decree.

For those residential properties that have levels greater than 2 mg/kg in floodplain soil that are not in specified actual/potential lawn areas, and for properties with riverbank soil and/or sediment concentrations adjacent to residential properties at levels greater than the SRBCs, a separate analysis will be performed that will include exposure to all media. Two age groups will be evaluated due to the different habits and exposure potentials of children and adults. The child resident will be assumed to have an age range of 1 to 6 years and will be exposed to a greater degree to pathways such as incidental soil and sediment ingestion. The adult resident will range from 7 to 30 years of age. Each residence will be evaluated separately, or if a likely riverbank soil/sediment contact location overlaps several properties, several contiguous residential properties may be evaluated together for exposure to these media.

Recreational Scenario

The Lower River is one of the most attractive recreational venues in the area and supports a wide variety of recreational activities. These activities include, but are not limited to, hiking, walking, canoeing, picnicking, fishing, hunting, wading, and swimming. It is possible that these activities will increase in the future as the area becomes more attractive as a result of anticipated environmental improvements.

Three separate recreational scenarios will be evaluated in this risk assessment:

- **Direct-contact recreational user**—This scenario will be a site-specific analysis based on the likelihood and degree of direct contact by recreational users with soil, sediment, and surface water at each designated recreational area. Indirect pathways, i.e., fish/duck/plant consumption, will not be evaluated.
- **Hunter**—This scenario will be an analysis of the potential risk to local hunters associated with consumption of game, primarily duck meat.
- **Angler**—This scenario will involve an analysis of the potential risks to local anglers associated with the consumption of various fish species.

Direct-Contact Recreational—This scenario will evaluate potential risks to individuals who may experience direct contact with sediment, soil, and surface water during typical recreational activities, but will not include consumption of game and fish taken from the area. This scenario would include such activities as picnicking, canoeing, wading, swimming, dirt biking, and hiking, among others. Up to three age groups will be evaluated to reflect the different habits and exposure potentials of younger children, older children, and adults. The younger child’s age is assumed to range from 1 to 6 years. The older child's age is assumed to range from 7 to 18 years of age, and the adult is assumed to be 19 years and older.

Depending on the results of the Phase 1 screening analyses of recreational areas, the following areas in Reaches 5 and 6, among others, may be evaluated:

- Paintball Area
- Canoe Meadows
- Decker Canoe Launch
- DeVos Farm
- Lenox Sportsmans Club
- October Mountain Road Access Areas
- Duck Blinds
- Woods Pond Boat Launch Area

Additional areas in Reaches 7 through 9 will also be evaluated in a similar manner, again depending on the results of the screening analysis.

Hunter—It is anticipated that a significant risk could result from the consumption of game (primarily duck meat) harvested from the area near the Lower River. For this reason, this exposure scenario will evaluate only this pathway of exposure. Direct contact with soil, sediment, and surface water could obviously occur to individuals hunting in the area, but are not included in this scenario because they are planned for site-specific evaluation as noted in the Direct-Contact Recreational scenario. Risks from these separate exposures will be presented in the risk characterization section and decisions on adding risks across scenarios will be made as part of the overall risk management process.

Angler—It is anticipated that a potential risk could result from the consumption of fish caught from the Housatonic River regardless of the existence of a prohibition on fish consumption. The angler pathway will focus on recreational fishing activities. There is, however, some indication that subsistence-type fishing activities may occur among certain ethnic communities in

Connecticut. If further investigations indicate a realistic potential for such activities, a subsistence fishing scenario will also be evaluated.

The angler exposure scenario evaluates only fish consumption. Direct contact with soil, sediment, and surface water, which could obviously occur to individuals during fishing activities, is not included in this scenario because consideration of these exposures is planned for site-specific evaluation as noted in the Direct-Contact Recreational scenario. Risks from these separate exposures will be presented in the risk characterization section and decisions on adding risks across scenarios will be made as part of the overall risk management process.

Other indirect exposures are possible in the Lower River area, including consumption of frog legs, turtle meat, and fiddlehead ferns. Based on a preliminary evaluation of the existence of such practices in the Lower River and surrounding areas, it is not likely that these exposures represent significant pathways of exposure, and therefore they will not be evaluated quantitatively in the risk assessment. However, these potential exposures will be discussed qualitatively. If during the risk assessment process any additional information on these potential exposures is identified, inclusion of some or all of these scenarios will be reconsidered.

Agricultural Scenario

Some active farmland (raising of crops) exists within the 10-year floodplain in Reach 5. Farms have been identified in the lower reaches (7 through 9) with portions of their farmland in the floodplain. These farms grow a wide variety of crops and also raise dairy cows. Because of the uncertainties associated with chemical uptake into dairy milk and subsequent exposure to humans, consumption of dairy milk will be evaluated separately. The approach to this evaluation will be determined after more data become available on potential floodplain soil contamination of existing dairy farms.

Three age groups will be evaluated due to the different habits and exposure potentials of younger children, older children, and adults. The younger child is assumed to range in age from 1 to 6 years. The older child has an age range of 7 to 18 years, and the adult age range is 19 to 30 years. Each of these receptors is assumed to be potentially exposed to all the exposure pathways identified below.

The agricultural scenario will evaluate potential exposure from the following pathways:

- Incidental ingestion of floodplain soil.
- Dermal contact with floodplain soil.
- Ingestion of homegrown vegetables.
- Inhalation of fugitive dust.

Exposure assumptions will be modified from typical assumptions to account for the portion of the total exposure that is related to the potentially contaminated floodplain soils.

Commercial/Industrial Scenarios

Two worker scenarios will be evaluated in the risk assessment—a commercial/industrial worker (groundskeeper) and a utility worker. An adult will be evaluated in both of these scenarios for a 25-year exposure period.

Utility Worker—There are various utility easements located along the study area. It will be assumed that a utility worker visits these areas and is required to excavate in both floodplain and riverbank soils and is thereby exposed through the following pathways:

- Incidental ingestion of riverbank and floodplain soils.
- Dermal contact with riverbank and floodplain soils.

Groundskeeper—Several areas in the Lower River are zoned industrial. For the purposes of the risk assessment, it will be assumed that the worker with the greatest potential for exposure to floodplain soil would be a groundskeeper employed at a commercial or industrial facility. The groundskeeper would be exposed through the following pathways:

- Incidental ingestion of floodplain soil.
- Dermal contact with floodplain soil.

6.3.4.4 Exposure Point Concentrations

The EPCs calculated in the risk assessment are scenario-specific as discussed in the following subsections. Consistent with EPA guidance (99-0003), EPCs for the reasonable maximum exposure (RME) evaluation will be calculated for each data set for each exposure area based on the 95% upper confidence limit (UCL) concentrations of the means, using the appropriate equation for data distribution recommended by EPA (99-0003). If the 95% UCL concentration exceeds the maximum detected concentration for a chemical, the maximum detected concentration will be used as the EPC for the RME cases. The medium-specific EPCs will be presented in the risk assessment in accordance with RAGS Part D guidance (99-0010) as Table 3. The 95% UCL of the COPCs will be calculated as discussed previously in Subsection 6.3.2.4.

The sampling depths identified for each of the exposure scenarios described below are based on the likelihood of exposure for typical activities within that scenario, as well as preliminary information of the depth of contamination. If field sampling efforts indicate significant contamination at lower depths, the approach outlined below may be modified.

6.3.4.4.1 Residential Scenario

EPCs for the residential scenario will be based on sediment, surface water, and soil data collected as noted below:

- **Floodplain Soil—**For each residential property not turned over to GE based on the Consent Decree (00-0388), surface soil samples (0 to 0.5 and 0.5 to 1 ft) will be collected. The number of samples depends on the property's size and the likelihood of contamination.
- **Sediment—**Surface samples (0 to 0.5 ft) collected from areas where residences abut the river.
- **Surface Water¾** Twelve monthly surface water samples collected at six locations along the Lower River in Reaches 5 and 6 as shown in Figure 5.3-1. The closest upstream location for the residential property under evaluation will be used.
- **Riverbank Soil—**Surface soil (0 to 0.5 and 0.5 to 1 ft) samples collected for each residential property where riverbanks exist.

6.3.4.4.2 Recreational Scenarios

EPCs will be based on sediment, soil (riverbank and floodplain), and surface water data collected as noted below:

- **Sediment—**For each recreational area, surface sediment samples (0 to 0.5 ft) from recreational areas collected and analyzed to establish an EPC.

- **Surface Water**—Twelve monthly surface water samples collected at six locations along the Lower River in Reaches 5 and 6 as shown in Figure 5.3-1. The closest upstream location for the residential area under evaluation will be used.

- **Riverbank Soil**—For each recreational area that has existing riverbanks, samples (0 to 0.5 ft and 0.5 to 1 ft) will be collected to establish an EPC. The number of samples will depend on the length of riverbank and the likelihood of exposure.

- **Floodplain Soil**—For each recreational area, surface soil samples (0 to 0.5 ft and 0.5 to 1 ft) will be collected. The number of samples depends on the area's size and the likelihood of exposure.

- **Food Chain (Hunter and Angler)**—EPCs will be estimated for waterfowl consumption based on concentrations in duck meat. EPCs for fish consumption will be based on area-specific fish tissue samples. The exact approach to this EPC calculation will be developed in the risk assessment.

Other biota (e.g., frogs and fiddlehead ferns) will be assessed qualitatively. If additional information on these potential exposures is identified during the risk assessment process, a quantitative assessment will be considered.

6.3.4.4.3 Agricultural Scenario

EPCs for the agricultural scenario will be developed from soil and foodstuff data collected as noted below:

- **Floodplain Soil**—For each of the agricultural properties that extend into the floodplain, surface soil samples (0 to 0.5 ft and 0.5 to 1 ft) will be collected. EPCs for soil and fugitive dust will be calculated from these data. The number of samples will depend on the amount of acreage in the floodplain.

- **Foodstuffs ¾** Exposure from consumption of homegrown vegetables will be evaluated based on a combination of soil concentration data used to model concentrations in vegetables and direct vegetable concentration data. As noted previously, exposure through consumption of dairy milk will be evaluated separately, if necessary.

6.3.4.4.4 Commercial/Industrial Scenarios

EPCs will be based on floodplain and riverbank soil data as noted below:

- **Floodplain and Riverbank Soil**—For the commercial/industrial land use areas, two exposure scenarios will be evaluated. For the groundskeeper, surface (0 to 0.5 ft) floodplain soil samples will be collected based on a review of current land use and the acreage in the floodplain. For the utility worker, surface soil samples (0 to 0.5 ft) and subsurface samples (0.5 ft to 1 ft and 1 ft to 6 ft, as appropriate) will be collected. The number of samples will be based on the length of the easement in the floodplain. EPCs will be developed based on composited data. The groundskeeper EPC will be based on surface sampling, and the utility worker EPC will be based on composited surface and subsurface sampling.

6.3.4.5 Identification of Exposure Models and Assumptions

Mathematical models are used to calculate the daily intakes (i.e., doses) of site contaminants for each receptor through the applicable exposure routes. Chemical intakes resulting from exposure to affected media will be estimated by applying specific intake equations appropriate for the exposure pathways being assessed. The equations include the variables used in estimating dose, including such factors as exposure frequency and duration, contact rates, body weight, and averaging times. The equations and default and site-specific assumptions for the various models of exposure are not presented in this Work Plan, but will be developed for the risk assessment based on EPA and DEP guidance and recommendations along with site-specific data. Table 6.1-1 lists additional references that may be sources for this information. When agency-recommended values are not available, professional judgment will be used.

Two sets of doses will be calculated using the mathematical models. Average daily doses (ADDs), in which the doses are averaged over the exposure duration, will be used to evaluate noncancer health effects. Lifetime average daily doses (LADDs), in which the doses are averaged over a 70-year lifetime, will be used to evaluate potential cancer risk. The exposure doses will be expressed as either administered (oral, inhalation) or absorbed (dermal) doses in milligrams of chemical per kilogram of body weight per day (mg/kg-day).

The specific exposure models and input assumptions used in each scenario will be presented in RAGS Part D-Table 4 format (99-0010) in the risk assessment.

6.3.5 Risk Characterization

6.3.5.1 Objective

The objective of the risk characterization is to integrate the information developed in the exposure assessment and the dose-response assessment into an evaluation of the potential health risks associated with site contaminants in each exposure scenario. Both cancer risks and noncancer health effects will be evaluated.

6.3.5.2 Cancer Risk

Potential cancer risk will be calculated by multiplying the estimated LADD intake that is calculated for a chemical through an exposure route by the exposure-route-specific (oral, inhalation, or dermal) CSF, as follows:

Risk = LADD * CSF

Where:

LADD = Lifetime average daily dose; intake averaged over a 70-year lifetime as mg chemical/kg-body weight per day.

CSF = Chemical- and route-specific cancer slope factor $(mg/kg\text{-}day)^{-1}$.

All lifetime chemical cancer risks will be calculated separately for the child and adult receptors (i.e., there will be no age-adjusted calculations). However, cancer risks will be summed across all relevant pathways for a given receptor and exposure scenario to yield a cumulative lifetime risk. For recreational exposures, cancer risks will be determined separately for the direct-contact, hunter, and angler scenarios. The cumulative effects of duck meat and/or fish consumption on recreational users and residents will be considered.

Results of the cancer risk evaluation will be presented in RAGS Part D Table 8-1 format (99-0010) in the risk assessment report.

6.3.5.3 Noncancer Health Effects

The potential for noncancer health effects will be evaluated by the calculation of hazard quotients (HQs) and hazard indices (HIs). An HQ is the ratio of the exposure duration-averaged estimated daily intake (ADD) through a given exposure route to the chemical- and route-specific (oral, inhalation, or dermal) RfD. The HQ-RfD relationship is illustrated by the following equation:

$$HQ = ADD/RfD$$

Where:

HQ = Hazard quotient.
ADD = Average daily dose; estimated daily intake averaged over the exposure period (mg/kg-day).
RfD = Reference dose (mg/kg-day).

HQs will be summed to calculate HIs for each scenario. HIs will be calculated for each exposure route, and a total HI will be calculated based on exposure to all site contaminants from all exposure routes for each receptor (age group).

If the hazard index for any scenario exceeds a value of 1, the data will be reevaluated by segregating toxic effects according to organ endpoint as recommended by EPA (99-0002).

The presentation of summary information for the noncancer health effects in the risk assessment will follow the format presented in Table 8-1 in RAGS Part D guidance documentation (99-0010). Both cancer risks and noncancer health effects will be summarized in the risk assessment as presented in Tables 9 and 10 of RAGS Part D guidance (99-0010).

6.3.6 Uncertainty Analysis

The uncertainty analysis will present the major assumptions and uncertainties associated with the risk assessment. This discussion will include general uncertainties associated with each step of the risk assessment process, including data evaluation, exposure assessment and toxicity assessment, and specific uncertainties associated with each scenario. The predicted impact of each major assumption or uncertainty on the estimation of risk (i.e., over-estimate, under-estimate, or uncertain) will be indicated. Probabilistic risk assessment approaches like Monte Carlo analyses will be considered for those COPCs and exposure pathways that result in significant risk estimates. In addition, while the risks associated with human exposure will be assessed primarily by using the EPA IRIS database, other published research and site-specific health studies, which may provide useful information in characterizing risks and understanding exposures, will be discussed.

7. ECOLOGICAL RISK ASSESSMENT

7.1 INTRODUCTION

The purpose of this section of the Work Plan is to present the technical approach for the Ecological Risk Assessment (ERA), which will be prepared as part of the Supplemental Investigation for the Lower Housatonic River.

The objective of the ERA is to characterize, and quantify where appropriate, the current and potential baseline ecological risks that would prevail should no further remedial action be taken to address chemical contamination of the Lower River resulting from the releases from activities at the GE Pittsfield Facility. While the ERA does not recommend cleanup levels for use in the Corrective Measures Study, GE is required to take into account data generated from studies used to develop the ERA when deriving the Interim Media Protection Goals (IMPGs) and selecting appropriate response action(s) for the site.

The comprehensive site database, including data collected previously by GE that meet EPA's risk assessment data usability guidelines, will be considered in the preparation of the ERA. However, the assessment of baseline ecological risk will focus principally on data collected concurrent with the ecological investigations discussed in this work plan. As a starting point, the area of focus for the ERA is the Housatonic River and associated floodplain from the confluence of the east and west branches (hereafter referred to as the confluence) of the river downstream approximately 10 miles to, and including, Woods Pond. Evaluation of the historical data suggests that this is where, in general, the highest levels of the contamination are found. However, areas upstream of the facility, in Housatonic River tributaries, and outside of the Housatonic drainage will be used as reference areas for different aspects of the ecological assessment. The study area findings will be used, together with contaminant concentrations detected below Woods Pond, to assess the potential risks to the ecological receptors in other locations farther downstream in both Massachusetts and Connecticut. The final determination of the areal extent of the ERA will depend on the sampling results, ecological studies, and subsequent discussions between the risk assessors, risk managers, and other appropriate parties.

7.1.1 Guidance Documents

EPA's *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (hereafter, referred to as the Guidance) (99-0138) will serve as the primary source of guidance in developing the baseline ecological risk assessment.

The following documents, among others, will also be consulted for general or subject-specific risk assessment guidance:

- *Guidelines for Ecological Risk Assessment* (EPA 630/R-95/002F, April 1998) (99-0033).
- *Framework for Ecological Risk Assessment* (EPA 630/R-92/001, February 1992) (99-0032).
- *Ecological Risk Assessment Issue Papers* (EPA/630R-94/009, November 1994) (99-0037).
- *Wildlife Exposure Factors Handbook, Volumes I and II* (EPA 600/R-93/187a and 187b, December 1993) (99-0040).
- *Guidance for Disposal Site Risk Characterization: Method 3 Environmental Risk Characterization* (MADEP, 99-0338).
- *EPA Eco Update*, Volumes 1, 2, and 3 (1991-1996). (99-0339, 99-0340, 99-0341, 99-0342, 99-0343, 99-0348, 99-0349, 99-0350, 99-0351)

EPA's *Ecological Risk Assessment Guidance for Superfund* (99-0138) uses as it foundation the approach for performing ERAs outlined in EPA's *Framework for Ecological Risk Assessment* (99-0032; see Figure 7-1). Although the *Framework* document provides a basic structure and a consistent approach for conducting ecological risk assessments, it is not intended to provide program-specific guidance.

The approach outlined in the Guidance describes an 8-step process and several scientific/management decision points (SMDPs). An SMDP represents a significant communication point in the conduct of the ERA requiring the interaction of the risk manager and the risk assessment team. The purpose of the SMDP is to evaluate the relevant information and to re-evaluate the scope, focus, and direction of the ERA.

Although the proposed ERA does not explicitly require the six SMDPs outlined in the Guidance, meetings between EPA's risk managers and the risk assessment team have and will occur formally and informally on a regular basis to evaluate and approve or redirect the work up to that point (analogous to the SMDPs). Specifically, the following subset of the six decision points are incorporated into the development of this ERA:

- Agreement on the need to conduct a full ecological risk assessment, based on previous discussions and the Consent Decree (00-0388) between the Federal and State Regulatory Agencies and the National Resource Trustees and General Electric.
- Agreement regarding the conceptual model design including assessment endpoints, exposure pathways, and risk hypotheses determined in previous discussions between the Federal and State Regulatory Agencies and Natural Resource Trustees and General Electric, and meetings with the project Peer Input Panel.
- Agreement on measurement endpoints, study design, and data interpretation and analysis determined in previous discussions between the Federal and State Regulatory Agencies and Natural Resource Trustees and General Electric, and meetings with the project Peer Input Panel.
- Approval of the Work Plan and Sampling and Analysis Plan following review by the Federal and State Regulatory Agencies and Natural Resource Trustees, the project Peer Input Panel, General Electric, and the public.

Many factors are involved in the procedural (not substantive) departure from the eight-step procedure. Given the historical discussions regarding the ecological risk assessment that have occurred with GE on the scope and details of the assessment (e.g., EPA, the States of Massachusetts and Connecticut, the Federal Trustees, and GE had already determined the need for a full-scale ecological risk assessment and discussed and reached agreement on the required assessment endpoints), and the aggressive schedule established in the settlement for this project, several of the steps in the process (e.g., the screening level assessment – Steps 1 and 2) have already been addressed or are incorporated in the existing Regional Management Review Process. An ecological risk assessment was conducted in May 1998 for the Upper Reach of the Housatonic River in which many of the technical issues relevant to this screening level assessment were raised and subsequently have been incorporated as part of the study plan. In 1998, a final *Preliminary Ecological Characterization* (TechLaw, 05-0062) of the study area was performed which also addressed much of the substance of Steps 1 and 2. In addition, the project has an internal Peer Input Panel that has reviewed and will continue to review the project at all critical junctures (again analogous to the SMDPs). Moreover, EPA has agreed, as a component of the settlement, to a formal external Peer Review of the ERA.

7.1.2 Site History

The GE plant in Pittsfield, MA, in operation from the 1930s through the 1970s, was the major handler of PCBs in western Massachusetts. The release of PCBs and other substances to the Housatonic River is mostly attributable to releases from the GE facility operations and known disposal areas with wastes associated with the GE facility. These releases have resulted from the discharge of free product and surficial runoff of PCB-contaminated soils, as well as the discharge of contaminated groundwater to the river. A more detailed discussion of potential chemical/contamination of the Housatonic River resulting from activities at the GE property is presented in the *Source Area Characterization Report* (00-0275). Key contaminant sources include groundwater NAPL and the former coal gasification plant. Secondary sources of contamination include the river sediments and the floodplains themselves that continue to transfer the contamination downstream during precipitation/runoff events and periods of high flow in the river.

During the 1930s, efforts to straighten the reach of the Housatonic River in the center of downtown Pittsfield by the City and USACE to reduce flood impacts resulted in 11 oxbows being isolated from the river channel. These oxbows were filled with material, some of which was later discovered to contain PCBs and other hazardous materials from the GE facility. In 1968, a PCB storage tank located in Building 68 of the GE Pittsfield facility collapsed and released liquid Aroclor 1260 onto the riverbank and into the river, subsequently contaminating sediments and riverbank and floodplain soils.

Numerous studies conducted since 1988 document PCB contamination in Housatonic River sediments and floodplain soils. The most significant PCB contamination historically is found within the 10-year floodplain of the Housatonic River above Woods Pond dam; however, the transport of PCBs below the dam and into Connecticut is documented as well. A fish consumption advisory due to PCB contamination is in effect for approximately 80 miles downstream of the facility. A waterfowl consumption advisory for PCBs was also issued for the river from Pittsfield to Rising Pond. In addition, consumption advisories are in place for both turtles and frogs in the study area. The widespread PCB contamination is attributed to redistribution of PCBs through river flow, sediment transport, and overbank flooding. A comprehensive presentation of the site history is provided in Section 2 of this Work Plan.

7.2 BASELINE PROBLEM FORMULATION

The baseline problem formulation stage is the first stage in the development of the baseline ERA. In the problem formulation stage, the risk assessment objectives are stated, the problem is defined in the form of a conceptual model, and the approach for analyzing and characterizing the ecological risk(s) is determined (Figure 7-2). The baseline problem formulation stage typically results in several primary products which include: (1) assessment endpoints that adequately reflect the risk management goals and the ecosystems under investigation, (2) complete exposure pathways that incorporate fate and transport information with potential ecological receptors, (3) a conceptual model that describes key relationships between the stressor(s) and assessment endpoints, and (4) the risk questions and associated working hypotheses that the site investigation will address.

The discussion that follows presents an overview of site-specific stressors, a description of the stressor selection process, a description of ecosystems potentially at risk, the assessment endpoint selection, the conceptual model development (including testable hypotheses), and the measurement endpoint selection (including the weight-of-evidence approach).

7.2.1 Stressor Description and Stressor Identification Process

EPA defines a stressor as any physical, chemical, or biological entity that can induce an adverse response (99-0032). After a review of the historical data and the preliminary data collected for this investigation, the potential dominant stressor(s) initially identified as contaminants of potential concern (COPCs) in the Housatonic River drainage are PCBs (as well as dioxin-like congeners of PCBs) and dioxin/furans, which are found as byproducts of Aroclor production. Additional contaminants are being evaluated as potential COPCs as part of the ongoing evaluation of the Lower River.

As part of the stressor identification process, the ERA will include data collected as part of EPA's current characterization efforts as well as any previously collected data that meet established risk assessment data quality objectives (DQOs). Previously collected data are being assessed to determine the extent to which these data meet the project DQOs and can be used in the risk assessment. Selection of COPCs to be carried through the ecological risk assessment process will be determined using several screening methodologies. COPC screening methods incorporated in this assessment are consistent with EPA Region 1 practice and will include, but will not be limited to, the following:

- Frequency of detection greater than 5%. Note: contaminants that exhibit a high potential for toxicity (based on benchmark screening), bioaccumulation, bioconcentration, or other concerns may also be retained.
- Screening of inorganic media concentrations against established site-specific background sample data for each of the potentially affected media.
- Comparing media-specific concentrations to the most current benchmarks available during the preparation of the ecological risk assessment.

A summary of medium-specific data used in the ERA will be prepared displaying frequency of detection, minimum and maximum detected concentrations and sample quantitation limits, and mean and standard deviation for each chemical and its retention status as a COPC, or the basis for its elimination.

7.2.1.1 Fate, Transport, and Toxicity

Information on how COPCs are transported and transformed physically, chemically, and biologically in the environment is used to identify contaminants and associated exposure pathways that might lead to significant ecological effects. Similarly, the COPC selection is also based on an understanding of the toxicity potential of the contaminants under review. A summary of the fate, transport, and potential toxicological effects of PCBs, the main COPC, is provided in the following subsections.

7.2.1.1.1 PCBs

General PCB Fate and Transport

PCBs are stable compounds that degrade slowly under normal environmental conditions and that can persist in the environment for decades. In general, the environmental persistence of PCBs increases with an increase in the degree of chlorination. Mono-, di- and tetrachlorinated biphenyls, typically associated with commercial PCB formulations Aroclors 1221 and 1232, biodegrade relatively rapidly; tetrachlorinated biphenyls associated with Aroclors 1016 and 1242 biodegrade slowly; and higher chlorinated biphenyls associated with Aroclors 1248, 1254, and 1260 are extremely resistant to biodegradation. In aquatic environments, biodegradation appears to be the only significant PCB degradation process. Studies by GE within the Hudson River have demonstrated that some PCB dechlorination does occur in sediments at levels > 30 ppm. However, biodegradation rates are highly variable because they depend on a number of factors in addition to chlorination such as: concentration, type of microbial population, available nutrients, temperature, and chlorine position on the biphenyl ring (Callahan et al., 99-0359; Leifer et al., 99-0361, Sugiura, 99-0369).

The solubilities of PCB congeners in water also decreases with increased chlorination. In water, PCB adsorption to sediments, organic matter, and suspended particulates is a major fate process that partitions PCBs to a solid phase; therefore, in aquatic systems, sediment tends to serve as reservoir from which PCBs may be released slowly over time. Lower chlorinated PCBs will sorb less strongly than higher chlorinated PCBs. Volatilization of dissolved PCBs is an important aquatic process, although volatilization rates are low for the higher chlorinated congeners that have lower solubilities and high adsorption coefficients.

PCBs in aquatic systems accumulate in plant tissues by adsorption of particulate PCBs and absorption of dissolved PCBs from water. PCB uptake in animal tissue occurs through a number of mechanisms including uptake directly from water (bioconcentration) and sediment, and indirectly through the ingestion of food (bioaccumulation). The partitioning of PCBs from aqueous solution into algae and phytoplankton lipids is well documented (Rohrer et al., 99-0366). The bioconcentration of PCBs in aquatic organisms can be estimated from their K_{ow} values using a number of regression equations (Bysshe, 99-0358). Benthic organisms accumulate

PCBs from interstitial sediment water and from the intake of sediments, phytoplankton, zooplankton, and other aquatic insects (Pruell et al., 99-0365; Secor et al., 99-0368; Porte and Albaiges, 99-0364). In general, the rate of bioconcentration and bioaccumulation in aquatic organisms increases with increased chlorine substitution; however, uptake, absorption, and elimination of PCBs is both species- and congener-specific. PCB congeners with limited chlorine substitution at the meta- and para-positions in at least one aromatic ring are more readily metabolized by aquatic organisms (Pruell et al., 1993).

Food chain biomagnification has been demonstrated for several fish-consuming (piscivorous) birds (Mackay, 99-0362). Further evidence of the potential for PCB biomagnification in aquatic food chains was provided by Ankley et al. (99-0357), who found that PCB concentrations in Forster's terns, which are primarily piscivores, were higher than PCB concentrations in tree swallows and red-winged blackbirds, which are insectivores and omnivores, respectively.

Biotransformation of PCBs in vertebrates and, to some extent, invertebrates is mediated primarily by cytochrome P-450 dependent mixed-function oxygenase (MFO) (Safe et al., 99-0060, 99-0079, and 99-0367; Winston et al., 99-0356; Cockerham and Shane, 99-0360). The biotransformation process is typically divided into two phases. Phase I reactions expose or introduce a reactive function to the PCB molecule that usually makes it more polar and water soluble. Phase II reactions involve the conjugation of the Phase I product with another substance that usually makes it less bioactive and more readily excreted. In addition to congener and organism specificity, other factors that can influence the rate of PCB transformation within an organism include diet, lipid content, liver condition, circadian rhythms, presence of enzyme inhibitors, sex, age, and resistance. Although not a direct indicator of effect, measurements of MFOs in organisms are frequently used as a biomarker of exposure to several classes of xenobiotic chemical stressors including PCBs. Within an organism, depuration of accumulated PCB is slow; and, as a result, PCBs tend to remain stored in lipids (where PCBs are soluble) (99-0017).

General Toxicity

The peer-reviewed literature includes many studies demonstrating a variety of adverse ecological effects associated with exposure to PCBs. These effects include lethality, birth defects, reproductive failure and impairment, liver damage, tumors, behavioral modifications (such as abandonment of nest-building activities), and a “wasting” syndrome (Eisler, 99-0220, 99-0067; Moore and Walker, 99-0363).

A number of studies indicate that exposure to a number of chemicals including PCBs may modulate the endocrine system in vertebrate species. Effects associated with endocrine disruption include abnormal thyroid function. Thyroid hormone levels are critical for normal growth and development, and alterations in thyroid hormone levels may have significant metabolic and physiological implications. Other effects elicited by impairment of the endocrine system include increased immunosuppression, disruption of reproductive function, and sex alteration.

Several congeners of PCBs have been shown to exhibit toxic responses in vertebrate species similar to those caused by exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Adverse effects implicated in exposure of vertebrates to “dioxin-like” congeners of PCBs include among others, early life stage mortality in fish (Tillitt and Wright, 99-0371); adverse effects on hatching, growth, and overall productivity in birds (Hoffman et al., 99-0370); and reproductive effects in mink exposed to these congeners in a fish diet (Tillitt et al., 99-0372).

To assess the ecological risk associated with dioxin-like (2,3,7,8-TCDD) toxicity, the concept of toxic equivalency factors (TEFs) has been developed for mammals, birds, and fish. The TEF approach is based on the recognition of a common mechanism of action of 2,3,7,8-TCDD and the dioxin-like compounds, including 6 additional congeners of polychlorinated dibenzo-p-dioxins (PCDDs), 10 congeners of polychlorinated dibenzofurans (PCDFs), and 12 congeners of PCBs. At present, there is sufficient evidence to suggest that this mechanism involves the binding of these compounds in varying degrees to the aryl hydrocarbon receptor (AhR), an intracellular macromolecule that serves as a binding substrate for organic xenobiotics. This binding of the ligand (chemical) to the AhR represents an initial step in a sequence of events that results in the detoxification and potential bioactivation of the compound (Knutson and Poland, 99-0306; Safe, 99-0307; Hankinson, 99-0305; Birnbaum, 99-0304). The receptor-ligand complex is subsequently transferred into the cell’s nucleus where it, in turn, binds to DNA (Stegeman and Hahn, 99-0310). It is assumed that most of the toxic response associated with these compounds is due to AhR-mediated modulation of gene expression (Knutson and Poland, 99-0306, and Whitlock, 99-0311, as cited in Safe, 99-0309). The development of a TEF compares the relative toxicity of a “dioxin-like” compound to that of 2,3,7,8-TCDD and is based on available in vivo and in vitro studies (Van den Berg et al., 99-0275).

The studies documented in the literature demonstrate that different animals (for example, fish versus mammals) have greatly varying sensitivities and resulting effects from exposure to PCBs. Even different species within a group (such as river otter versus mink) may have varying sensitivities to PCBs. As a rule, as with most chemicals found at hazardous waste sites, it is difficult to quantify the magnitude of an effect at a species sub-population level because of the difficulty in distinguishing responses that are chemically induced from those responses that are due to natural population dynamics and sensitivities as well as other factors. Most studies that are sufficiently rigorous to do so typically require years of field data collection with large sample sizes. Therefore, as stated in the July 1997 WHO report (99-0312), “methods to assess and predict effects on individuals are required.”

As stated above, there is a broad base of scientific study that has demonstrated adverse effects as described above to fish, birds, and mammals from exposure to PCBs. Many of these responses are of a nature that, although observed at an individual level, could be expected to result in a subpopulation level effect (such as reduced embryo survival). Within this broad base of study, however, the range of species, life stage, and individual sensitivities is obvious. The result is that there is a large range of concentrations over which different interpretations can be made regarding the resulting PCB effects. Comprehensive, rigorous, site-specific studies on the effects of PCBs in the Housatonic River ecosystem have not been conducted to date.

7.2.1.1.2 Other Potential Contaminants of Concern

Contaminants known to have fate and toxicity profiles similar to PCBs include dioxin/furans, dioxin-like congeners of PCBs, and select organochlorine pesticides. Based on the data evaluated and summarized in the Upper Reach ERA, as well as historical information available for the Lower River, a conceptual model of the PCB (and similar organochlorine compounds) fate and transport processes is incorporated in the design of the sampling program as presented in this

SIWP. As stated in Subsection 7.2.1, a full evaluation of COPCs will be performed in the ERA using data collected under this SIWP, and the conceptual model will be modified if necessary.

Presentation of contaminant concentrations, affected media, and toxicity information will be accomplished primarily with geographic information system (GIS)-based tools. This approach will reduce the need to rely solely on statistical summaries of data and will allow for a spatial presentation and evaluation of information.

7.2.2 Ecosystems Potentially at Risk

The following discussion provides a brief characterization of the approximately 10-mile section of the Housatonic River extending from the confluence downstream to the Woods Pond Dam that, upon review of the historical data, appears to be the most likely segment of the Housatonic River system to be impacted by site-related contaminants. Contaminant levels below Woods Pond will be characterized as described in Section 5. Decisions to evaluate other downstream components will be made upon the assessment of this data. Two distinct areas in the stretch between the confluence and Wood Pond Dam can be identified based on land use, historical development, river impacts, and land management practices: (1) the upper portion, from the confluence to the New Lenox Road Bridge, a moderately flowing reach bordered primarily by forested floodplains, and (2) the lower portion, from the New Lenox Road Bridge downstream to the Woods Pond Dam, where the effects of the dam are observed, and the river and riparian zones widen (up to 3,000 feet), river velocity is reduced, and emergent and scrub-shrub wetlands dominate.

The vicinity between the confluence and Woods Pond, and downstream along the Housatonic River comprise part of the second-most biologically diverse area in Massachusetts (99-0352) (second only to Cape Cod and the coastal islands). Reasons for the high level of diversity include the unique geologic setting (i.e., the circumneutral to calcareous soil and water [that displays pHs of approximately neutral to basic due to high concentrations of calcium carbonate] from the underlying limestone bedrock), the extent of undeveloped forested land in and near parts of the study area, the existence of a complex mosaic of wetlands that provide habitat for a number of rare species, and the overall size of the floodplain. Preliminary data (04-0004) indicate PCBs are present in soils throughout much of the 10-year floodplain, demonstrating the importance of understanding the physical and ecological setting sufficiently to develop a responsive ERA.

More in-depth discussions of the habitat and other ecological parameters in the study area are presented in Section 2 of this Work Plan and/or in the *Final Preliminary Ecological Characterization, Newell Street to Woods Pond* (TechLaw, 05-0062). Data presented in these two forums result from surveys performed to identify the species and ecological communities present within the study area. Particular importance was placed on identifying species that are in constant contact with contaminated abiotic media (e.g., benthic organisms in contact with contaminated sediment) and species at higher trophic levels that could be susceptible to bioaccumulating or biomagnifying PCBs (e.g., mink), and identifying the occurrence of species or habitats of special concern or status. These ecological characterization efforts have several common potential uses in the ERA, including:

- Use in guiding the development of the conceptual model.
- Identification of species most likely to contact contaminated abiotic media and/or contaminated prey items.
- Qualitative comparison of difference or similarities among species occurrences between areas with different PCB concentrations.
- Use in the development of site-specific food webs.
- Identification of species of management concern to United States Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Agency (NOAA), or MA Division of Fisheries and Wildlife (MADFW).

In addition, these studies will be used later to understand the resources potentially impacted by various response actions. Table 7-1 presents the specific surveys performed to characterize the ecosystems potentially at risk, as well as the specific objective(s) and reference to the appendix containing the detailed SOP for each survey. Based upon the results of these and other historical surveys, the following subsections provide brief descriptions of the aquatic and terrestrial habitats and the species identified within the study area that are potentially at risk. The information provided in the aforementioned TechLaw (05-0062) document and previous historical studies answers the key questions proposed in the Guidance (99-0138) checklist for ecological/assessment sampling.

Table 7-1

Surveys Conducted for Ecosystem Characterization and their Specific Objective(s)

Survey	Specific Objective(s)	Appendix
Rare Plants and Natural Communities	Determine the potential rare, threatened, or endangered plants or animals occurring within the study area. Determine the presence and areal extent of habitats capable of supporting special status species potentially occurring within the study area. Determine the presence and areal extent of exemplary natural communities within the study area.	A.6
Dragonfly	Determine species of dragonflies present in the study area, with particular attention to rare species.	A.7
Mussel	Determine historical and current distribution within and upstream of the study area. Identify potential mussel hosts. Identify wildlife species that prey upon mussels.	A.8
Reptile and Amphibian Use	Estimate amphibian and reptile species richness in the study area by habitat type. Sample larval amphibians in breeding habitats over a range of PCB concentrations. Determine chemical concentrations in herptiles lost incidentally during trapping. Note: The latter two objectives for use in ERA exposure and effects characterization (see Subsection 7.3).	A.9
Raptors and Waterfowl	Identify raptors breeding in study area.	A.10
Forest Bird and Marsh and Wading Bird	Identify birds using the study area floodplain forests and scrub-shrub habitats. Identify birds using the study area wetland and aquatic habitats.	A.11
River Otter, Mink, and Bat	Determine if mink and otter are present in the study area and reference areas. Identify bat species present in study area. Determine habitats bats use for feeding and roosting.	A.12

7.2.2.1 Aquatic Habitats

Upstream of the confluence, the river has been altered by channelization, filling of adjacent floodplains, and subsequent lateral erosion of the channel caused by the surface water hydrology of the immediate watershed. Below the confluence, the river resumes a primarily natural flow through a broad floodplain in a meandering channel. The floodplain is characterized by meanders, oxbows, point bars, cut banks, backwater sloughs, abandoned channels, and alluvial bars. Floodplains in the lower reach of the river are often inundated by water backed up from the Woods Pond Dam. Channel widths range from 40 to 60 ft in the upper reaches, and 60 to 120 ft in the lower reach. Stream depths at mean flow (140 cfs above the confluence) range from approximately 1½ ft in the urbanized areas of the upper reaches to more than 8 ft below the confluence where natural meanders, cut banks, and point bars have developed. Downstream from the confluence, there are larger sand deposits in point bars. A detailed description of the aquatic habitats is presented in Subsection 2.3.

7.2.2.1.1 Benthic Invertebrate Communities

Shallow Water

Three distinct benthic invertebrate habitats have been characterized in the study area. Shallow-water habitats can be found from Newell Street to north of the New Lenox Road Bridge. A benthic invertebrate community assessment performed by GE (ChemRisk, 02-0048) in shallow water habitats in the study area found numerous orders of insects, including *Diptera* (true flies), *Trichoptera* (caddis flies), *Ephemeroptera* (mayflies), and *Hydracarina* (water mites).

Deep Water

Deeper-water stream habitats are present from just north of the New Lenox Road Bridge to Woods Pond. The GE study found that the invertebrate communities within these habitats were dominated by members of the midge group (*Diptera*) and by oligochaete worms. These habitats tended to be less diverse than the shallow water habitats due to the predominately fine-grained silt substrate (02-0048).

Pond

Pond habitat found in Woods Pond was found in the GE study to support a distinct benthic invertebrate community primarily as a result of a reduction in river flow conditions and increased sediment deposition. Woods Pond had a typical lentic species assemblage of benthic invertebrates. Dipterans were more dominant, with oligochaetes common. Other taxa present in the area were mostly found in the shoreline habitat of Woods Pond.

A detailed evaluation of benthic community structure was conducted in 1999 (Appendix A.13); results of this evaluation will be incorporated into the ERA.

7.2.2.1.2 Fish Communities

Twenty species of fish were collected by GE from the study area in 1992 and 1993 by Chadwick & Associates (02-0101, 02-0102) (see Subsection 2.3.3.4). Earlier studies have identified as many as 40 fish species within the Housatonic River system. A more comprehensive assessment of fish species found within the study areas will be available when data collected as part of fish tissue sampling and community assessment are presented in the ERA. The following subsections discuss the fish community composition present within the three most common habitats (i.e., shallow water, deep water, and pond) in the study area as identified by Chadwick & Associates (02-0101, 02-0102).

Shallow Water

Eight families, representing game fish, rough fish, and forage fish, were reported by Chadwick & Associates (see Subsection 2.3.3.4.1). The minnow (Cyprinidae) and sunfish (Centrarchidae) families contained the most species. The white sucker (*Catostomus commersoni*), common shiner (*Notropis cornutus)*, and bluntnose minnow (*Pimephales notatus*) were the numerically dominant species.

Deep Water

Species representing game fish, rough fish, and forage fish were reported by Chadwick & Associates (see Subsection 2.3.3.4.2). Most of the fish collected in surveys of these areas were taken from deep pools. The sunfish family, which prefers the deeper, more pond-like conditions found in this portion of the river, was the dominant taxa. The white sucker and yellow perch (*Perca flavescens*) were the numerically dominant species.

Pond

Game fish, rough fish, and forage fish were reported by Chadwick & Associates (02-0101) as abundant in Woods Pond (see Subsection 2.3.3.4.3). Sunfish and white suckers were the most abundant fish. The fish were mostly associated with the deep, open water areas near the middle of the channel.

7.2.2.2 Terrestrial Habitats

7.2.2.2.1 Vegetation

The Housatonic River study area contains a wide variety of topography, riparian zone widths, and wetland communities. The primary sources of information on vegetation in this region include the *Final Preliminary Ecological Characterization Newell Street to Woods Pond* (05-0062) and the *Preliminary Wetland Characterization and Functional-Value Assessment* (00-0309).

Historic and active land use management practices have fragmented the Housatonic River floodplain and its vegetative communities. Currently, vegetative communities in the study area are a mosaic of floodplain forests, shrub swamps, and emergent wetlands.

In the upper reaches above the study area, between Newell Street and the confluence, early successional trees and shrubs or exotic shrubs line most of the riverbanks. In the vicinity of the confluence, floodplain wetlands with a mosaic of forested wetlands occur on somewhat more established and higher ground; shrub and emergent wetlands occur on lower areas that are more regularly flooded. Floodplain wetlands become more abundant farther south in the study area, where they are interspersed with farmland. South of New Lenox Road, floodplain wetlands fill the base of the stream valley. These wetlands are interspersed with backwater ponds, channels, and abandoned oxbows (i.e., oxbow lakes) (00-0309).

Wetland types classified in the study area include the following: riverine, upper perennial, streambed cobble-gravel; palustrine unconsolidated bottom (PUB); palustrine; emergent marsh, persistent and non-persistent marsh (PEM); palustrine, scrub/shrub, broad-leaf deciduous (PSS1); palustrine, forested, broad-leafed deciduous (PFO1); palustrine aquatic bed (PAB); and combination types. Detailed wetland community maps are provided in the wetland functional assessment report (00-0309).

Section 2 presents a detailed discussion of the dominant species for the following major vegetative communities: riverbanks, wet meadows, emergent wetlands, scrub/shrub wetlands, forested wetlands, and aquatic beds.

A rare plant and natural community study was conducted in 1998 to further evaluate the composition of vegetative communities within the study area. This study identified the presence of rare species, potential habitats for rare species, and exemplary natural communities as defined by the Massachusetts Natural Heritage and Endangered Species Program (MNHESP). The study plan followed for this evaluation is presented in Appendix A.6. The results of this study are presented in the *Final Preliminary Ecological Characterization Newell Street to Woods Pond* (05-0062).

7.2.2.2.2 Fauna

The study area floodplain communities provide a broad range of wildlife habitats. While some habitat has been changed by fragmentation, development activities, and the invasion of exotic plant species (e.g., purple loosestrife), many of the vegetative communities continue to support a diverse fauna.

Wildlife species identified within the study area are reviewed in Subsection 2.3.3. A more comprehensive list of species using the study area is presented in the *Final Preliminary Ecological Characterization Newell Street to Woods Pond* (05-0062). This survey information was extended through the 1999 field season as a part of the other ecological studies, and will be incorporated into the ERA. A summary of the findings is presented below by class.

Amphibians and Reptiles

A list of 39 amphibian and reptile species potentially inhabiting the Housatonic River drainage was developed by Woodlot Alternatives, Inc., as part of its amphibian and reptile survey plan (Appendix A.9). A total of 15 species of amphibians and reptiles were documented in the Housatonic River Drainage (see Subsection 2.3.3.1). Frogs were the most common group of species observed; eight of the nine expected species were observed in the study area. Red-spotted newts (*Notophthalmus viridescens*) were the most commonly observed salamanders in the study area. Painted turtles (*Chrysemys picta*) were the most commonly observed turtle. Garter snakes (*Thamnophis sirtalis*) were the most widespread snake.

Birds

Approximately 70% of the 165 bird species expected to be present in the valley were observed during 1998 (see Subsection 2.3.3.2). The diversity of the bird community is a reflection of the diverse nature of the habitats in the study area. An abundance of large, open wetlands surrounded by forested and scrub-shrub habitats in the lower part of the study area provides suitable habitat for many species of water birds and forest birds.

Mammals

Twenty-one of the 52 mammal species expected to occur in the study area were observed in the mammal survey conducted in fall 1998 (see Subsection 2.3.3.3). Mammals in the study area use the wide range of floodplain habitats available, including forested, nonforested, riverine, shoreline, wetland, and upland habitats. In general, species that have more cosmopolitan habitat requirements and that are easily observed, such as red fox (*Vulpes vulpes*), coyotes (*Canis latrans*), white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), and gray squirrels (*Sciurus carolinensis*) were more commonly observed in the study area.

7.2.3 Assessment Endpoint Selection

Knowledge of the relationship of site-related contamination to ecological endpoints contributes significantly to the ERA decision-making process (Suter, 99-0042). An endpoint is defined as an ecological characteristic (e.g., fish survival) that may be adversely affected by site contaminants

(EPA, 99-0032). In the ERA process, two distinct types of endpoints are identified: assessment endpoints and measurement endpoints. The following discussion provides definitions and criteria used to develop the assessment endpoints that will be used to evaluate potential ecological risks in the Lower Housatonic River.

Assessment endpoints are unambiguous statements or goals concerning an ecological characteristic (e.g., reproductive effects in aquatic receptors) that are to be evaluated and/or protected (EPA, 99-0044, 99-0033).

Assessment endpoints determine the foundation for an ERA because they:

- Provide guidance for evaluating the site and the extent of contamination.
- Establish a basis for assessing the potential risks to identified receptors.
- Assist in the identification of the ecological structure and function at the site.

Each site or area evaluated in an ERA has the potential to be biologically unique; therefore, there is no universal list of assessment endpoints (Suter, 99-0043). Since it is not practical or possible to directly evaluate risks to all of the individual components of the ecosystem at a site, assessment endpoints should focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site (99-0138). According to EPA's *Ecological Assessment Guidance for Superfund* (99-0318):

> "Assessment endpoints for the baseline ERA must be selected based on the ecosystems, communities, and/or species potentially present at the site. The selection of assessment endpoints depends on:
>
> - The contaminants present and their concentration;
> - Mechanisms of toxicity of the contaminants to different groups of organisms;
> - Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the contaminant and attributes of their natural history; and
> - Potentially complete exposure pathways."

In addition, specific assessment endpoints should define the ecological value in sufficient detail to identify measures needed to answer specific questions or to test specific hypotheses (99-0138). Ultimately, the true value of any ecological risk assessment depends on whether it can be used to make appropriate managerial decisions. Therefore, the careful selection of assessment endpoints is crucial in determining the success or failure of the risk assessment process. Once assessment endpoints have been selected and the conceptual model of exposure has been adequately developed, testable hypotheses and measurement endpoints can be developed to determine whether or not a potential threat to the assessment endpoints exists (99-0138). As previously noted, EPA and other stakeholders have met, discussed available information on contaminants and contaminant levels, and determined the assessment endpoints to be incorporated in this ERA. Past discussions between GE and the government agencies have demonstrated that the government agencies have a preference for measurement endpoints utilizing controlled studies, while GE has a preference for field-based observations and studies. This ERA Work Plan has addressed both of these preferences by including both a field and a controlled study component for assessment endpoints, where possible. Assessment endpoints specific to this study are presented in Table 7-2.

7.2.4 Conceptual Model

The conceptual model provides a description and visual representation of the fate, transport, and effects that stressors may have on the environment. In essence, the conceptual model presents a series of working hypotheses regarding how the stressors might affect ecological components of the natural environment. Risk hypotheses are specific assumptions about potential risk to assessment endpoints and may be based on theory and logic, empirical data, or mathematical or probability models (99-0033). The hypotheses are formulated using professional judgment and available information of the ecosystem at risk, potential stressor sources and characteristics, and observed or predicted effects on assessment endpoints. As with the entire ERA process, the development of a conceptual model is a complex, non-linear process, with many parallel activities that may result in modifications to the conceptual model as additional information becomes available.

Conceptual model diagrams are visual representations of the multiple relationships between stressors and receptors and the pathways of exposure at a site. Evaluation and inclusion of each relationship in the conceptual model diagram are based on several criteria:

- Data availability.
- Strength of relationship between stressor and effects.
- Endpoint significance.
- Relative importance or influence of stressor.
- Importance of effects to ecosystem function.

Table 7-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site

Receptor	Assessment Endpoint	Measurement Endpoint
Benthic Invertebrates	Community Structure	Community composition; species diversity, evenness, and density; and other metrics compared with similar metrics at reference locations.
		Sediment Triad evaluation—Evaluation includes benthic community composition, sediment toxicity testing, and sediment chemistry.
	Survival, Growth, and Reproduction	Sediment macroinvertebrate chronic toxicity testing using *Hyalella azteca* to determine survival, growth, and reproduction; and *Chironomus tentans* to determine survival, growth, and emergence. In situ toxicity studies using *C. tentans*, *Daphnia magna*, *H. azteca*, and *Lumbriculus variegatus* to determine survival and growth. (Growth evaluated only in *C. tentans*.) Toxicity Identification Evaluation (TIE) laboratory 24-hour study using *Ceriodaphnia dubia* to determine survival for different pore water fractions of contaminant classes.
		Comparison of sediment chemistry with benchmarks including, but not limited to, EPA SQG, Long et al. (99-0014) ER-Ls and ER-Ms, and Ontario LELs and SELs.
		Sediment Triad evaluation—Evaluation includes benthic community composition, sediment toxicity testing, and sediment chemistry.
	Survival and Physiological Condition of Freshwater Mussels	In situ toxicity study using mussels collected from a reference area in the Connecticut River and deployed in the Housatonic River upstream and downstream of the GE facility. Toxicity endpoints include mortality and general health, as determined from glycogen levels measured in mantle tissue.
Amphibians	Community Condition	Semiquantitative sampling of larval amphibians in breeding habitats with different sediment concentrations of stressors. Endpoints include species richness per habitat type; species abundance; gross pathology; and body, tail, and total length measurements.
	Reproductive Success	Surveys of vernal pools to quantitate amphibians entering vernal pools and determine breeding behavior and condition; egg laying, hatching success, and larval growth and development; metamorphosis and emigration.

Table 7-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site
(Continued)

Receptor	Assessment Endpoint	Measurement Endpoint
Amphibians (cont'd)	Reproduction, Development, and Maturation	Amphibian toxicity tests designed with exposure over a gradient of stressor concentrations in site sediments. Toxicity endpoints include morphology of embryos and juveniles, limb development, skin maturation, and tail resorption of *Rana pipiens*.
		Gravidity of females; egg count; necrotic eggs; oocyte maturity; sperm count, morphology, and viability; fertilization rate; embryo viability; hatching success; mortality; and teratogenesis of *Rana pipiens* collected from the study area compared with a reference area.
Fish	Survival, Growth, and Reproduction	Fish toxicity tests using adult fish from the study area and fish eggs injected with PCB extracts from Housatonic River fish. Toxicity endpoints include mortality, time to hatch, growth, gross pathology, histopathology, weight and length, apoptosis, and cytochrome P4501A induction in eggs and fry; and ethoxyresorufin-*O*-deethylase (EROD) induction, and plasma 17β-estradiol, testosterone levels, and vitellogenin in adult fish.
		Comparison of surface water chemistry with surface water benchmarks, including but not limited to AWQC.
		Comparison of stressor concentrations in forage and adult fish tissue with reference area concentrations and with residue effects levels from literature.
Insectivorous Birds	Reproduction and Survival	Reproductive performance of tree swallows (*Tachycineta bicolor*) based on the nest box study conducted in areas of varying stressor sediment concentrations. Parameters for evaluation include nest building, egg presence/absence, number of eggs, and hatching success.
		Comparison of site-specific tissue concentrations in tree swallows with reference area concentrations and with residue effects levels from literature.
	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors by tree swallows from emergent aquatic insects using site-specific stressor levels in insects and comparison with literature-based effect values.
Piscivorous Birds and Mammals	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific fish tissue concentrations and site-specific stressor levels in other aquatic-related food items (e.g., crayfish and frogs), and comparison with literature-based effect values.
	General Condition, Survival, Growth, and Reproduction of Mink	Mink toxicity tests using Housatonic River fish as a dose in the diet. Toxicity endpoints include body weight, feed composition, length of gestation, reproductive success (measured by number of females whelping, newborns/female, litter weight, etc.), survival, histopathology, cytochrome P450 analysis and other biochemical analyses, and organ weights.

Table 7-2

Ecological Assessment and Measurement Endpoints
Lower Housatonic River Site
(Continued)

Receptor	Assessment Endpoint	Measurement Endpoint
Carnivorous Birds	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in soil invertebrates, and comparison with literature-based effect values.
Small Mammals (Omnivorous and Carnivorous)	Reproduction	Reproductive evidence in trapped small mammals (e.g., examination of placental scars to determine number of litters, and number/ litter).
	Survival, Growth, and Reproduction of Carnivorous Small Mammals	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in soil invertebrates and comparison with literature-based effect values.
Omnivorous Mammals	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific stressor levels in a variety of small mammals collected in the impacted area, and comparison with literature-based effect values.
Special Status Species (Endangered, Threatened)	Survival, Growth, and Reproduction	Toxicity quotient based on dietary intake of stressors using site-specific media concentrations and comparison with literature-based effect values.

Information used to develop the conceptual model is often one of the most significant sources of uncertainty in a risk assessment. This uncertainty arises from lack of knowledge of how ecosystems function in general, and how the system being evaluated functions specifically; how stressors move through the environment and cause adverse effects; and how the confounding variables associated with multiple stressors interact. The availability of historical data on stressors and receptors, and a comprehensive ecological characterization reduces the uncertainty associated with the development of the conceptual model at this site. Although general uncertainties associated with assumptions will be addressed throughout the ERA, a detailed discussion of specific uncertainties and their implications for the interpretation of risk results is reserved for the Risk Characterization.

Contaminants, contaminant source areas, and associated migration pathways are discussed in detail in Subsections 3.1 and 3.2. As an overview, contamination of the sediment and surface water in the Housatonic River with PCBs and other contaminants from the GE facility has occurred, either directly or through various transport and redistribution mechanisms. In addition, contaminated sediments were deposited on the Housatonic River floodplain soils in a variety of habitat types during periodic flood events. Because of the lipophilic properties of PCBs, they are subsequently transported from these media to biota through bioaccumulation and subsequent trophic transfer. The assessment endpoints for the ERA were selected to address both the potential direct and indirect impacts to the environment, focusing primarily on the PCBs found throughout the Housatonic River drainage.

The conceptual model discussed below addresses the relationship of the PCBs and other COPCs to the receptors selected for assessment. For each receptor, the mechanisms of exposure, and selected assessment and measurement endpoints will be presented. When possible, potential effects to other organisms that may result from a decline in the receptor population will be introduced. For example, a decline in an organism population could result in a decrease in the food base for predatory organisms. Detailed protocols for the studies noted below are found in Appendix A.

Organisms inhabiting contaminated sediments may be exposed through direct contact with sediments and interstitial water, ingestion of contaminated sediments, or consumption of contaminated organisms. Initial evaluations conducted during the *Upper Reach Ecological Risk Assessment* (99-0085) identified the potential for adverse impacts to benthic and epibenthic communities. The Sediment Quality Triad is being used to investigate these potential impacts. The community structure of benthic macroinvertebrates is being evaluated through community metrics performed on samples collected from the Housatonic River and reference areas. Survival, growth, and reproduction will be evaluated via sediment macroinvertebrate toxicity tests, in situ studies, and comparisons of sediment chemistry with benchmarks. The survival and physiological condition of freshwater mussels will also be evaluated through in situ tests.

The release of sediment-bound as well as dissolved phase contaminants into the overlying water may adversely impact pelagic organisms (e.g., fish, amphibians, and plankton). Dermal contact, ingestion, and trophic transfer are also primary exposure pathways of concern for pelagic species. The community reproduction, development, condition, and maturation of amphibians will be evaluated through morphological metrics collected from field sampling, surveys of reproductive success in vernal pools, and amphibian toxicity tests. The survival, growth, and reproduction of fish will be assessed through field and laboratory investigations, comparison of surface water chemistry with benchmarks, and a comparison of tissue concentrations with residue effects levels from literature.

A large proportion of the benthic macroinvertebrate community in aquatic systems is composed of the early life stages of insects. Because benthic macroinvertebrates are exposed to contaminated sediments and PCBs bioaccumulate in these organisms, insectivorous birds can be exposed to contamination through the ingestion of emerging, adult insects. The reproduction, growth, and survival of insectivorous birds will be assessed through the tree swallow study, the comparison of tissue concentrations with residue effects levels from literature, and toxicity quotient method. (See Subsection 7.4.2 for an explanation of the toxicity quotient method.)

Given that the existence of sediment-bound contaminants and the potential for release of contaminants into the overlying water may result in the pelagic community bioaccumulating contaminants, piscivores (both birds and mammals) may be exposed to contaminants in their diet. In addition, these species may be exposed to contamination through the incidental ingestion of sediment and floodplain soils and surface water that occurs during foraging activities, and through the deliberate ingestion of surface water. The general condition, survival, growth, and reproduction of mink will be evaluated from toxicity tests. In addition, survival, growth, and reproduction of piscivorous birds (e.g., kingfisher and great blue heron) and mammals (e.g., river otter, mink) will be assessed by the toxicity quotient method.

Soil invertebrates and plants may accumulate contaminants from floodplain soils. These invertebrates and plants can serve as mechanisms for exposure to contaminants by carnivorous and omnivorous small mammals. In addition, these species may be exposed to contamination through the incidental ingestion of soil occurring during foraging or burrowing activities. The reproduction of omnivorous and carnivorous small mammals will be assessed through an examination for reproductive evidence in trapped individuals. In addition, the survival, growth, and reproduction of carnivorous birds (e.g., American robin) and small mammals (e.g., Northern short-tailed shrew) will be assessed through the toxicity quotient method. Moreover, large omnivorous mammals, e.g., raccoon, may be exposed to contamination through the bioaccumulation and trophic transfer of these contaminants in prey and forage species. In addition, these larger omnivorous mammals can be exposed to contaminants from the incidental ingestion of soil during foraging and burrowing activities, and the deliberate ingestion of surface water. The survival, growth, and reproduction of omnivorous mammals (e.g., red fox) will be assessed through the toxicity quotient method.

The survival, growth, and reproduction of a special status species (i.e., endangered or threatened) may be evaluated through the toxicity quotient method. Mechanisms of exposure of the selected species will be discussed in the risk assessment.

Because PCBs have demonstrated the potential for biomagnification, the bioaccumulation potential and subsequent trophic transfer of PCBs to algae, phytoplankton, zooplankton, macrophytes, benthic macroinvertebrates, freshwater mussels, earthworms, amphibians, fish, waterfowl, insectivorous birds, and small mammals will be evaluated. Contaminant concentrations identified in tissue will be compared with reference concentrations and, when appropriate, included in exposure models developed to assess potential impacts to insectivorous, piscivorous, and carnivorous birds, and piscivorous, omnivorous, and carnivorous mammals.

Much of this information will also be used in AQUATOX, the PCB fate and effects model being used in the modeling study.

Subsection 7.3 details the numerous investigations (laboratory, in situ, and field) that will be conducted to assess the potential for exposure, bioaccumulation, and direct impacts to the above-mentioned receptors.

Figure 7-3 provides a simple graphical representation of the pathways of exposure to stressors through the aquatic/wetland and terrestrial environments at the Housatonic River, and identifies key ecological components that have been selected for further analysis. This flow diagram provides a working, dynamic representation of the relationships that exist between stressors and key ecological receptors that may be modified as additional information becomes available, and is not meant to characterize all possible mechanisms or species.

7.2.4.1 Risk Questions/Testable Hypotheses

Following the development of the site conceptual exposure model, testable hypotheses or "risk questions" are developed to provide a basis for the study design and the selection of measurement endpoints. These hypotheses represent statements regarding anticipated ecological effects and define the general focus of the individual studies. In general, the primary question to be asked by the risk hypothesis is "does (or could) contaminant "x" (e.g., PCBs) cause adverse effects on the assessment endpoint (99-0138)?" There are four dominant lines of evidence that can be used to answer this question:

1. Comparing an estimated or measured exposure level to chemical "x" with levels that are known from the literature to be toxic to receptors associated with the assessment endpoints.
2. Comparing laboratory bioassays with media from the site and bioassays with media from a reference site.
3. Comparing in situ toxicity tests at the site with in situ toxicity tests in a reference location.
4. Comparing observed effects in the receptors associated with the site with effects or lack of effects in similar receptors at a reference site.

The following presents the primary risk question for each receptor group. Within each study, specific test hypotheses are presented. Although PCBs represent the only class of contaminants presented in the primary risk questions, pending the COPC selection process, other contaminants may also be pertinent to the underlying questions.

- Benthic Invertebrate Community—Are ambient PCB levels in sediments sufficient to cause adverse effects in benthic organisms in the Housatonic River?
- Amphibian Community—Are ambient levels of PCBs present at concentrations in amphibian habitat sufficient to cause adverse effects in amphibians in the Housatonic River?
- Fish Community—Are ambient levels of PCBs present at concentrations in fish habitat sufficient to cause adverse effects in fish in the Housatonic River?
- Avian Community—Are ambient levels of PCBs present at concentrations in avian prey species sufficient to cause adverse effects in birds inhabiting the affected reaches of the Housatonic River and the adjacent floodplain?
- Mammal Community—Are ambient levels of PCBs present at concentrations in mammalian prey species sufficient to cause adverse effects in mammals inhabiting the affected reaches of the Housatonic River and the adjacent floodplain?

7.2.5 Selection of Measurement Endpoints

A measurement endpoint is defined as “a measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint.” Measurement endpoints link the conditions existing on-site to the goals established by the assessment endpoints through the integration of modeled, literature, field, or laboratory data (99-0072).

“Measurement endpoints are frequently numerical expressions of observations (e.g., toxicity test results, community diversity measures) that can be compared statistically to a control or reference site to detect adverse responses to a site contaminant" (99-0138). Measurement endpoints can include measures of exposure (e.g., contaminant concentrations in water or tissues) as well as measures of effect.

It is desirable to have more than one measurement endpoint for each assessment endpoint, thereby providing multiple lines of evidence for the evaluation. However, the primary consideration for selecting measurement endpoints should always be how many and which lines of evidence are needed to support risk management decisions at the site. Once it has been determined which lines of evidence are required to answer questions concerning the assessment endpoint, the measurement endpoints by which the questions or test hypotheses will be examined are selected (99-0138).

In selecting an appropriate measurement endpoint to represent an assessment endpoint, the following criteria are considered (99-0042):

- Corresponds to or is predictive of an assessment endpoint.
- Readily measurable.
- Appropriate to site scale, exposures pathways, and temporal dynamics.
- Diagnostic.
- Broadly applicable.
- Standard.

With the selection of measurement endpoints, the conceptual model development is essentially completed. The conceptual model, which is discussed in Subsection 7.2.4, then is used to develop the study design and data quality objectives (DQOs).

Historical correspondence between the Agencies and GE indicated that while GE favored the use of field studies over laboratory investigations, the Agencies found merit in laboratory studies, particularly for determining dose-response relationships. To take this philosophical difference into account, where possible, both field- and laboratory-derived measurement endpoints were identified for a given assessment endpoint. The assessment and associated measurement endpoints that will be used to evaluate potential ecological risks resulting from PCBs, and possibly other chemical contamination in the Lower Housatonic River, are presented in Table 7-2. Many studies conducted as part of this investigation include multiple measurement endpoints in their design. Rather than list these individual measurement endpoints separately, the assessment endpoint and principal measurement endpoints are presented. The conceptual model for the site demonstrates the complexity of the ecosystem being evaluated. It was necessary to develop assessment endpoints which were representative of the varying habitats and exposure pathways which exist at the site, and for which there is potential for differing baseline risk to occur (i.e., a deepwater riverine reach versus a forested floodplain).

The approach outlined above will allow interrelated measurement endpoints to be evaluated concurrently when evaluating the associated assessment endpoint.

Several field surveys are being conducted to provide information specifically on species presence. Although field surveys can also be used to assess community condition, the field surveys were designed for community characterization, will not be used as measurement endpoints, and therefore are not included in Table 7-2.

Tissue samples will be collected for contaminant analyses for a number of species in support of the ecological exposure assessment, human health risk assessment, and PCB fate and effects modeling. To date, definitive literature-based tissue residue effect levels comparable to the endpoints selected for this study are lacking for soil invertebrates, waterfowl, and small mammals. Endpoints typically associated with residue effect levels range from general toxicity to reproductive effects and lethality. If comparable literature-based residue effects data are identified through various literature and toxicity database searches, then these will be incorporated to provide a comparison of site-specific tissue data with literature-based effects levels in the risk assessment to provide additional lines of evidence.

Although many of the endpoints presented here are linked to organism-level effects (e.g., survival and reproduction), these endpoints are in fact strong indicators of potential population-level effects (e.g., viability of a bass population within the Housatonic River study area) (99-0032). Extrapolation from organism-level to population-level effects may be logically achieved based on the predictive nature of the endpoint and/or through the use of process-based models. A general description of these models is discussed in Subsection 7.3.3.1.3, *Linking Measurement Endpoints to Assessment Endpoints.*

The current list of assessment and measurement endpoints may be revised pending the iterative review of ongoing investigations. Any resulting modification to the endpoint list will be provided in an addendum to this Work Plan.

7.2.5.1 Weight-of-Evidence Approach

The assessment methods that will be used in this ERA consider a wide variety of endpoints and effects that differ in their suitability for, and sensitivity to, assessing the potential risks at the site.

In assessing ecological risk, not all measurement endpoints are equivalent in their ecological significance or in their ability to predict risk. For example, it can be argued that comparison of chemical concentrations in sediments to benchmark values is less compelling than the results derived from chronic sediment toxicity testing.

To account for the strengths and weaknesses of different measurement endpoints that will be used in this assessment and to provide a framework for evaluating multiple lines of evidence, a weight-of-evidence (WOE) approach will be used. The objective of this WOE framework is to provide a more rigorous consideration of the strengths and weaknesses of various measurements, the nature of uncertainty associated with them, and their potential utility in the ERA. The framework for this approach was developed by the Massachusetts Weight-of-Evidence Workgroup (the Workgroup) and is detailed in the *Special Report of the Massachusetts Weight-of-Evidence Workgroup: A Weight-of-Evidence Approach for Evaluating Ecological Risks* (Menzie et al., 99-0041). In this paper, the Workgroup defines the weight-of-evidence approach as:

> "…the process by which measurement endpoints are related to an assessment endpoint to evaluate whether a significant risk of harm is posed to the environment. The approach is planned and initiated at the problem formulation stage, and results are integrated at the risk characterization stage."

The approach provides the option of performing either a quantitative or qualitative weight-of-evidence evaluation. For this assessment, a more qualitative approach using a low-medium-high significance rating will be used. This approach is more flexible in determining the relative importance of each attribute.

The question of how well a measurement endpoint represents an assessment endpoint arises at two separate points in the risk assessment process: (1) in the Problem Formulation Phase, where the measurement endpoints for evaluating each assessment endpoint are selected and evaluated through a weighting process, and (2) in the Risk Characterization Phase, where the magnitude of the observed effect, the quality of the data, and the concurrence of the results of the various measurements are evaluated and weighted or judged on the likelihood and ecological significance of risk.

In the problem formulation phase, the weight-of-evidence approach applied to the selection and weighting of measurement endpoints involves the consideration of three principal components and the attributes associated with each of these components:

- **Strength of Association Between Assessment and Measurement Endpoints—**This attribute indicates the degree to which the measurement endpoint is representative of, correlated with, or applicable to the assessment endpoint. Attributes associated with this component include:
  - Biological linkage between measurement and assessment endpoints.
  - Correlation of stressor to response.
  - Stressor specificity.
  - Availability of an objective measure for judging environmental harm.
- **Data Quality—**This attribute indicates the degree to which data quality objectives established for the measurement endpoint are comprehensive and rigorous.
- **Study Design and Execution—**This attribute indicates the degree to which the study design and execution are applicable to the assessment endpoint. Attributes related to this component include:
  - Site-specificity.
  - Sensitivity of the measurement endpoint to detecting changes.
  - Spatial representativeness.
  - Temporal representativeness.
  - Quantitativeness.
  - Use of a standard method.

The attributes can be defined as characteristics of a measurement endpoint that determine how well it estimates or predicts the effects defined by the assessment endpoint.

The operational definitions for each of the 11 attributes are provided in Table 7-3. For the weight-of-evidence procedure, each of the 11 attributes will be evaluated and an overall assessment of high, medium, or low will be assigned for each measurement endpoint evaluated. Based on the scores and the relative importance of the individual attributes, an overall score of high, medium, or low will be assigned to each measurement endpoint indicating how well the measurement endpoint represents the assessment endpoint. A brief discussion of the overall qualitative weight for each measurement endpoint and the key attributes supporting the weight assigned is presented in the Analysis Phase (Subsection 7.3). This approach is taken so that a more thorough presentation of each measurement endpoint can be provided in conjunction with a

Table 7-3

Attributes for Judging Measurement Endpoints

1. Attributes Related to Strength of Association Between Assessment and Measurement Endpoints
Biological linkage between measurement endpoint and assessment endpoint—This attribute refers to the extent to which the measurement endpoint is representative of, correlated with, or applicable to the assessment endpoint. If there is no biological linkage between a measurement endpoint (e.g., a study that may have been performed for some other purpose) and the assessment endpoint of interest, then that study should not be used to evaluate the stated assessment endpoint. Biological linkage pertains to similarity of effect, target organ, mechanism of action, and level of ecological organization. **Correlation of stressor to response**—This attribute relates to the degree to which a correlation is observed between levels of exposure to a stressor and levels of response and the strength of that correlation. **Stressor specificity**—This attribute relates to the degree to which the measurement endpoint is associated with the specific stressor(s) of concern. Some measurement endpoints may respond to a broad range of stressors, so that it is difficult to interpret results with regard to the stressors of concern, while other measurement endpoints are more specific to a particular stressor. **Availability of an objective for judging environmental harm**—This attribute relates to the ability to judge results of the study against well-accepted standards, criteria, or objective measures. As such, the attribute describes the applicability, certainty, and scientific basis of the measure, as well as the sensitivity of a benchmark in detecting environmental harm. Examples of objective standards or measures for judgment might include ambient water quality criteria, sediment quality criteria, biological indices, and toxicity or exposure thresholds recognized by the scientific or regulatory community as measures of environmental harm.
2. Attributes Related to Data and Overall Study Quality
Quality of data and overall study—This attribute reflects the degree to which data quality objectives and other recognized characteristics of high quality studies are met. The key factor affecting the quality of the data is the appropriateness of data collection and analysis practices. The key factor of the quality of the study is the appropriateness and implementation of the experimental design and the minimization of confounding factors. If data are judged to be of poor or no quality, the study would be rejected for use in the ecological risk assessment.

Table 7-3

Attributes for Judging Measurement Endpoints (Continued)

3. Attributes Related to Study Design and Execution
Site-specificity—This attribute relates to the extent to which media, species, environmental conditions, and habitat types that are used in the study design reflect the site of interest.
Sensitivity of the measurement endpoint to detecting changes—This attribute relates to the ability to detect a response in the measurement endpoint, expressed as a percentage of the total possible variability that the endpoint is able to detect. Additionally, this attribute reflects the ability of the measurement endpoint to discriminate between responses to a stressor and those resulting from natural or design variability and uncertainty.
Spatial representativeness—This attribute relates to the degree of compatibility or overlap between the study area, locations of measurements or samples, locations of stressors, and locations of ecological receptors and their points of potential exposure.
Temporal representativeness—This attribute relates to the temporal compatibility or overlap between the measurement endpoint (when data were collected or the period for which data are representative) and the period during which effects of concern would be likely to be detected. Also linked to this attribute is the number of measurement or sampling events over time and the expected variability over time.
Quantitativeness—This attribute relates to the degree to which numbers can be used to describe the magnitude of response of the measurement endpoint to the stressor. Some measurement endpoints may yield qualitative or hierarchical results, while others may be more quantitative.
Use of a standard method—The extent to which the study follows specific protocols recommended by a recognized scientific authority for conducting the method correctly. Examples of standard methods are study designs or chemical measures published in the Federal Register or the Code of Federal Regulations, developed by ASTM, or repeatedly published in the peer-reviewed scientific literature, including impact assessments, field surveys, toxicity tests, benchmark approaches, toxicity quotients, and tissue residue analyses. This attribute also reflects the suitability and applicability of the method to the endpoint and the site, as well as the need for modification of the method.

Source: Menzie et al., 1996 (99-0041).

brief discussion of qualitative weight assigned. A comprehensive description of the weighting decision and professional judgment involved in this process will be provided in the ERA.

As previously mentioned, the weight-of-evidence approach also plays a key role in the risk characterization portion of the ERA where multiple lines of evidence are brought together. During this process, the outcome of each measurement is evaluated with respect to the magnitude of response. The final step in the whole evaluation of measurement endpoints occurs when the risk assessor integrates the measurement endpoint weight, magnitude of response, and concurrence with other measurement endpoints to determine if the overall evidence indicates a risk of harm to the associated assessment endpoint. A more detailed discussion of this process is presented in Subsection 7.4.3.1 (Lines of Evidence).

7.2.5.2 Study Plans

With the completion of the initial conceptual model and the presentation of the testable hypotheses, a study plan can be developed to address questions/hypotheses concerning the assessment endpoints that were identified. All of the biological studies that were developed to support the conceptual model are presented in Appendix A. These field study plans, in conjunction with the rest of the Work Plan, the Sampling Analysis Plan, and the Quality Assurance Project Plan, comprise the DQO process that ensures that the type, quantity, and quality of data collected during the ecological investigation are adequate to support the intended application. The specific goals of the general DQO process are to:

- Clarify the study objective(s) and define the most appropriate types of data to collect;
- Determine the most appropriate field conditions under which to collect the data; and
- Specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support risk management decisions (99-0138).

Since this ERA section is part of the larger SI Work Plan, many of these issues are covered in other sections (e.g., Subsection 5.5, Biological Investigations) or in the Study Plans themselves. Any relevant analysis plan not previously presented will be included in the following Analysis Phase section.

7.3 ANALYSIS PHASE

7.3.1 Introduction

The analysis phase of an ecological risk assessment consists of the technical evaluation of data on the potential exposure to the stressor(s) identified during the problem formulation and the relationship between those stressors and their ecological effects (Norton et al., 99-0076; EPA, 99-0032). The objective of this portion of the ERA is to provide the information necessary to determine or predict the ecological responses to stressors under the exposure conditions that are present within the study area (99-0033). The analysis phase is based on the conceptual model developed during the problem formulation and consists of two primary components: (1) the characterization of exposure and (2) the characterization of ecological effects. Information typically associated with the analysis phase includes exposure source information; measurements of stressor levels (i.e., chemical concentrations); and direct and indirect measurements of exposure (i.e., exposure models) and biological effects. The format of the analysis phase, in general, follows EPA's *Guidelines for Ecological Risk Assessment* (99-0033) and is presented in Figure 7-4.

In complex assessments such as the Lower River ERA, the exposure and effects characterizations are sufficiently intertwined as to be difficult to distinguish at times. Moreover, there is often significant overlap of information provided in the analysis phase and the risk characterization. This is especially true when incorporating information derived from toxicity tests that evaluate both exposure and effects simultaneously. In the analysis phase, discussions regarding toxicity tests are provided primarily with regard to characterization of ecological effects. In the exposure characterization, data are presented that describe the distribution of the stressor in the affected area and the co-occurrence of the stressor with ecological receptors. In the ecological effects characterization, data are presented that evaluate the relationship between the stressor and the potential response in the ecological receptor. If exposure exists, then the effects characterization presents the line of evidence that links the assessment and measurement endpoints.

The analysis phase focuses solely on discussions of exposure and potential effects. As with the other major sections of the ERA, the analysis phase represents a flexible and potentially iterative process that may be modified as data become available. The risk characterization, which is the final phase of the ERA, presents an integration and interpretation of exposure and effects information.

In the Lower River ERA, as in most ecological risk assessments, direct measurements of exposure and effects are not available for all aspects of the analysis, and, in some situations, the absence of data will require that certain assumptions and their associated uncertainties be recognized. Key assumptions and simplifications made during the analysis phase will be presented and their associated uncertainties discussed.

Because of the absence of site- or condition-specific data for all aspects of the evaluation, the risk assessment process necessarily includes the use of data or approaches that have inherent uncertainty and variability that may limit the interpretive power of the risk assessment. Uncertainty and variability present in the analysis phase most frequently take three forms - parameter variability, measurement error, and extrapolation uncertainty (99-0032):

- *Parameter variability* refers to the true heterogeneity of characteristics; an example of the variability of a characteristic would be the range of chemical concentrations in sediment. Variability can often be quantified by presenting a distribution, or by presenting one or more points of a distribution (e.g., mean, range, and 95 % UCL).
- *Measurement error* is the difference between the true value and the measured value that results from random variation in the characteristic of interest and limited available data.
- *Extrapolation uncertainty*, the last major form of uncertainty, is present in any ecological risk assessment in which the measurement and assessment endpoints are not identical. One of the more common forms of extrapolation uncertainty is encountered when laboratory analyses are used to evaluate an attribute of a natural system. While this type of uncertainty is unavoidable, it can also be reduced by careful attention to study design and the use of good professional judgment and common sense (99-0076).

Where possible, explicit descriptions of the magnitude and direction (i.e., over- or underestimate) of uncertainties presented in the analysis phase are provided. However, although uncertainty-related information is provided throughout the analysis phase, this uncertainty is more fully discussed during the risk characterization phase when the ecological significance of the assessment results is evaluated. In addition, in an effort to more quantitatively characterize uncertainty and variability in parts of the risk assessment process, EPA plans to evaluate the potential for applying probabilistic approaches, such as Monte Carlo analysis, to portions of the exposure characterization and subsequent uncertainty analysis.

The main body of the analysis phase is organized into two subsections: the characterization of exposure (Subsection 7.3.2) and the characterization of ecological effects (Subsection 7.3.3). As stated previously, the information presented in these subsections will be integrated in the risk characterization to estimate the potential for adverse ecological risks resulting from chemical releases at the site.

7.3.2 Characterization of Exposure

The objective of the exposure characterization is to combine the spatial and temporal distributions of both the chemical stressors and the ecological component (i.e., potential species, communities, or habitats) to evaluate the co-occurrence or contact between the stressor and the ecological component (99-0076). The most common approach for characterizing ecological exposure is to measure the concentrations of stressors and combine them with assumptions about receptor co-occurrence, contact, or uptake (99-0032). The exposure characterization attempts to evaluate quantifiable routes of exposure (e.g., direct contact with soil, sediment and surface water; ingestion of surface water and biological tissue) through which species or communities present at the site may be exposed.

The characterization of exposure encompasses two principal activities: (1) a description of the source(s) and the spatial and temporal distributions of stressors within the study area, and (2) a characterization of the potential contact between target receptors and the chemicals of potential concern (COPCs). As part of the first activity, media-specific chemical concentrations, which will be used to directly assess exposure, are summarized in the following subsection. In addition, GIS-generated spatial representations of contaminant distributions will be provided. To the extent data allow, temporal representation of the data also will be provided. As part of the characterization of potential contact between receptors and COPCs, avian and mammalian receptor exposure modeling approaches are presented. A description of exposure models that will be used and the justification for the input parameters selected for each model is provided.

7.3.2.1 Media-Specific Chemical Characterization

This section of the exposure characterization summarizes the types and distribution of COPCs in different media to which various receptors identified in the problem formulation may be exposed. Summary statistics, raw data, and chemical distribution information will be presented only for those COPCs positively identified during laboratory analyses.

Specifically, the exposure characterization will present a summary of existing information and data relating to the nature and extent of COPC contamination in selected environmental media (i.e., surface water, sediment, bank soils, floodplain soils, and biological tissue) within the study area. Several different biological tissues will be analyzed to support the ERA. These tissue types include benthic invertebrates, crayfish, frog, fish, soil invertebrates, duck, tree swallows, and small mammals. These species are potential prey items for mammalian and avian predators and when consumed may result in adverse effects to the target receptor species. Much of these data, and additional tissue types, including macrophytes, algae, phytoplankton, and zooplankton, will be analyzed to support the AQUATOX model, which will evaluate PCB fate and effects in the food chain.

The following narrative provides a discussion of the data evaluation and data reduction procedures that will be used to summarize media-specific data.

The objectives of the data evaluation and reduction are as follows:

- Review and organize analytical data into spatially relevant groups for each medium and for each target species analyzed.
- Discuss the origin and quality of data that will be incorporated into the ecological risk assessment.
- Provide a discussion of data treatment as it pertains to qualified data, duplicate samples, and multiple sampling rounds.
- Summarize data statistically so that appropriate exposure information is readily available and in a form that permits effective comparisons between data groups.

Analytical data will be organized into spatially relevant groups for each of the media. The term "spatially relevant group" refers, in large part, to how a representative exposure of an animal or plant species to a COPC in a specific medium will be defined. Typically, an animal's foraging area is used to estimate the areal extent within which an animal is expected to contact an environmental medium such as soil and any chemical contamination within that soil. The size and the spatial attributes of the foraging area are species-dependent, and the data groupings for each of the target receptors will reflect this dependency. For example, since the foraging radius of a short-tailed shrew is much smaller than that of a red fox, the calculation of an exposure point concentration for incidental soil ingestion for these species would be expected to incorporate different data groupings, provided that the data are available. In many cases not only is the size of the foraging area species-dependent, but it also depends on a number of factors including life stage, dietary requirements, and the proximity of sufficient food to meet those requirements. To the extent this information is available and to the extent that the data will allow, these factors will be considered in establishing the spatially relevant groupings.

Comprehensive discussions of the sampling methodologies and analytical procedures that will be used for the data presented in this assessment can be found in the individual reports referenced throughout the Work Plan. The analysis of the data contained in this risk assessment will be based on guidance presented in *Guidance for Data Usability in Risk Assessment, Part A* (EPA, 99-0084). The following guidelines will be used when evaluating data qualifiers, sample quantitation limits, duplicate samples, and multiple sampling rounds, prior to the data summarization.

- Data qualifiers will be provided by the laboratories with the raw data, and the qualified new data will be used based on established criteria (99-0084). All J-qualified data will be assumed to be valid data. ("J" values are estimated concentrations, usually because they are reported below the minimum confident quantitation limit.)

- All U-qualified data represents non-detected samples for the parameter evaluated. EPA is currently evaluating several approaches for dealing with non-detect (i.e., censored data) and how these approaches may impact the development of exposure concentrations.

- If a sample duplicate is collected and analyzed, the average of the two reported concentrations will be used for subsequent calculations unless there is a greater than 30% difference in surface water concentrations or a greater than 50% difference in soil, sediment, or tissue concentrations, in which case the higher of the two concentrations will be used.

- Data from multiple sampling rounds will be treated as individual, discrete data points.

Prior to calculating summary statistics, a distribution analysis will be performed on the data groupings selected. For environmental data, this analysis typically involves a determination of whether data are normally or lognormally distributed, after which appropriate summary statistics are calculated. Summary statistics that will be presented include measures of central tendency, sample variability, and, if sufficient data are available, cumulative distribution functions.

As is typical of most risk assessments, the lower of the maximum detected concentration and the upper 95% confidence limit (UCL) concentration based on the mean will be used to estimate the exposure point concentrations for each of the exposure media, whenever a deterministic model (see following subsection) approach is used. The 95% UCL values will be calculated using the guidelines presented in *Supplemental Guidance to RAGS: Calculating the Concentration Term* (EPA, 99-0003).

In situations where a Monte Carlo simulation is applied (see following subsection), multiple exposure point concentrations will be established by random sampling of the proposed media-specific concentration distribution.

In addition, for some data, such as floodplain soils and sediments, spatial averaging techniques may be considered depending on, among other things, spatial distribution of the data, data density, and variability in the area of concern (e.g., foraging radius, habitat, or river reach). Surface averaging techniques that may be evaluated include non-interpolative techniques, such as Thiessen polygon and Zone of Influence methods, and interpolative techniques, such as Inverse Distance Weighting (IDW). Of course, all averaging methods have their strengths and weaknesses, which will be evaluated once the data are available and the chemical database is fully populated. The suitability of these techniques for specific circumstances can then be fully evaluated.

In general, summary information provided for each data group will include frequency of detection, range of detected concentrations, range of sample quantitation limits, mean concentration, standard deviation, and the 95% UCL. In addition to tabular summaries of data previously discussed, the exposure characterization will also use GIS as a tool for illustrating contaminant distribution and stressor/receptor co-occurrence, thereby providing a spatial dimension to the exposure assessment.

7.3.2.2 Avian and Mammalian Receptor Exposure Modeling

The potential for food chain impacts of bioaccumulative chemicals in both aquatic and terrestrial systems is well recognized. Because of the significant biomagnification potential associated with PCBs and the potential risk to terminal receptors in the food chain, representative upper trophic level receptors will be evaluated as part of the ERA. Since fish generally represent the terminal receptor in aquatic systems, avian and mammalian species foraging upon these fish may be at substantially higher risk than those receptors at a lower trophic level. Consequently, piscivorous avian and mammalian species that forage from the affected portions of the Housatonic River will be evaluated as representative ecological receptors.

Since bioaccumulation and trophic transfer are also potential pathways in terrestrial ecosystems, the ERA will also evaluate potential exposure to several primarily carnivorous receptors that inhabit the Housatonic floodplain. All of the species selected for evaluation are known or expected foragers within the study area. While several potential exposure pathways will be evaluated (e.g., soil or sediment ingestion, surface water ingestion) for each receptor, the primary exposure pathway will be through the ingestion of animal tissue.

Exposure models incorporated in the ERA will take the following general form:

$$EDI_{total} = EDI_{tissue} + EDI_{soil/sediment} + EDI_{surface\ water}$$

and

$$EDI_{tissue} = (C_{tissue} \times IR_{tissue} \times FI_{tissue}) / BW$$

$$EDI_{soil/sediment} = (C_{soil/sediment} \times IR_{soil/sediment} \times FI_{soil/sediment}) / BW$$

$$EDI_{surface\ water} = (C_{surface\ water} \times IR_{surface\ water} \times FI_{surface\ water}) / BW$$

where:

EDI_{total} = Total estimated daily intake (mg/kg-day).

EDI_{tissue} = Estimated daily intake through tissue ingestion (mg/kg-day).

$EDI_{soil/sediment}$ = Estimated daily intake through soil/sediment ingestion (mg/kg-day).

$EDI_{surface\ water}$ = Estimated daily intake through surface water ingestion (mg/kg-day).

C_{tissue} = Chemical concentration in tissue (mg/kg fresh weight).

$C_{soil/sediment}$ = Chemical concentration in soil/sediment (mg/kg).

$C_{surface\ water}$ = Chemical concentration in surface water (mg/L).

$IR_{soil/sediment}$ = Soil/sediment ingestion rate (kg dry weight/day).

IR_{tissue} = Tissue ingestion rate (kg fresh weight/day).

$IR_{surface\ water}$ = Surface water ingestion rate (L/day).

FI_{tissue} = Fraction of tissue ingested from contaminated area (unitless).

$FI_{soil/sediment}$ = Fraction of soil/sediment ingested from contaminated area (unitless).

$FI_{surface\ water}$ = Fraction of surface water ingested from contaminated area (unitless).

BW = Body weight (average) (kg).

7.3.2.2.1 Modeling Approaches

Two modeling approaches exist for quantifying risk and they differ dramatically in the level of effort involved and in their abilities to distinguish variability and uncertainty (Thompson and Graham, 99-0347). The first and most commonly used approach is the “point estimate” or “deterministic” approach, which involves selecting a single number for each of the model inputs from which a point estimate of risk is generated. Choosing single numbers for inputs reduces the level of effort required for the exposure modeling process, but unavoidably ignores uncertainty and variability in the risk estimate. In contrast, the probabilistic approach (e.g., Monte Carlo simulation) can be a viable statistical tool for analyzing uncertainty and variability. These input distributions are then propagated through the model to produce a probability distribution of risk.

As was previously mentioned, a number of receptor-specific exposure models are planned for the ERA. In an attempt to limit the effort expended as part of the exposure modeling process, a “tiered approach” that includes fairly simple deterministic models and progresses to more sophisticated probabilistic models (i.e., Monte Carlo-based) will be used. This approach will begin by using conservative point estimates in deterministic models to evaluate risk. Should exposure levels calculated fall above levels of concern, then professional judgment will be used to determine if Monte Carlo analysis is warranted. The following discussion provides an overview of the Monte Carlo analysis process and key evaluation points that should be considered when ecological exposure models using Monte Carlo analysis are generated.

Monte Carlo Analysis

The EPA Science Policy Council (99-0299) outlined the conditions for using Monte Carlo analysis to develop more realistic risk assessments. Although the Council principally addressed the use of probabilistic assessment techniques in the characterization of human health risks, Monte Carlo analysis, nevertheless, has utility in the characterization of ecological risk. Monte Carlo methods use numerical simulation involving the sampling of pseudo-random numbers to solve estimation problems (Morgan and Henrion, 99-0294; Cullen and Frey, 99-0283; Reinert et al., 99-0297; Warren-Hicks and Moore, 99-0302). In Monte Carlo simulation, statistical distributions are used to represent the uncertainty in all or some of the input variables for a mathematical expression of interest; for example, a dietary exposure model for the great blue heron. The purpose of expressing an exposure factor as a set of possible values is to describe the range, variability, and uncertainty for each factor. Specific values for the model inputs are randomly selected from the distribution of data for that input and the results of those selections on the model are evaluated. The process is repeated many times and the distribution of the model results obtained over the many replications reveals the range of possible outcomes. As such, the result of a Monte Carlo simulation is a probability distribution of risk with a most likely value, an average value, extreme values, and a shape that describes the variability and uncertainty associated with the calculated risk.

Choosing Input Distributions—Of particular importance in performing the Monte Carlo analysis is the selection of the statistical distributions of the input variables that will be used to model the variability and uncertainty for each of the model's variables. For many of the input variables used in the ERA, little empirical data are available with which to determine the underlying probability distribution. For those situations for which data are severely limited, several approaches to assigning a distribution are generally evaluated and include the use of (1) default distributions; (2) empirical distributions; (3) maximum entropy; (4) extrapolation; and (5) elicitation from experts.

Default distributions represent those distributions whose shapes and possibly even parameters are specified in advance of performing the assessment. An example might be the use of a triangular distribution with some knowledge of the minimum, most likely, and maximum expected values. Although default input distributions are still common throughout risk assessment, they often represent an arbitrary selection.

Empirical distributions make use of the existing data to determine the underlying distributions. When data are abundant or when the input variable is "data-rich," this approach provides an excellent characterization of the patterns of variability. When data are more sparse, the characterization may still be reasonably good depending on the degree to which the data are representative of their underlying distribution.

The maximum entropy approach essentially uses whatever information is available about the variable to define the distribution. This approach makes no assumptions regarding the shape of the distribution but allows one to select the input distribution in an optimal way using only limited information about the varieties (Grandy and Schick, 99-0287; Lee and Wright, 99-0291).

In the absence of species-specific or other specific data with which to characterize a distribution, data from related or surrogate species may be used to extrapolate an input variable distribution for the target species. Nevertheless, the use of surrogate data usually requires theoretical justifications (e.g., similarity of species) for its use.

Finally, in the situation where available information on an input variable is "data-poor," elicitation of information from experts may be considered. For example, local fishermen may be expected to be more knowledgeable about fish catch and consumption patterns from local waters than published information from unrelated water bodies or geographical areas. There are various approaches to eliciting information about input variables from experts or otherwise knowledgeable persons. These approaches range from simply asking them in informal and uncontrolled settings to making inquiries in more formal, organized gatherings (Morgan and Henrion, 99-0294; Warren-Hicks and Moore, 99-0302; Cooke, 99-0282; Meyer and Booker, 99-0293).

The approaches discussed above and possibly others can be used to specify the input distributions in the ecological risk assessment for the Housatonic River. The approach(es) used will depend on the availability of relevant empirical information about each variable. For some variables, there may be enough empirical information to fit parametric distributions or even specify empirical histograms. For other variables, the available data may be limited or completely absent, in which case one of the less information-intensive approaches will be used.

Correlation and Dependence Among Variables—In many of the commercial software packages available for performing Monte Carlo simulations (e.g., Crystal Ball [Decisioneering, 1998]; @Risk [Palisade, 1998]), input variables are generally treated as statistically independent of one another unless specifically instructed otherwise. This default condition is generally not appropriate for ERAs where numerous ecological phenomena can produce complex dependencies that, although perhaps empirically subtle, can have a substantial impact on the risk that is being estimated (Ferson, 99-0284). Peer review of ERA guidance from EPA (Risk Assessment Forum, 99-0300) identified the evaluation of the effect of the assumption of independence on the propagation of error as one of three primary research needs under the topic of uncertainty in ERAs. Failing to account for patterns of correlation and dependency can result in substantial under- or over-estimates of the dispersion (variance) and tails of the risk distribution. There are several strategies that are typically used to account for knowledge and uncertainty about correlations and dependencies in an ecological risk analysis. These strategies are listed below. For a description and discussion of these approaches, the reader is referred to the following references:

- Simulation of observed correlations (Scheuer and Stoller, 99-0298; Iman and Conover, 99-0267; Nelsen, 99-0295, 99-0296; Clemens and Reilly, 99-0281; Lurie and Goldberg, 99-0292; Cario and Nelson, 99-0280).

- Assumption of perfect covariance (Bratley et al., 99-0278; Frechet, 99-0286; 99-0285; Hoeffding, 99-0288).
- Stratification (Frey, 99-0333).
- Conditioning (Voit et al., 99-0301).
- Modeling dependencies (Cullen and Frey, 99-0283).
- Linear dependency (Bukowski et al., 99-0279; Ferson, 99-0284; Bratley et al., 99-0278; Whitt, 99-0303).
- Dependency bounds analysis (Frank et al., 99-0264; Williamson and Downs, 99-0272; Ferson and Long, 99-0263).

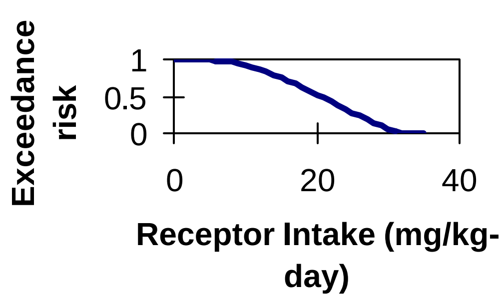
One or more of the approaches presented above will be used to account for correlations and dependencies. The specific approach to be used is data-dependent. Assumptions regarding the correlations and dependencies as well as justification for the approach selected and a discussion of how the dependency structure was simulated will be provided in the ERA.

Once the shapes and the parameters of the input distributions and their dependencies have been decided, a number of commercial software programs (referred to above) are available with which to generate numeric values for each input (randomly selected according to their respective distributions). Two methods for random sampling from the probability distributions are available in the simulation software: traditional simple random sampling and Latin hypercube. Traditional Monte Carlo analysis uses random (or pseudorandom) numbers to sample from the input distribution. One of the shortcomings of the technique is that the samples are more likely to be drawn from values that have higher probabilities, i.e., near the mode, and less likely to be drawn from values that have low probabilities, i.e., near the tails of the distribution. In order to compensate for this, multiple iterations (often greater than 1,000 trial runs) of the simulation are necessary to guarantee representative sampling of the distribution. In addition to simple random sampling, most simulation software can also run simulations using Latin hypercube sampling. This technique uses random sampling within intervals of the input cumulative frequency distribution. Latin hypercube minimizes the number of iterations necessary to sufficiently represent the distribution. When combining distributions of multiple variables, Latin hypercube maintains complete independence of the variables. If any correlation between variables is expected, the method allows for a variable to be defined as a function of a related variable. It is expected that one of the commercial packages will be acceptable for running the probability simulations if needed for the ERA.

***Presentation of Monte Carlo Results*—**As an overview, Monte Carlo results, if generated, will be supported by graphs and tables describing each input distribution, the risk distribution for each exposure route, and the distribution of total ecological risk. More detailed presentations of the Monte Carlo inputs and outputs will be included as noted below.

All input parameters and conditions specific to the model run will be presented. First, summary inputs used in the assessment will be presented; most likely by listing the input run stream or presenting the input files used. Second, each variable and constant used in the model will be characterized and a synopsis as to its estimation or a reference given. Finally, how the simulation was conducted will be described. Any programming or software, along with its vendor, and all program options and settings used during the assessment will be referenced. The results will also include the number of Monte Carlo replicates, the sampling strategy used, the random number generator algorithm used, and the value of the random number generator seed.

Since quantitative results of a Monte Carlo output presented in extensive tabular displays or text are often difficult to interpret, wherever possible, results will be displayed in graphs or figures. Traditionally, probability distributions are displayed as probability density functions (PDFs) or cumulative probability functions (CDFs). In an ERA, risk managers are particularly interested in the chances that the outcome will be adverse and, if so, how severe it might be. For this reason, it is almost always the tail probabilities that are of primary concern in a Monte Carlo risk assessment. When adversity is associated with high values of the random variable rather than low values, it is often convenient to invert the graph to display the complementary cumulative distribution function (CCDF). The graph below is an example of a distribution that might arise from such a simulation. The y-axis is cumulative probability for the random variable receptor



intake and it gives the risk (i.e., probability) that a receptor intake exceeds a level given on the abscissa (x-axis). The y-axis can be labeled "exceedance risk" because it gives the probability of the quantity of interest (e.g., intake) exceeding any threshold value (given on the x-axis). The example outlined in the graph below shows that there is approximately a 50% chance that the dietary intake will be greater than 20 mg/kg-day. The chance is small that the intake will be greater than 30, and practically zero that it will be greater than 35.

Full reports (both input and output) generated from the Monte Carlo analysis may be included in the risk assessment as one or more appendices, with highlights being presented within the body of the text.

7.3.2.3 Other Exposure Assessment Methodologies

Exposure modeling, whether probabilistic or deterministic, represents one of many ways to characterize exposure. The results generated from chemical analysis on tissue samples (that is, determining residue concentrations) can be used for the characterization of exposure as well. Concentrations of chemicals are determined within organisms (i.e., whole body) or within specific tissue (e.g., liver), thereby reducing the uncertainty associated with using generic bioaccumulation factors to predict tissue levels. These uncertainties are reduced since the direct measurement of residue concentrations explicitly incorporates site- and organism-specific bioavailability, accumulation kinetics, uptake from food in addition to the ambient environment (e.g., surface water in the case of fish), and metabolism (McCarty and Mackay, 99-0317). Tissue for analysis will be collected from benthic invertebrates, crayfish, frogs, fish, soil invertebrates, ducks, and small mammals. Results from these tissue analyses will be used to assess effects to the organisms themselves, to determine the effects of contamination on higher trophic level species during exposure modeling, and to determine whether there is a difference in contaminant concentrations between the study and reference areas. Additional advantages of determining residue concentrations are presented in Subsection 7.3.3.1.1, Stressor-Response Analysis.

In addition to direct measurement of contaminant levels in tissues, biomarkers such as cytochrome P450 and EROD can be used as indicators of exposure to specific contaminant groups. The use of biomarkers in effect provides an additional line of evidence when trying to identify a causal relationship between contaminants and potential or observed adverse ecological effects. Biomarker evaluations will be employed in several of the ERA studies, including the fish and mink toxicity testing, and are discussed in more detail in Appendix A.

Other methodologies that will play a critical role in assessing exposure (in conjunction with effects) include: macroinvertebrate sediment toxicity testing, in situ freshwater mussel bioaccumulation and condition testing, amphibian toxicity testing, fish toxicity testing, tree swallow testing, and mink toxicity testing. A more comprehensive list of these methodologies is provided in Subsection 7.3.3.

7.3.3 Characterization of Ecological Effects

The Ecological Effects Characterization is the qualitative and quantitative description of the relationship between the stressor and response (effects) in the exposed individuals, populations, or ecosystems (Suter, 99-0037), and, more specifically, the relationship between stressors and the assessment and measurement endpoints identified during the Problem Formulation (Norton et al., 99-0076). The Characterization of Ecological Effects begins with an evaluation of effects data in the scientific literature relevant to the COPCs (e.g., PCBs). The majority of effects data for many of the COPCs that exist in the literature are based on toxicity texts conducted with the contaminant added to water, sediment, or food, or from tests of direct exposure to contaminated water and sediment. Specifically, for the ERA, ecological effects will be primarily characterized by:

- Comparisons with EPA's Freshwater Ambient Water Quality Criteria and other appropriate surface water quality benchmarks.
- Comparisons with sediment guidelines [including, but not limited to, Ontario Ministry of the Environment and Energy (OMEE) and NOAA effect levels, and values based on the equilibrium partitioning approach].
- Benthic invertebrate community evaluation.
- Sediment macroinvertebrate toxicity, bioaccumulation, and stressor identification.
- Freshwater mussel inventory and in situ bioaccumulation and condition study.
- Amphibian toxicity testing, field surveys, and in situ reproduction evaluation.
- Fish health and toxicity testing.

- Comparisons of fish tissue concentrations with established effect levels and reference area concentrations.
- Tree swallow nestling accumulation and toxicity studies.
- Mink toxicity testing.
- Comparisons of modeled avian and mammalian exposure doses with literature-based toxicity data.

In addition, numerous tissue samples have been collected in support of the ecological exposure assessment and AQUATOX modeling. To date, comparable literature-based tissue effect levels have not been identified for macrophytes, filamentous algae, phytoplankton, crayfish, bullfrog, soil invertebrates, waterfowl, and small mammal tissue concentrations. If comparable literature-based residue effects data are identified through various literature and toxicity database searches, comparisons of tissue concentrations with the literature-based residue effects data will be added as another line of evaluation to characterize ecological effects.

In general, most risk assessments have found that using a “suite” of stressor-response approaches, such as those selected for this site, provides a more complete characterization of ecological effects (99-0032).

Because assessment endpoints frequently cannot be measured directly, one or more measurement endpoints are selected as surrogates to characterize assessment endpoints. Surrogate selection is accomplished by first establishing the relationship between the stressor and assessment endpoint, then identifying relevant measurement endpoints and any additional extrapolations, analyses, and assumptions necessary to predict or infer changes in the assessment endpoint. Table 7-3 of the Problem Formulation (Subsection 7.2) presents the assessment and measurement endpoints that were selected for evaluation in the ERA.

As the cause-effect relationship between the measurement endpoint and the assessment endpoint becomes stronger, the uncertainty in extrapolation of the effects data in the risk assessment is reduced. Similarly, the more closely related the test species is to the species of interest, the less uncertainty there is in the risk assessment (Suter, 99-0043, 99-0037). Extrapolations that frequently occur in an ERA include those from laboratory to field conditions, across taxonomic classifications, and across spatial and temporal scales.

For the most part, this ERA will concentrate on evaluating direct effects that may be associated with contaminant exposure in various media throughout the affected portion of the Housatonic River to eliminate the uncertainties that are associated with extrapolation. However, when supported by the scientific literature, indirect effects that also may be associated with site contamination will be discussed.

Another component integral to the Characterization of Ecological Effects is the selection of stressor-response data that best illustrate a causal relationship. Attributing the causality of effects, particularly with complex mixtures of chemicals and stressors, continues to be a challenge in ERAs. Individual stressors rarely occur alone; typically there are a host of other chemical, biological, or physical stressors that co-occur and that may alter or compound the effects and risk associated with the subject stressor, thereby increasing the difficulty and uncertainty when trying to identify causality. Physical stressors, such as the channelization of the Housatonic River through Pittsfield, have altered the natural habitat and could confound the identification of causality.

As stated previously, the most valuable approach for assessing effects and causality is to provide multiple lines of evidence. The key lines of evidence that can be provided to assist in assigning cause-and-effect relationships, which were formalized by Hill (99-0069) and adapted to risk assessment by Suter (99-0043), are summarized as follows:

- Analogy—Cause-and-effect relationship similar to well-established cases.
- Experiment—Changes in effects should follow experimental treatments representing the hypothesized cause.
- Coherence—Implicit relationships should be consistent with available evidence.
- Plausibility—Underlying theory should make it plausible that the effect resulted from the cause.
- Biological gradient—Effect should increase with increasing exposure.
- Temporality—Cause must precede its effect.
- Strength—High magnitude of effect is associated with exposure to stressor.
- Specificity—The more specific the cause, the more convincing the association with an effect.

- Consistency—Consistent association of an effect with a hypothesized cause.

This approach is similar to and consistent with several of the attributes used to assess potential weights associated with each measurement endpoint (see Subsection 7.2.5.1).

While information relevant to illustrating a causal relationship between stressor and response needs to be provided in the Characterization of Ecological Effects, the interpretation of the strength of this relationship is presented in the Risk Characterization.

The remainder of the Characterization of Ecological Effects is divided into two main subsections: 1) Ecological Response Analysis and 2) Stressor-Response Profile. These subsections are presented in detail below.

7.3.3.1 Ecological Response Analysis

The ecological response analysis will provide information on three main subject areas:

- Stressor-response analysis—Provides a description of the potential types of stressor-response relationships; a description of the specific effects information that will be used in the ERA; and a general discussion of the qualitative weight-of-evidence associated with each measurement endpoint or endpoint group.
- Causality—Provides a description of the general criteria that will be used to assess the strength of causal relationships between stressors and response.
- Linking measures of effects to assessment endpoints—Provides a discussion type of extrapolations typically required to link measurement and assessment endpoints.

These subject areas will examine the relationship between stressor levels and effects, present the supporting evidence that the stressor causes the effect, and provide a link between the measurable effect and the assessment endpoint (99-0033). This information will be combined and assessed in the Lines of Evidence portion of the Risk Characterization. The following subsections provide a more detailed discussion of the key components essential to developing a comprehensive ecological response analysis.

7.3.3.1.1 Stressor-Response Analysis

The stressor-response relationship used in an assessment depends on the scope and nature of the ecological risk assessment defined in the problem formulation. Several different relationships can be established, including:

- Single point estimates.
- Stressor-response curves.
- No-effect levels.
- Cumulative effects distributions.

The majority of quantitative techniques have been developed for univariate analysis. These studies, in which one response variable (e.g., incidence of abnormalities, mortality) is measured, reflect the simplest stressor-response relationship. Multivariate techniques, those in which the response of interest is composed of many individual variables (e.g., abundances in an aquatic community), have long been used in ecological evaluations (99-0033).

The different stressor-response relationships have inherent uncertainties. Point estimates can be useful in simple assessments or to compare risks, but provide little information regarding uncertainty and variability surrounding the point estimate (99-0033).

Curve-fitting approaches are advantageous in that all of the available experimental data are used, and values other than the data points measured can be interpolated. However, sufficient data points necessary to complete the curve may not be available. Sometimes, particular levels of effect (e.g., LD_{50}) are determined from curve-fitting analyses. These are point estimates interpolated from the fitted line. Although the level of uncertainty is minimized at the midpoint of the regression curve, a 50% effect level may not be protective for the assessment endpoint (99-0033).

When a no-effect level is established, it is based on comparisons between experimental treatments and control treatments. Statistical hypothesis testing is generally used for this purpose. With this method, the risk assessor does not pick an effect level of concern, and the no-effect level is determined by the experimental conditions (e.g., number of replicates and data variability). Uncertainty exists with using this relationship when the stressor levels or receptors in the control differ from those used in the experiment. Statistical hypothesis testing also is used often in observational field studies to compare site and reference conditions. Confidence in statistical hypothesis testing can be increased through the use of experimental field studies, which, unlike observational studies, can be replicated (99-0033).

Multiple-point estimates that can be displayed as cumulative effects distribution functions are generated from combining experimental data. Distributions can be used to identify stressor levels that affect different numbers of species. The amount of data necessary to derive these distributions is often a limiting factor. Cumulative effects distribution functions can also be derived from probabilistic methods such as the Monte Carlo method (99-0033).

The stressor-response analysis becomes more intricate when multiple stressors are present (e.g., more than one COPC). Although it is preferable to directly evaluate chemical mixtures present in environmental media, the relationships between the samples tested and the potential spatial and temporal variability in the mixture must be considered. Multiple stressors can, at times, be empirically related to a response through the use of a multiple regression analysis. However, if the stressors are dependent upon each other, the analysis can be difficult to interpret. A principal components analysis can be used to extract independent variables (stressors) from linear combinations of the original variables (99-0033).

The measures to be evaluated in this risk assessment will be related to effects using all of the above approaches. The specific ecological effects to be characterized in this ERA were listed at the beginning of Subsection 7.3.3, Characterization of Ecological Effects. The following subsections briefly discuss the protocols for the studies used to determine the site-related ecological effects and present the weight-of-evidence for each study. The measurement endpoints are classified into three categories: (1) Sediment and Surface Water Effects, (2) Floodplain Soil Effects, and (3) Avian and Mammalian Effects Evaluation. Endpoints were assigned to these groups based on the primary medium (sediment, surface water, or soil) through which the receptor may be exposed to COPCs. Higher trophic level receptors, such as tertiary avian or mammalian species that may be exposed to both aquatic and terrestrial sources of COPCs, are discussed under Avian and Mammalian Effects Evaluation. The appendices containing the specific protocols are referenced within the brief description of each study, and all associated chemical analyses are presented in the associated appendices and Subsection 5.5.

The use of tissue residue concentrations is applicable to many of the measurement endpoints listed below. Although tissue residue concentrations have been described as being useful for the characterization of exposure, tissue chemical analysis also is useful in the characterization of effects. Where data are available, residue concentrations provide the ability to relate body or specific tissue (e.g., liver) residues to various acute and chronic effects determined in toxicity tests and other investigations. In addition, using residues has several advantages over comparisons between media concentrations and criteria because toxic potencies are less ambiguous, allowing for the identification and investigation of different modes of action; mixture toxicity is more readily assessed; and experimental verification can be determined in the lab and field. This method also avoids using a surrogate, such as the amount of toxicant in the water, to represent the amount of toxicant in the organisms at the site of the toxic action producing the observed effect. The advantages of residue use do not invalidate or render useless the exposure concentration methodology. Providing that intermediary relationships are understood, an exposure dose still can be an effective surrogate dose (McCarty and Mackay, 99-0317).

As noted in Subsection 7.2.5, "Selection of Measurement Endpoints," literature-based tissue effect levels comparable to the endpoints selected for this ERA are lacking for macrophyte, filamentous algae, periphyton, plankton, crayfish, bullfrog, soil invertebrate, duck, and small mammal tissue concentrations. Therefore, comparisons to literature-based effect levels are not currently considered a measurement endpoint. Although the tissue concentrations will be used mainly in the exposure characterization, the tissue sampling will be discussed along with the studies providing measurement endpoints below because:

- They will be used to model dietary intakes of higher trophic level organisms to ultimately determine potential effects.
- Comparable literature-based residue effects data may be identified and comparisons with site-specific tissue residue concentrations deemed appropriate to be incorporated into the ERA as measurement endpoints.

Sediments and Surface Water Effects

Numerous evaluations will be used to assess effects to ecological entities primarily from the exposure to COPCs in sediments and surface water. These evaluations include: (1) comparisons with benchmarks and criteria; (2) benthic invertebrate community evaluation; (3) sediment toxicity tests; (4) mussel studies; (5) amphibian toxicity testing, field surveys, and in situ reproduction evaluations; (6) fish health and toxicity testing; and (7) comparison of fish tissue concentrations with established effect levels, and are discussed in the following subsections. In addition, tissue sampling associated with aquatic-related biota (e.g., macrophytes, filamentous algae, periphyton, plankton, crayfish, and bullfrogs) are presented.

Macrophytes, Filamentous Algae, Periphyton, and Plankton/Detritus Sampling— The lower reaches of the Housatonic River have physical properties conducive to the propagation of vegetative and planktonic communities that contribute significantly to the nature of the aquatic ecosystem in addition to forming the base of many aquatic food chains. Because these communities are intimately associated with the sediments and surface water, they are likely contacting and may be accumulating PCBs.

The major objectives of this sampling effort are to provide biomass per unit area (standing crop) during a period when significant biomass is present and to determine contaminant concentrations in macrophytes, filamentous algae, periphyton, and plankton/detritus. A secondary objective is to provide contaminant concentrations.

Macrophytes, filamentous algae, periphyton, and plankton/detritus will be sampled from the four major aquatic habitats that occur in the study area (i.e., shallow, swift stream; deep, slow river channel; backwater; and pond) for chemical analysis. The deep, slow river channel habitat will be further partitioned into two study reaches to address the potential influence of discharges from the WWTP on the aquatic system, and two areas consisting largely of shallow, swift stream habitat have been identified for sampling at the upstream end of the study area.

As previously noted, the major use of the macrophyte, filamentous algae, periphyton, and plankton/detritus chemical data is for the AQUATOX model (see Subsection 5.5.1). In the ERA, the potential use of this data is to provide actual tissue concentrations for contaminant exposure dose estimation in higher organisms. In addition, if appropriate data are available from the scientific literature, potential effects to macrophytes, filamentous algae, periphyton, and plankton from COPCs may be evaluated by comparing COPC concentrations in the respective tissues to literature-based concentrations in tissues of these organisms exhibiting symptoms of toxicity. A complete discussion of the study plan for the macrophyte, filamentous algae, periphyton, and plankton/detritus sampling is provided in Appendix A.5.

Comparison of Surface Water Concentrations with Benchmarks and Criteria—Potential direct effects associated with surface water contamination at the site will be evaluated by comparing detected COC concentrations in surface water with federal and state criteria and effects-based benchmarks.

Point estimate surface water concentrations will be compared with EPA's ambient water quality criteria (AWQC) for the protection of aquatic life for both acute and chronic exposure. (Note that MADEP uses federal AWQCs and does not have its own water quality values). Under CERCLA, AWQC are considered applicable or relevant and appropriate requirements (ARARs). EPA's 1985 Guidelines (99-0111) describe an objective, internally consistent and appropriate way for deriving chemical-specific, numeric water quality criteria for the protection of the presence of, as well as the uses of, fresh water aquatic organisms. AWQC are derived to protect most of the aquatic communities and their uses most of the time (99-0346). When sufficient data are available to support their derivation, EPA provides acute criteria or criterion maximum concentration (CMC) that correspond to concentrations that would cause less than 50% mortality in 5% of the exposed population in a brief exposure (99-0081). Chronic criteria or criteria continuous concentration (CCC) are selected by choosing the most protective value after reviewing and analyzing acute and chronic toxicity information for aquatic organisms, aquatic plants, and tissue residue level studies that demonstrate a water tissue concentration relationship that is unacceptable for consumption by humans or wildlife. If an AWQC for a chemical is unavailable or based on a questionable receptor for the site, the lowest observable effect level (LOEL) determined by EPA (99-0110), or literature-based lowest observable effect concentrations (LOECs) may be used for the comparison with surface water concentrations. Other appropriate benchmarks (e.g., Tier II values calculated by Suter and Tsao [99-0316]) may be selected to identify surface water concentrations associated with deleterious effects on aquatic biota.

In general, the surface water concentration comparisons with benchmarks or criteria will be given a Low to Medium weight when evaluating potential adverse impacts to survival, growth, or reproductive success in endemic benthic and fish communities. Whereas the databases used to develop these benchmarks and criteria are robust, their major limitation is a limited ability to incorporate site-specific conditions when assessing the potential for adverse effects.

Sediment Quality Triad—The Sediment Quality Triad (Triad) approach is an effects-based approach used to describe sediment quality that incorporates benthic infaunal community evaluations, sediment chemistry, and sediment toxicity to determine the extent of pollution-induced effects in sediment. This approach also may be used to prioritize and rank areas and to predict where effects will occur based on contaminant levels and toxicity. Sediment toxicity, contamination, and biological alterations are independently measured and a weight-of-evidence is used to assess sediment quality based on all three measurements (99-0050, 99-0052). Measurements used in the Triad approach are discussed below.

Comparison of Sediment Concentrations with Benchmarks and Guidelines—Potential direct effects associated with sediment contamination at the site will be evaluated by comparing detected COPC concentrations in sediment with several effects-based guidance values and equilibrium-partitioning approach (EqP)-based effect levels.

Effects ranges reported in the OMEE Sediment Quality Guidelines (Persaud et al., 99-0015) and the NOAA Sediment Screening Guidelines (Long et al., 99-0014) will be used to identify concentrations above levels associated with deleterious effects on fish and invertebrates. OMEE Sediment Quality Guidelines were derived specifically for freshwater sediments, while NOAA effects levels are based on a database that includes only estuarine and marine species and environments. The effects levels reported by NOAA have been evaluated against numbers derived for freshwater systems and found to be comparable (99-0014).

The OMEE Sediment Quality Guidelines (99-0015) define three levels of chronic effects on benthic organisms. The no-effect level is defined as the level at which no toxic effects have been observed on aquatic organisms and food chain biomagnification is not expected. The lowest-effect level (LEL) indicates a level of sediment contamination that can be tolerated by most benthic organisms. The severe-effect level (SEL) indicates a level of contamination at which pronounced disturbance of sediment-dwelling organisms will occur and the contaminant concentration will be detrimental to the majority of benthic species (99-0015). For this assessment, both LELs and SELs will be used to assist in evaluating potential effects on the benthic community.

Using data from samples collected primarily from marine and estuarine environments, Long et al. (99-0014) reported the lowest (ER-L) and median (ER-M) effects ranges from a database compiled from nearly 350 publications, 89 of which met the strict screening criteria for inclusion in the evaluation. The ER-L is a concentration equivalent to the lower 10th percentile of the range of reported values associated with biological effects, a concentration below which effects were rarely observed. The ER-M represents the 50th percentile of the data in which effects were observed, a concentration above which adverse effects were frequently or always observed or predicted with most aquatic species tested (99-0014). For this assessment, ER-Ls and ER-Ms will be used in conjunction with OMEE guidelines to evaluate potential impacts of the COPCs on the benthic community within the Housatonic River study area.

Sediment or chemical quality characteristics at a site alter the bioavailability and consequently the toxicity of contaminants in sediment. In the case of nonionic hydrophobic chemicals, like PCBs, research has demonstrated that sediment toxicity is governed by chemical concentrations in interstitial waters and that sediment organic carbon content has a direct influence on the partitioning from sediments to interstitial water (Di Toro et al., 99-0013). The U.S. EPA Science Advisory Board has endorsed the EqP for developing sediment guidelines as the most defensible approach for establishing numerical chemical-specific concentrations for nonionic hydrophobic chemicals (EPA, 99-0016, 99-0083). The three principal observations that underlie the EqP method for establishing sediment quality guidelines (SQGs) are:

- The concentrations of nonionic organic chemicals in sediment, expressed on an organic carbon basis, and in pore water correlate to observed biological effects on sediment-dwelling organisms across a range of sediments.
- Partitioning models can relate sediment concentrations for nonionic organic chemicals on an organic carbon basis to freely dissolved concentrations in pore water.

- The distribution of sensitivities of benthic and water column organisms to chemicals is similar, thus the currently established water quality criteria (WQC) final chronic value (FCV) can be used to define the acceptable effects concentration of a chemical freely dissolved in pore water (EPA, 99-0018).

EPA has published EqP-based guidelines only for dieldrin, endrin, acenaphthene, fluoranthene, and phenanthrene. If the COPC selection process determines that other nonionic organic compounds are of concern, the EqP methodology using the freshwater chronic AWQC or other appropriate water quality measures will be used to calculate an EqP-based value to assess potential impact. Other appropriate benchmarks may be selected to identify sediment concentrations above levels associated with deleterious effects on sediment-dwelling invertebrates. For example, Ingersoll et al. (99-0318) biological effect levels and Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (99-0315) may also be used to assess potential sediment toxicity.

In general, the sediment concentration comparisons with benchmarks or guidelines will be given a Low to Medium weight when evaluating potential adverse impacts to survival, growth, or reproductive success in endemic benthic and fish communities. Whereas the databases used to develop these benchmarks and criteria are robust, their major limitation is a limited ability to incorporate site-specific conditions when assessing the potential for adverse effects.

Benthic Macroinvertebrate Community Evaluation—The benthic macroinvertebrate community in streams, rivers, and ponds plays a key role in ecosystem functions, such as nutrient cycling, organic matter processing, and as an important food source for instream consumers, as well as some bird and mammal species. Benthic macroinvertebrates are relatively sedentary organisms that inhabit or depend on the sediment environment for their various life functions; therefore, benthic macroinvertebrates are sensitive to both long-term and short-term changes in habitat, sediment, and water quality.

Benthic community sampling is being conducted at several locations within the study area, including upstream areas, tributaries, and an adjacent reference site. The sampling will focus on depositional areas at these locations. Additional qualitative samples will be collected for determination of tissue residue concentrations in various trophic levels of benthic macroinvertebrates.

Community structure analysis with co-located sediment samples will be used to correlate community metrics (e.g., species richness, species density, and similarity indices) with contaminant concentrations in the Housatonic River, above and below the GE facility, to determine if increasing concentrations of COPCs result in a community effects gradient. A complete discussion of the study plan for the benthic invertebrate community evaluation is provided in Appendix A.13 of this Work Plan.

By itself, the benthic community evaluation can provide an indication of macroinvertebrate community health; but it is limited in its ability to relate findings to the presence of individual stressors. However, when conducted and evaluated in conjunction with the other components of the Triad, sediment toxicity testing and chemical analysis, it can provide a High weight-of-evidence for evaluating effects to the benthic community structure, and the survival, growth, and reproduction of resident macroinvertebrates.

Macroinvertebrate Toxicity, Bioaccumulation, and Stressor Identification Testing—Sediment toxicity investigations will be carried out in the laboratory and in situ. The results of these tests, in combination with sediment chemistry data and the results of the benthic macroinvertebrate community studies, will contribute to the application of the Triad approach to assessing the overall quality of Housatonic River sediments. Discussions on the macroinvertebrate toxicity (laboratory and in situ), bioaccumulation, and stressor identification tests are presented below. A complete discussion of the study plan for the sediment toxicity investigations is provided in Appendix A.14 of this Work Plan.

Laboratory Sediment Toxicity: *Hyalella azteca* and *Chironomus tentans* Chronic Test (Task 1)—*H. azteca* (Amphipoda: Hyalellidae) and *C. tentans* (Diptera: Chironomidae) are widely distributed throughout North America (Pennak, 99-0077) and commonly inhabit permanent lakes, ponds, and streams. Amphipods and dipterans such as *H. azteca* and *C. tentans* are a major food source for fish and are voracious feeders on plant, animal, and detrital material. Because *H. azteca* is epibenthic and *C. tentans* is a sediment burrower for a majority of their life stages, they are particularly valuable for assessing the chemical and physical interactions that occur at the sediment/surface water interface and within sediment pore space.

H. azteca and *C. tentans* have many desirable features that make them well-suited for use in sediment toxicity testing, (i.e., relatively sensitive to sediment contamination, short generation time, ease of culture, direct contact with sediments, and tolerance to varying physicochemical characteristics in sediments). Numerous studies have identified *H. azteca* and *C. tentans* as sensitive indicators of various types of sediment contamination (Ankley et al., 99-0065, 99-0141, 99-0143; Chapman et al., 99-0050; Cairns et al., 99-0066; Kemble et al., 99-0071; Nebeker et al., 99-0075; and West et al., 99-0142). The specific objectives of the *H. azteca* and *C. tentans* chronic tests are to assess the potential for mortality, reduction in growth, reproductive toxicity *(H. azteca),* and emergence *(C. tentans)* resulting from exposure to sediments collected from the study area within the Housatonic River.

In Situ Toxicity and Bioaccumulation (Task 2)—Four test species (*Daphnia magna, H. azteca, C. tentans*, and *Lumbriculus variegatus*) will be evaluated for survival and/or bioaccumulation during low- and high-flow exposure periods using in situ exposure chambers to determine effects and contaminant uptake from overlying water, suspended solids, and bedded sediment. The age of the organisms, handling, and culturing will follow EPA toxicity test methods for short-term chronic toxicity testing. For bioaccumulation testing, additional organisms will be placed in exposure chambers to provide enough tissue mass for chemical analyses.

Sample treatments will include site references, and four target sites representing sediments over a range of PCB concentrations. Site selection criteria will include the following: depositional versus large-grained sediments, PCB gradient, previous sampling locations, habitat, indigenous benthic communities, and stormwater sampling.

Toxicity Identification Evaluation (Task 3)—A laboratory evaluation will be conducted following EPA guidelines for Toxicity Identification Evaluations (TIEs) for sediments where toxicity is observed in Task 1. This Phase I evaluation will consist of exposing *Ceriodaphnia dubia* neonates to pore water fractions for 24-hour periods, then measuring survival. Fraction treatments will target ammonia, metals, and nonpolar organics to determine the groups responsible for toxicity.

The three-task sediment toxicity, bioaccumulation, and identification study, which is a critical portion of the sediment triad evaluation, is expected to provide a High weight-of-evidence. The testing protocol presented in Appendix A.14 is comprehensive because it evaluates chronic exposure, includes in situ measurements of toxicity and bioaccumulation, and incorporates standard toxicity identification procedures in an effort to identify site-specific stressors. This comprehensive evaluation program will ideally provide key site-specific cause and effect information that is often difficult to obtain when multiple stressors are present.

In Situ Freshwater Mussel Bioaccumulation and Condition Study—Bivalve mollusks (e.g., mussels) have been used as indicators of general water quality and chemical contamination over the last several decades (Levings and McDaniel, 99-0382; Wu and Levings, 99-0383; Metcalfe and Charlton, 99-0379; de Kock and Kramer, 99-0381; Salazar and Salazar, 99-0324). The utility of mussels in water and sediment quality investigations is due, in part, to the widespread distribution and sedentary nature of mussels, as well as their easy collection and handling. Moreover, mussels have been shown to be useful as biological indicators of chemical exposure because of their ability not only to tolerate elevated contaminant concentrations, but also to concentrate and integrate chemicals such as PCBs from water and sediment in their tissues (Koenig and Metcalfe, 99-0378; Phillips and Rainbow, 99-0380, and Bruner et al., 99-0375). The response of mussels to chemical contamination includes both lethal and sublethal effects depending on, among other things, the nature of the chemical as well as the magnitude and duration of exposure.

The mussel species to be used in this study (*Elliptio complanata)* is endemic to the Housatonic River drainage. Study stations will be set up in the Housatonic River downstream of the GE site and in the river upstream of the site. In addition to the monitoring locations to which the mussels are transplanted in the Housatonic River, the Connecticut River from which the resident mussels are collected will also serve as a reference monitoring location. Sample testing and sample design will be replicated at that location.

Mussels will be collected for tissue analysis at the midpoint (42 days) and the end of the study (84 days). During the retrieval of the mussels at the study's midpoint and end, mortality and general mussel condition (e.g., gaping) will also be recorded. Mussel tissue will be analyzed for glycogen in addition to chemical content.

In this study, glycogen is being used to monitor the physiological condition of the mussels. Patterson et al. (99-0322) have shown glycogen changes to be a sensitive indicator of the physiological condition of freshwater mussels. Glycogen, the primary energy reserve in bivalves, drives many important physiological processes and may be used to endure short-term exposure to anoxia, emersion, and reduced food supplies (Bayne, 99-0373; Gabbott, 99-0376; Bayne et al., 99-0374; Hummel et al., 99-0321). Glycogen stores also have been shown to change in response to environmental perturbations such as temperature extremes, anaerobiosis, chemical pollutants, and general nutrition (Hummel et al., 99-0321; de Zwann and Wijsmann, 99-0320). While drastically reduced glycogen levels may lead to reduced survival, smaller reductions in the glycogen levels of adult bivalves also may have sublethal effects on reproduction including reduced fecundity and reduced growth rates of developing offspring (Bayne, 99-0373; Helm et al., 99-0377; Bayne et al., 99-0374).

The data generated in this study will be used in the assessment of ecological risk both to the mussel community itself and to animals that may forage mussels as part of their diet. Data collected as part of the study will be used to demonstrate site-specific differences as well as temporal and spatial variability. Data analyses will include summary statistics, determinations of variance, and significant ($p<0.05$) differences between monitoring stations. A detailed discussion of the approach that will be used to conduct the transplanted mussel study is presented in Appendix A.15.

The in situ mussel study provides valuable data on mussel survival, contaminant accumulation, and overall condition, but may have some limitations in its ability to identify a stressor/response relationship. Because of the potential limitations associated with the stressor identification and stressor/response correlations, this study is given Medium to Low weight-of-evidence. However, in conjunction with the mussel survey, this study may provide valuable insight into the presence/absence and/or condition of the mussel community in the river.

Crayfish Tissue Analysis—Because of their life history characteristics, crayfish are useful indicators of the potential impacts of PCB contamination on the aquatic food web of the

Housatonic River. Crayfish live in stream and lake habitats, are in direct contact with sediment and surface water for most of their lives, and feed on decaying organic matter. In addition, they have a limited home range, and are consumed by several species of fish, birds, and mammals. The objective of this sampling effort is to collect crayfish for tissue residue analysis and to provide data in the accumulation of these materials in the aquatic food web. Crayfish will be collected at each of six locations (four locations in Reach 5 plus two reference locations) in the study area.

As previously noted, the principal use of the crayfish data in the ERA is to provide actual tissue concentrations for contaminant exposure dose estimation in higher trophic level organisms. In addition, if appropriate data are available, potential effects to crayfish from COPCs may be evaluated by comparing COPC concentrations in crayfish to literature-based concentrations in crayfish exhibiting symptoms of toxicity. A complete discussion of the study plan for the crayfish sampling is provided in Appendix A.16.

Amphibian Studies—Riverine habitats and adjacent floodplain wetlands in the Lower Housatonic River study area provide habitat for a variety of reptiles and amphibians. Breeding amphibians use temporary and permanent pools for courtship, egg laying, and larval development. Amphibians inhabiting these wetland areas are potentially exposed to contamination present in sediment, surface waters, and prey items. To address the potential for toxic effects associated with site-specific contamination, three studies are proposed: (1) reptile and amphibian use study; (2) amphibian reproductive success study; and (3) amphibian toxicity testing study. The following narrative presents a brief overview of the bullfrog sampling program and the three aforementioned studies, highlighting study objectives and referencing protocols that provide a detailed description of study methodologies.

Bullfrog Tissue Analysis—As noted above, amphibians inhabiting riverine habitats and adjacent floodplain wetlands in the Lower Housatonic River and using temporary and permanent pools for courtship, egg laying, and larval development may be exposed to contamination present in sediment, surface waters, and prey items. In addition, bullfrogs may be prey items themselves, for both human and ecological receptors. There is currently a consumption advisory posted for frogs in the study area. The two basic objectives of this sampling effort are to provide leg muscle tissue residue concentrations for use in the HHRA and to collect bullfrog tissue to determine residues for use in the fate and effects model and the ERA.

Four sampling areas—Woods Pond, backwater areas within 1 mile north of Woods Pond, Three-Mile Pond (reference location), and Muddy Pond (reference location)—were selected for sampling based on a field reconnaissance to identify areas of appropriate bullfrog habitat, followed by a review of available contaminant data to identify areas indicative of a range of sediment PCB concentrations.

As previously noted, the major use of the bullfrog data in the ERA is to provide actual tissue concentrations for contaminant exposure dose estimation in higher organisms. In addition, if appropriate data are available, potential effects to bullfrog from COPCs may be evaluated by comparing COPC concentrations in bullfrog to literature-based concentrations in bullfrog exhibiting symptoms of toxicity. A complete discussion of the study plan for the bullfrog sampling is provided in Appendix A.17.

Reptile and Amphibian Use Survey—In spring and summer 1998, an extensive survey of the Housatonic River from Newell Street to Woods Pond and adjacent floodplains was conducted to evaluate reptile and amphibian presence within the study area. The specific objectives of this task were to: (1) provide an estimate of amphibian and reptile species richness in the study area per habitat type; (2) sample larval amphibians in breeding habitats that are expected to have different sediment concentrations of PCBs based on previously collected data; and (3) submit samples for chemical analysis, should mortality occur during sampling activities.

As part of the reptile and amphibian community structure evaluation, aquatic funnel trapping was conducted at 17 permanent or temporary pools. Ten aquatic funnel traps were placed randomly in each pool. All pools were trapped within a single week, and surveys were reported every other or every third week, starting in late May and ending by early June. The total number of larval amphibians of each species was recorded for each trap daily, or more frequently when traps became too full, resulting in trap mortality. Individuals captured in traps were evaluated for gross pathology, and body, tail, and total length for 25 individuals of each species, and results were recorded. In addition, visual encounter surveys and pit trap array sampling was conducted to support and supplement the funnel trapping effort. A complete discussion of the study plan for the larval amphibian sampling is provided in Appendix A.9.

The reptile and amphibian use survey is primarily a characterization study designed to identify potential receptors within the study area to guide the selection of endpoints for measurement in the ERA, and to characterize the basic herpetological community structures and use within the study area. Amphibian species richness and abundance within a range of PCB-contaminated vernal pools and the gross pathology provide a general indication of community conditions within study area vernal pools for select species; however, because this study has limited ability to discriminate stressors and associated responses and its sensitivity is unknown, its overall weight for use in the ERA is considered Low. However, taken with the other amphibian measurement endpoints, it may provide additional insight on effects if observed.

Amphibian Vernal Pool Reproductive Success Study—Amphibian reproductive success within vernal pools may be influenced by exposure to PCBs in contaminated sediments and, as previously discussed, amphibians inhabiting these pools may bioaccumulate PCBs, which can then be passed on to other animals in the food chain. The objectives of this task are to: (1) determine if PCB contamination is potentially having a negative effect on amphibian reproduction in vernal pools, and (2) submit amphibian tissue that results from incidental mortality for PCB tissue analysis.

The reproductive success within up to five vernal pools exhibiting a range of PCB concentrations will be evaluated. Amphibians entering vernal pools initially will be sampled using drift fences and pit traps. Courtship, breeding behavior, and reproductive condition will be evaluated for animals captured before entering the vernal pool. Once reproductive activities have begun, egg laying, hatching success, and larval growth and development will be monitored. Amphibians that succumb incidentally during this study or that are sacrificed may be preserved and submitted for PCB analysis. Egg mass materials remaining after hatching may also be submitted for developmental evaluation and/or PCB analysis. A complete discussion of the study plan for the amphibian in situ reproductive success study is provided in Appendix A.18.

The vernal pool reproduction study provides a more quantitative assessment of amphibian use and reproductive success in vernal pools with varying degrees of PCB contamination. In addition to the reproduction analysis, the evaluation of contaminant bioaccumulation may help to identify potential cause and effect relationships, particularly when evaluated with the other amphibian endpoints. However, as with many field studies, the inability to control and assess the potential impacts of non-monitored stressors may limit the effectiveness of the study in the area of stressor specificity; therefore, the weight-of-evidence for this measurement endpoint is considered Medium.

Amphibian Toxicity Testing—To assess the potential for toxic effects to amphibians, amphibian laboratory toxicity tests will be conducted using northern leopard frogs (*Rana pipiens*). Leopard frogs will be collected from areas of leopard frog habitat that exhibit a gradient of PCB contamination. The focus of this investigation is on the potential impact that PCB contamination may have on reproduction, early development, and maturation (metamorphosis) in northern leopard frogs. Previous field surveys have identified sufficient numbers of leopard frogs throughout the study area, which will provide the capability of using animals exposed at the site in the testing.

Specific reproductive performance and early developmental effects that will be assessed include: gravidity, number of eggs produced, necrosis, oocyte maturity, sperm count, sperm morphology and viability, fertilization, early embryogenesis, hatching success, mortality, and morphological development (teratogenesis).

Post-hatch larvae will be cultured and assessed for approximately 3 months; effects that will be monitored include: mortality, limb development, skin maturation, and tail resorption. A complete discussion of the study plan for amphibian (laboratory) toxicity testing is provided in Appendix A.19.

The leopard frog toxicity study uses individuals captured and surface water and sediment collected from a number of locations within the study area that have a range of PCB-concentrations. This study, with its extensive list of reproductive, growth, and developmental endpoints, provides a comprehensive evaluation of potential population-level effects. The study-specific biological endpoints, when evaluated in conjunction with tissue, water, and sediment chemistry, and the other amphibian evaluations, have the potential to establish a strong association between the assessment and measurement endpoints, and stressor/response relationships. Because of the high quality of the data being collected, the direct relevance to amphibians in the Housatonic River watershed, and the strong study design, the weight-of-evidence for this study is considered High.

Fish Health and Toxicity Testing—Fish health evaluation and toxicity testing will be conducted to determine if the contamination in the Housatonic River downstream of the GE facility is adversely affecting fish in the study area. The study will be conducted in two phases: (I) laboratory rearing of eggs from Housatonic River fish and (II) laboratory egg injection studies. The primary objectives of this study are to: determine embryotoxic effects of PCBs found in study area fish; determine the validity of the embryo toxicity model for PCB-related effects in fish embryos collected from the study area; and determine the responses in fish health attributable to PCB contamination. For Phases I and II, test species that are endemic to the study area (e.g., largemouth bass and bluegill) will be used. Other species that are routinely used as laboratory surrogates (e.g., fathead minnow) or that may be useful surrogates for species that are less common in the Housatonic River but have differing sensitivities (e.g., rainbow trout) also will be used in Phase II. Measurement endpoints that will be evaluated include: fertilization rates, embryo viability, time to hatch, post-hatch survival, fry growth, gross pathology, histopathology, apoptosis, and cytochrome P-4501A induction. In addition, PCB exposure will be determined through EROD induction, and plasma estrogen, testosterone, and vitellogenin in field-collected adult fish. The protocol for conducting this evaluation is provided in Appendix A.21 of this Work Plan.

The two-phase fish health and toxicity study is a comprehensive evaluation of the potential impacts of aryl hydrocarbon receptor (AhR)-mediated contaminants to fish within the Housatonic River. This study evaluates multiple levels of biological organization (biochemical, histological, and organismal) in an attempt to identify adverse ecological impacts and their associated causal agents. The strength of association between assessment and measurement endpoints, data quality, and study design attributes has a High weight, resulting in an overall High weight-of-evidence rating for this measurement endpoint.

Comparisons of Fish Tissue Concentrations with Established Effect Levels—Fish have been collected for chemical analysis in the Housatonic River from locations upstream of the

GE facility in Dalton, MA, Goodrich Pond, downstream of the GE facility from the confluence to the Pittsfield WWTP, the WWTP to Woods Pond, Woods Pond and backwater areas, Rising Pond, and from a reference location within the watershed at Three-Mile Pond for chemical analysis.

Potential effects to fish from COPCs will be evaluated by comparing COPC concentrations in fish tissue to maximum allowable tissue concentrations (MATCs) generated as part of the fish toxicity study (Appendix A.21) or literature-based concentrations in tissues of fish exhibiting symptoms of toxicity. Site-specific fillet and whole body concentrations will be compared with muscle and whole body effect levels, respectively. A complete discussion of the study plan for the fish tissue sampling is provided in Appendix A.20.

The tissue residue approach for evaluating potential effects to resident fish provides excellent information on the bioavailability of site-related stressors, but is limited by the quantity and quality of the scientific literature available for assessing potential residue-associated effects. While providing a critical piece of information for subsequent human health and ecological exposure modeling, the comparison of tissue residue concentrations to known toxicological effect levels is limited when corresponding effects are not observed or cannot be assessed for all species of fish collected for tissue analysis in the contaminated portions of the study area. When evaluated in conjunction with the Fish Health and Toxicity study, it may provide additional insight in interpreting the data. The weight-of-evidence for this measurement endpoint is Medium-Low.

Soil Effects

Several evaluations may be used to assess effects to ecological entities primarily from the exposure to COPCs in floodplain soils. These evaluations include the comparison of soil invertebrate concentrations with literature-based residue effects levels, if comparable literature-based residue effects data can be identified. In addition, if appropriate phytotoxicity values are identified, soil concentrations may be compared with benchmarks to determine the potential for phytotoxic effects. To reiterate, effects to higher trophic level organisms from direct exposure to soil or from bioaccumulative effects from the terrestrial food chain will be discussed under the Avian and Mammalian Effects.

Soil Invertebrate Tissue Analysis—As previously discussed, PCB-contaminated sediments have been deposited throughout the Housatonic River floodplain. Being in nearly constant contact with the soil, soil invertebrates are continually exposed to soil contamination. In addition, soil invertebrates account for the majority of animal biomass in soil, and are preyed upon by a number of secondary consumers. Soil invertebrates themselves and organisms using soil invertebrates for prey may be affected by contaminated floodplain soils. The principal objective of the soil invertebrate sampling is to collect soil invertebrates to determine tissue residues for use in the ERA to model exposure to higher consumers. In addition, the results of tissue analyses and co-occurring soil analyses may be used to determine the relationship between earthworm tissue concentrations and corresponding soil concentrations.

Approximately 13 samples of earthworms (10 individual worms and/or composites depending upon earthworm size) and of other soil invertebrates (composite) will be collected at each of three locations over a range of PCB concentrations.

As previously noted, the major use of the soil invertebrate data in the ERA is to provide actual tissue concentrations for contaminant exposure dose estimation in higher organisms. In addition, if appropriate data are available, potential effects to soil invertebrates from COPCs may be evaluated by comparing COPC concentrations in soil invertebrates to literature-based concentrations in soil invertebrates exhibiting symptoms of toxicity. A complete discussion of the study plan for the soil invertebrate sampling is provided in Appendix A.22.

Avian and Mammalian Effects Evaluation

Numerous evaluations will be used to assess effects of contamination to ecological receptors that live and/or forage within the Housatonic River floodplain. These evaluations include the following: (1) tree swallow nestling bioaccumulation and toxicity; (2) small mammal morphometrics; (3) mink toxicity testing; and (4) comparisons of modeled avian and mammalian exposure doses with literature-based toxicity data. In addition, small mammal and waterfowl tissue concentrations will be compared with literature-based residue effects levels, if comparable literature-based residue effects data can be identified. All of the potential evaluations are discussed below.

Duck Collection—As a result of their dietary habits and the bioaccumulative potential of PCBs, mallards and wood ducks nesting in the study area and their offspring may be accumulating PCBs in their tissue at levels that may adversely affect the ducks themselves, as well as predators that use them as a food source. The objective of this duck sampling program is to collect ducks to determine tissue residue concentrations for use in the HHRA.

As previously noted, the major use of the duck data in the ERA is to provide actual tissue concentrations for contaminant exposure dose estimation in higher organisms. In addition, if appropriate data are available, potential effects to duck from COPCs may be evaluated by comparing COPC concentrations in duck to literature-based concentrations in duck exhibiting symptoms of toxicity. A complete discussion of the study plan for the duck sampling is provided in Appendix A.23.

Tree Swallow Study—A tree swallow bioaccumulation and toxicity study is being conducted to determine the potential for contamination in the Housatonic River downstream of the GE facility to undergo trophic transfer from sediments to emergent aquatic insects to insectivorous birds, and if so, whether the insectivorous birds exposed to COPCs are experiencing adverse effects.

Tree swallow boxes were erected at six sites—three along the Housatonic River downstream of the GE facility and three at reference areas. The number of eggs and young will be monitored; and eggs, pippers, and nestlings will be collected as appropriate, based on the number of swallows nesting at each site and the sample mass obtainable. The collected tree swallows will be euthanized, and the stomach contents will be removed and pooled for analysis separate from the carcasses. Eggs, carcasses, stomach contents, and prey items will undergo chemical analysis.

In addition, a neck ligature procedure will be performed on the nestlings, allowing for the direct collection of dietary items (i.e., emergent insects) without harming the young. The collected food items will undergo chemical analysis to determine a link between sediment contamination and exposure of tree swallows to the COPCs. These data will also be used for tree swallow exposure modeling and comparisons with literature-based toxicity data. In addition, some the benthic invertebrate sampling locations (Appendix A.13) were co-located with the tree swallow study areas, which will provide an additional measure of the dietary dose.

Overall, data from this study will yield COPC concentrations in tree swallow eggs and just-hatched young, accumulation rates in nestlings, and quantification of reproductive success using the Mayfield method. A complete discussion of the study plan for the tree swallow studies is provided in Appendix A.24.

The tree swallow bioaccumulation and effects study will directly measure reproductive success, exposure, and bioaccumulation in tree swallows nesting within the study area and reference locations. The strength of association between assessment and measurement is High for this study due to the direct link between measurement and assessment endpoints and the study's ability to develop correlation between stressor and response. The study design and execution also has a High associated weight because of its site-specificity, spatial representativeness, and endpoint sensitivity. It is therefore determined that the overall weight-of-evidence for this study and corresponding measurement endpoints is High.

Small Mammal Morphometrics—Small mammal trapping will be conducted primarily to identify the mammals using the riverine, wetland, and upland habitats within the study area. Morphometrics (weight; body, tail, hind limb length; sex; age; and placental scars and embryos in females) of trapped animals will be noted. Analyses will be performed to determine if there are differences between the metrics in animals from various PCB concentration gradients. A complete discussion of the study plan for small mammal use is provided in Appendix A.25.

Small mammals will be trapped along transects positioned at three locations within the Housatonic River floodplain. Transect positions will be selected in an effort to collect individuals from areas with varying concentrations of PCBs in soil. While tissue concentration information collected as part of this study will be used in receptor-specific exposure models, the remaining data collected for this investigation are limited to general community composition, morphometric data, and an evaluation of female reproductive tracks (i.e., placental scar counts). The study, as designed, has a relatively high degree of uncertainty regarding stressor response specificity and measurement endpoint sensitivity. Therefore, the weight-of-evidence for this study alone is Low.

Mink Toxicity Testing—Field surveys in the study area failed to identify the presence of mink and otter in suitable habitats in the study area, although these species occur in nearby reference areas. The scientific literature notes the sensitivity of these species to PCBs and other dioxin-like compounds. To assess the potential for toxic effects to mink exposed to contamination in site-specific prey items, a mink toxicity test will be conducted. The objectives of this study focus on the potential impact that PCB contamination may have on mink general condition, survival, growth, reproduction, and general condition.

Specific measures to be evaluated in this study include: adult body weight and feed consumption; number of females successfully mated; length of gestation, number of females whelping/not whelping; total newborn/female whelped; live newborn/female whelped; average kit birth weight; average litter weight; percent kit survival to 3 weeks; average 3-week body weight; percent kit survival to 6 weeks; average 6-week body weight; average adult and 6-week kit organ weights; histopathology of adult, 6-week-old, and 7-month-old kit organs; and liver enzyme analysis of adult, 6-week-old, and 7-month-old kits. In addition, the liver concentration of total PCBs, PCB congeners, and PCDDs/PCDFs will be analyzed for the three endpoint ages (adult, 6-week-old, and 7-month-old). Results will be compared among the five dose levels of PCBs (0.25, 0.5, 1.0, 2.0, and 4.0 ppm PCB) and between treated groups and the control. A complete discussion of the study plan for the mink toxicity test is provided in Appendix A.26.

The mink toxicity study uses fish collected from the Housatonic River as a dietary dose to assess reproductive and pathological effects from the site-related contaminants on farm-reared mink. The study, in addition to evaluating numerous reproductive, growth, and pathological endpoints; has a strong association between measurement and assessment endpoints; and is designed to be site-specific and very sensitive to detecting changes in the measurement endpoints. While uncertainties regarding resident mink dietary exposure are present, the overall data quality and study design of this investigation indicate that a High weight-of-evidence is warranted.

Comparisons of Modeled Avian and Mammalian Exposure Doses with Literature-Based Toxicity Data—As presented in the Characterization of Exposure subsection, doses will be estimated for avian and mammalian target receptors. These estimated doses will be compared with chemical-specific reference toxicity values (RTVs) representing a single dose or, if sufficient data exist, a range of doses associated with the most sensitive ecologically significant endpoints. The RTV methodology is presented below.

If the Monte Carlo analysis approach is selected for exposure modeling, it will provide a probability distribution of potential receptor exposures that can be compared to receptor-specific toxicity values. While several exposure and toxicity value uncertainties exist with this approach, efforts have been taken to ensure that primary dietary intake information (i.e., prey item residue levels) has been collected over a range of potential soil and sediment exposure concentrations and that key receptors evaluated are present or are probable study area receptors given habitat conditions present. Assuming that reasonable input parameters and distributions are applied to the modeling effort, a Medium weight-of-evidence will be given to this measurement endpoint.

Reference Toxicity Values—This section will present the methods for estimating the type and magnitude of ecological effects that result from the exposure of wildlife target species to the COPCs. In addition, the RTVs that are used to evaluate the risk resulting from COPC exposure will be presented.

EPA has yet to formally adopt toxicity values for the protection of wildlife. Therefore, RTVs will be derived using peer-reviewed methods and assumptions for specifically selected ecological receptors in the Lower Reach of the Housatonic River. RTVs are dose-based levels of contaminants that are not expected to elicit adverse effects.

Study and Dose Selection for Reference Toxicity Values. Doses used for avian and mammalian RTVs will be obtained from peer-reviewed primary research articles. The process used to identify primary research articles for use as RTVs includes a review of literature searches, database searches, and secondary sources as listed in Table 7-4. If primary research articles cannot be obtained, data from secondary sources will be used. To qualify for consideration, studies that include potential RTVs must meet the following criteria:

- Test species similar to the target receptor.
- In vivo study.
- Oral administration via food, drinking water, or gavage (feeding study preferred).

Table 7-4

Secondary Sources to be Reviewed for the Identification of Primary Articles for Reference Toxicity Values

Literature Search

The Dialog Information Retrieval Service will be accessed to perform a comprehensive literature search for avian and mammalian toxicity data. The databases to be searched include:

- Biosis Previews
- CA Search
- EM Base
- Life Sciences Collection
- Medline
- Toxline
- SciSearch

Database Searches

The databases listed as follows will be accessed via various internet sites.

- Hazardous Substances Data Bank (HSDB)
- Integrated Risk Information System (IRIS)
- Registry of Toxic Effects of Chemical Substances (RTECS)

Secondary Sources

The secondary sources listed as follows will be reviewed for studies relevant to the development of RTVs:

- Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles
- Great Lakes Water Quality Initiative Criteria Documents for the Protection of Wildlife (Proposed) (EPA, 99-0116)
- Toxicological Benchmarks for Wildlife (99-0117)
- USFWS Biological Reports, Contaminant Hazard Reviews

- No observed-adverse-effect level (NOAEL) or lowest-observed-adverse effect level (LOAEL) identifiable.
- Effects of potential "ecological significance" evaluated.

Articles meeting the criteria will be summarized, with information noted on study parameters, effects evaluated, and results. After all suitable articles are summarized for a specific chemical, both the studies and doses most appropriate for RTVs will be selected. Primary considerations in the selection process include study species, study duration, effect level, and toxicological endpoint. The following paragraphs present the considerations to be used in the study and dose selection process.

Studies using the site-specific target wildlife species will be preferentially sought. However, toxicological data for the target wildlife species are often unavailable; therefore, studies will be chosen that, to the extent possible, use species related to the target species and that have similar diets and digestive systems.

Where available, data for both acute and chronic toxicity will be presented. Acute exposure represents either an instantaneous single-dose exposure or a continuous exposure of minutes to a few days duration. Chronic exposure represents the extended exposure of an organism to a chemical, generally greater than one-tenth of the typical life span of the species (99-0043).

For those studies for which both a NOAEL and LOAEL are available, both the NOAEL and the LOAEL will be presented. By definition, a NOAEL is that dose of a chemical at which there is no statistically or biologically significant increase in the frequency or severity of adverse effects between the exposed population and its appropriate control. By comparison, a LOAEL is the lowest dose of a chemical in a study or group of studies that produces biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control (Dourson and Stara, 99-0119). Endpoints that could directly affect the target species at the population level will be given preference (e.g., reproductive effects and mortality of adults or offspring) in establishing ecological significance. The next preference will be given to serious histopathological effects (e.g., necrosis or damage to liver, kidney, or brain) that alter primary body functions. In the absence of preferred data, consideration will be given to effects such as alterations in biochemical functions of an organ that could be correlated with decreased survivability and alterations in normal behavior, resulting in decreased survivability of a receptor (e.g., impaired motor skills, increased reaction time, and altered feeding habits). Other effects such as altered body weight, decreased liver size, and changes in blood chemistry are not readily associated with decreased survivability or longevity and will be used only in the absence of the preferred toxicity data.

Best professional judgment will be used to select the most appropriate studies, doses, and endpoints for use in RTV development for the Housatonic River study area.

Congener-Specific Toxicity and the Toxic Equivalency Factors (TEF) Approach. Several congeners of PCBs have been shown to exhibit toxic responses in vertebrate species similar to those caused by exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). These responses include dermal toxicity, immunotoxicity, carcinogenicity, and adverse effects on reproduction, development and endocrine functions (World Health Organization (WHO), 99-0312; Van den Berg et al., 99-0275).

To assess the ecological risk associated with dioxin-like (2,3,7,8-TCDD) toxicity, the concept of toxic equivalency factors (TEFs) has been developed for mammals, birds, and fish. The TEF approach is based on the recognition of a common mechanism of action of 2,3,7,8-TCDD and the dioxin-like compounds, including 6 additional congeners of polychlorinated dibenzo-p-dioxins (PCDDs), 10 congeners of polychlorinated dibenzofurans (PCDFs), and 12 congeners of PCBs. At present, there is sufficient evidence to suggest that this mechanism involves the binding of these compounds in varying degrees to the aryl hydrocarbon receptor (AhR), an intracellular macromolecule that serves as a binding substrate for organic xenobiotics. This binding of the ligand (chemical) to the AhR represents an initial step in a sequence of events that results in the detoxification and potential bioactivation of the compound (Knutson and Poland, 99-0306; Safe, 99-0079; Hankinson, 99-0305; Birnbaum, 99-0304). The receptor-ligand complex is subsequently transferred into the cell's nucleus where it, in turn, binds to DNA (Stegeman and Hahn, 99-0310). It is assumed that most of the toxic response associated with these compounds is due to AhR-mediated modulation of gene expression (Knutson and Poland, 99-0306, and Whitlock, 99-0311, as cited in Safe, 99-0309). The development of a TEF compares the relative toxicity of a “dioxin-like” compound to that of 2,3,7,8-TCDD and is based on available in vivo and in vitro studies (Van den Berg et al., 99-0275).

In June 1997, the World Health Organization (WHO) convened a meeting in Stockholm, Sweden with the objective of deriving consensus TEFs for PCDDs, PCDFs, and dioxin-like PCBs for human, fish, and wildlife risk assessment. As part of the evaluation process, previous studies were reevaluated and new studies were reviewed that met several criteria laid out by the workgroup with which to develop the TEFs. In addition, the evaluation was limited to the vertebrate classes—mammals, birds, and fish. The workgroup concluded that insufficient data were available with which to develop TEFs for amphibians and reptiles. Moreover, the development of TEFs for invertebrates was not considered because available data suggested that there was limited evidence for ligand activation (binding) of AhR or for TCDD-like toxicity in invertebrates (99-0275).

As part of developing consensus TEFs, the workgroup established a set of criteria for establishing a TEF for dioxin-like PCBs for mammals, birds, and fish. These included:

1. A compound must show a structural relationship to PCDD and PCDF.
2. A compound must bind to the Ah receptor.
3. A compound must elicit Ah receptor-mediated biochemical and toxic responses.
4. A compound must be persistent and accumulate in the food chain.

Based on these criteria, and the review of studies of compounds demonstrating dioxin-like toxicity, consensus TEFs were derived for 7 PCDDs (including TCDD), 10 PCDFs, and 12 PCB congeners. The consensus TEFs developed by the Stockholm workgroup for mammals, fish, and birds are presented in Table 7-5.

The TEF approach provides an order-of-magnitude estimate of the toxicity of these compounds relative to 2,3,7,8-TCDD (99-0275). In addition, there are a number of simplifying assumptions and limitations associated with the use of the TEF approach for PCBs. Among the more important is the underlying assumption that the combined effects of the different congeners are dose or concentration additive. Several studies suggest that this assumption is problematic in that it fails to take into account the non-additive antagonistic interactions between the AhR agonists

Table 7-5

WHO TEFs for Humans, Mammals, Fish, and Birds

Congener	Toxic Equivalency Factor (TEF)		
	Humans/Mammals	Fish	Birds
Dioxins			
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PeCDD	1	1	1
1,2,3,4,7,8-HxCDD	0.1	0.5	0.05
1,2,3,6,7,8-HxCDD	0.1	0.01	0.01
1,2,3,7,8,9-HxCDD	0.1	0.01	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.001	<0.001
OCDD	0.0001	<0.0001	0.0001
Furans			
2,3,7,8-TCDF	0.1	0.05	1
1,2,3,7,8-PeCDF	0.05	0.05	0.1
2,3,4,7,8-PeCDF	0.5	0.5	1
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDF	0.0001	<0.0001	0.0001
PCBs			
3,4,4',5-TCB (81)	0.0001	0.0005	0.1
3,3',4,4'-TCB (77)	0.0001	0.0001	0.05
3,3',4,4',5-PeCB (126)	0.1	0.005	0.1
3,3',4,4',5,5'-HxCB (169)	0.01	0.00005	0.001
2,3,3',4,4'-PeCB (105)	0.0001	<0.000005	0.0001
2,3,4,4',5-PeCB (114)	0.0005	<0.000005	0.0001
2,3',4,4',5-PeCB (118)	0.0001	<0.000005	0.00001
2',3,4,4',5-PeCB (123)	0.0001	<0.000005	0.00001
2,3,3',4,4',5-HxCB (156)	0.0005	<0.000005	0.0001
2,3,3',4,4',5'-HxCB (157)	0.0005	<0.000005	0.0001
2,3',4,4',5,5'-HxCB (167)	0.00001	<0.000005	0.00001
2,3,3',4,4',5,5'-HpCB (189)	0.0001	<0.000005	0.00001

Source: Van den Berg, 99-0275.

(i.e., the dioxin-like compounds) and other PCB congeners that exhibit response-specific, as well as cell/species-specific antagonistic activity (e.g., PCB 153) (Safe, 99-0308; 99-0309). Moreover, the approach assumes that the dose-response curves for the dioxin-like compounds are parallel to the dose-response curve of 2,3,7,8-TCDD.

Although the Stockholm workgroup recognized a number of the limitations, the consensus of the group was that the use of the additive TEF model is unlikely "*to result in a great deal of error in predicting…responses at environmentally relevant levels due to non-additive interactions.*" Moreover, the workgroup concluded that the use of the TEF model "*is considered to be plausible and to be the most feasible approach for risk assessment of HAHs with dioxin-like properties.*"

In January 1998, EPA's Risk Assessment Forum convened a "*Workshop on the Application of 2,3,7,8-TCDD Toxicity Equivalency Factors to Fish and Wildlife*" (99-0068) to examine the applicability of the WHO's TEFs for assessing risks to fish and wildlife from dioxin-like PCDDs, PCDFs, and PCBs. During the workshop, many of the technical concerns for using the TEF approach previously expressed at the Stockholm meeting were reiterated and a consensus for additional research was reached. Despite its shortcomings, workshop participants concluded "*that the TEF approach is more valid than approaches using either total PCBs or TCDD alone.*" Tillitt (99-0384) also concluded that, "it would be scientifically unsound to disregard this approach and not use it in ecological risk assessment for fish and wildlife species." However, there is still a need for total PCB-based approaches, since some of the effects of these congeners are not mediated by the Ah receptor (99-0068; Tillitt, 99-0384).

Consequently, the TEFs presented in Table 7-5 will be used in this assessment to calculate the dioxin-like equivalency (TEQ) with which the species-specific exposure dose or exposure concentration through the relevant pathways will be estimated. To apply this TEF concept, the TEF of each congener present in a mixture is multiplied by the respective mass congener concentration, and the products are summed to represent the 2,3,7,8-TCDD toxic equivalence (TEQ) of the mixture, as determined by the equation (99-0275):

$$\mathrm{TEQ} = \sum\nolimits_{n1}(\mathrm{PCDD}_i \ \mathrm{x}\ \mathrm{TEF}_i) + \sum\nolimits_{n2}(\mathrm{PCDF}_i \ \mathrm{x}\ \mathrm{TEF}_i) + \sum\nolimits_{n3}(\mathrm{PCB}_i \ \mathrm{x}\ \mathrm{TEF}_i)$$

Where:

TEQ = Toxic equivalent concentration
PCDD = Polychlorinated dibenzo-p-dioxin
PCDF = Polychlorinated dibenzofuran
PCB = Dioxin-like polychlorinated biphenyl
TEF = Toxic equivalency factor

Dioxin-like dose estimates and media concentrations will be compared with RTVs and media-specific effect concentrations for 2,3,7,8-TCDD to determine the risk to mammals, fish, and birds potentially exposed to the dioxin-like compounds from a variety of media.

As part of the risk assessment, the nature and the magnitude of the uncertainties and limitations of the TEF approach, especially as it applies specifically to the findings of the studies in the Housatonic River, will be identified and discussed throughout the ecological risk assessment process including the dose-response assessment, the effects assessment, and the risk characterization. Probabilistic analyses may be used to address some of the uncertainty. Moreover, information on the sensitivity of the risk estimates associated with the use of the TEF approach will be identified and quantified if possible.

Derivation of Reference Toxicity Values from Study Exposure Doses. To encompass the range of toxicity of COPCs among species, when sufficient acceptable data exist, a range of doses will be compared with the estimated dietary doses of COPCs received by the site-specific avian and mammalian target species to determine the potential for deleterious effects.

As noted previously, toxicological data for the target wildlife species are often unavailable. Aside from selecting studies that use species related to the target species or that have similar diets and digestive systems, several allometric “scaling” factors can be used for interspecies extrapolation of a dose. Scaling methodology is used in EPA carcinogenicity assessments for adjusting from animal data to equivalent human doses. In addition, a scaling approach is proposed for use in the Great Lakes Water Quality Initiative (EPA, 99-0345) and is used in the development of the Oak Ridge National Laboratory Toxicological Benchmarks for Wildlife for extrapolating between animal species (Sample et al., 99-0117).

Scaling factors most commonly applied to toxicity include body surface area, metabolic rate, and body weight. There are arguments both for and against using allometric scaling factors to extrapolate toxicity values to different species. While it is generally agreed that toxicity can vary even between closely related species, the application of any particular scaling factor is weak (Sample and Arenal, 99-0344).

Limitations of the scaling factor approach include the lack of specific factors for many chemicals and the current database being most appropriate for acute toxicity data when RTVs for this assessment mostly will be based on chronic data. However, it is suggested that chemical-specific scaling factors reduce uncertainty associated with interspecies extrapolation of toxicity data (99-0344). Consideration of allometric scaling factors for this assessment will focus on body weight or surface area. The feasibility and uncertainties associated with scaling factors for the chemicals of concern and selected receptor species will be evaluated, and if appropriate, scaling factors will be used to modify toxicity values for interspecies extrapolation.

Doses selected for derivation of RTVs will be presented, as well as any scaling factors and the resulting avian and mammalian RTVs. The comparison of RTVs with the estimated daily intakes will be presented and discussed in the Risk Characterization.

7.3.3.1.2 Causality

Causality is defined as the relationship between one or more stressors and the response to the stressor(s). Uncertainty in the conclusions of an ERA would be high without the proper support to link the cause (stressor) and effect (response).

General criteria for affirming causality for observational data are: (1) strength of association; (2) predictive performance; (3) demonstration of a stressor-response relationship; and (4) consistency of association. Criteria for rejecting causality in observational data are (1) inconsistency in association; (2) temporal incompatibility; and (3) factual implausibility. Other factors relevant to assessing causality are the specificity of association and theoretical and biological plausibility (99-0033).

Once the results of the site-specific studies for the Housatonic River and floodplain are available, each study will be evaluated for causality.

7.3.3.1.3 Linking Measurement Endpoints to Assessment Endpoints

When assessment endpoints are different from their measures of effects, the two must be linked to evaluate the environmental values of concern. At times, extrapolations need to be used to link the endpoints. Extrapolations from the measurement to the assessment endpoints may include comparisons:

- Between taxa (e.g., black duck to mallard).
- Between responses (e.g., mortality to growth).
- From laboratory to field.
- Between geographic areas.
- Between spatial scales.
- Between exposure durations (e.g., acute to chronic).
- Between individual effects and population, community, or ecosystem effects.

Extrapolations have a level of uncertainty associated with the adequacy of the data on which they are based. Linkages can be based on professional judgment or empirical or process models (99-0033).

As mentioned during the selection of assessment and measurement endpoints, process models can be used to extrapolate individual effects to potential changes in populations, communities, or ecosystems. Process models can be of assistance in linking measurement to assessment endpoints. In addition, these models are also useful to evaluate risk hypotheses regarding duration and severity of a stressor on an assessment endpoint that cannot be readily tested in the laboratory. Process models fall into two major categories, single-species population models and multi-species community and ecosystem models (99-0033). Individual-based models are models that characterize dynamics of populations in terms of the physiological, behavioral, and other relevant properties of the individual organisms (Hallam et al., 99-0313). Individual-based models are useful in determining short- or long-term changes in population size and structure and can estimate the probability of population declines or increases from effects to individuals. Community and ecosystem models, also known as metapopulation models, are particularly useful when assessment endpoints involve structural (e.g., community composition) or functional (e.g., primary production) elements or when secondary effects are of concern (99-0033).

One approach for population simulation to predict the risk of population decline from chemical stressors uses the classical Leslie matrix for population projection (Caswell, 99-0355), modified by using Monte Carlo methods to represent interannual variation in reproduction and survival rates (Burgman et al., 99-0289). As with any population simulation approach, much life history information is needed, including density dependence and migration and demographic stochasticity. Essentially, natural probability for population decline is computed, then the algorithm is re-run using known or expected values for fecundity and survival rates from chemical stressor exposures. Chemical stressor risk to the population is determined by the difference between the natural and the stressor-specific values. If sufficient appropriate data are available for input, process models will be considered for use in this ERA.

7.3.3.2 Stressor-Response Profile

The final portion of the Analysis Phase will be the stressor-response profile. The stressor-response profile is a summary of the ecological response analysis. The objectives of the stressor-response profile are to ensure that the information necessary for the risk characterization has been collected and evaluated, and to verify that the assessment and measurement endpoints identified in the conceptual model were evaluated (99-0033).

This section may include a summarization of:

- Ecological entities affected.
- Nature of effects.
- Intensity of effects.
- Time scale for recovery, if known.
- Causality information.
- How alterations in the measurement endpoints affect the assessment endpoints.
- Uncertainties associated with the analysis.

7.4 RISK CHARACTERIZATION

7.4.1 Introduction

The Risk Characterization (Figure 7-5) is the final phase of the ERA, the purpose of which is to evaluate the likelihood that adverse effects have occurred or may occur as a result of exposure to COPCs (99-0032, 99-0033). The goal of the Risk Characterization is to provide estimates of risk to the assessment endpoints identified in the Problem Formulation by integrating information presented in the Analysis Phase and by interpreting the ecological significance of the estimated or observed effects.

The Risk Characterization will be divided into two stages: Risk Estimation and Risk Description. The risk estimation will integrate exposure and stressor-response information from the Analysis Phase and estimate the likelihood of adverse effects on the assessment endpoint of concern. A summary of the qualitative and quantitative elements of uncertainty also is included as part of the risk estimation. The risk description provides a complete and informative synthesis of the overall conclusions regarding risk estimates; addresses the uncertainty, assumptions, and limitations; and is useful for risk management decisionmaking.

The ultimate goal of the Risk Characterization is to fully describe the strengths and weaknesses of the risk assessment so that risk managers fully understand the conclusions reached in the ERA.

7.4.2 Risk Estimation

The risk estimation describes the likelihood of adverse effects to assessment endpoints by integrating exposure and effects data and evaluating any associated uncertainties (99-0032). The risk estimation process uses exposure and ecological effects information described in the Analysis Phase. However, it is important to recognize that the interpretation and synthesis of the results presented in the risk estimation are reserved for the risk description.

Risk estimations can range from highly quantitative to highly qualitative presentations. For example, it is likely that a qualitative approach will be used in the evaluation of the measurement endpoint derived from the task of evaluating soil invertebrate tissue concentrations, while a quantitative approach is typical for the evaluation of toxicity data. The ERA will evaluate, for each measurement endpoint, the relevant data accumulated during the SI process. The type, quality, and quantity of data to be collected will follow the approach outlined in the conceptual model and specified as part of the DQOs. The uncertainties specific to each estimate will be fully outlined. Regardless of the quantitative or qualitative nature of the assessment, professional judgment is needed for the interpretation (i.e., risk description) of any observed or predicted adverse effects.

Risks can be estimated by using one or a combination of the following approaches: (1) estimates expressed as qualitative categories; (2) estimates comparing single-point estimates of exposure and effects, i.e., the toxicity quotient approach; (3) estimates incorporating the entire stressor-response relationship; (4) estimates incorporating variability in exposure and effects estimates (e.g., Monte Carlo analysis); (5) estimates based on process models that rely on theoretical approximations of exposure and effects (e.g., sediment equilibrium partitioning); and (6) estimates based on empirical approaches, including field data (e.g., sediment toxicity testing). This ERA will combine several of these approaches as described in the previous sections to estimate the potential risks to ecological receptors.

7.4.2.1 Uncertainty Analysis

As mentioned previously, one of the major components of the Risk Characterization is the discussion of the uncertainties associated with estimating risk. Many of the uncertainties associated with the measurement endpoints selected as part of this risk assessment will be presented throughout the Problem Formulation and Analysis Phase. The primary objective of the uncertainty analysis is to combine and summarize the uncertainty present throughout the risk assessment process. This information can then be combined with other risk estimation information to more completely describe actual or potential risk and to assess the ecological significance of observed or predicted impacts. As stated previously, the actual integration and interpretation of the information presented in the risk estimation section will be provided in the risk description.

The Uncertainty Analysis will identify and, to the extent possible, quantify the uncertainties present in the Problem Formulation, Analysis Phase, and Risk Characterization. As previously discussed, virtually every step in a risk assessment involves numerous assumptions that contribute to the total uncertainty in the final evaluation of risk. The uncertainties that will be incorporated in the risk assessment may result in an increase or decrease in the estimated potential for adverse ecological effects. When methodologies and input factors for this risk assessment are selected, conservative, yet realistic approaches and values will be used when site-specific information is unavailable. This approach to handling uncertainty may tend to overestimate risks; however, it should be noted that only conservative assumptions compatible with sound scientific evidence or processes will be used.

Uncertainties in ecological risk assessments may be identified as belonging to one or more of the four following categories: conceptual model formulation uncertainty, data and information uncertainty, natural variability (stochasticity), and modeling error (99-0032). These are not discrete categories, and overlap does exist among them. U.S. EPA's Ecological Framework document provides a more detailed discussion of these generic uncertainty categories (99-0032).

Since there are some uncertainties that apply to several parts of the risk assessment, a description of the general uncertainties will be presented first. General uncertainty categories include: natural system variability, media sampling, data evaluation and reduction, and target receptor selection. After discussing general uncertainties associated with the risk assessment process, uncertainties specific to the measurement endpoints and the Monte Carlo analysis will be presented. A specific discussion on the potential approaches to handling Monte Carlo-associated uncertainties is presented below.

7.4.2.1.1 Monte Carlo Analysis Associated Uncertainty

Although Monte Carlo methods constitute a form of uncertainty propagation (Iman and Conover 99-0267; Iman et al., 99-0268), there is still a need to determine the effects of uncertainty on the probabilistic results. Several approaches are suggested for this purpose:

- *Interval analysis*. Interval analysis (Dwyer, 99-0261; Moore, 99-0270; Alefeld and Herzberger, 99-0259; Neumaier, 99-0271) is the simplest comprehensive method for uncertainty projection through mathematical expressions. With interval analysis, the uncertain value of a number is expressed as an interval or as a best estimate " some error. It is possible to use a Monte Carlo analysis of intervals to handle both statistical variation and systematic measurement error in a single comprehensive analysis.

- *Fuzzy arithmetic*. Fuzzy arithmetic (Kaufmann and Gupta, 99-0269) is a generalization of interval analysis based on possibility theory (Zadeh, 99-0273; Dubois and Prade, 99-0260). It is analogous to probability theory but applies to nonstatistical uncertainty such as measurement error or semantic ambiguity. Like interval analysis, fuzzy arithmetic does not incorporate correlation; therefore, the results of fuzzy arithmetic are not affected by unknown correlations.

- *Sensitivity analysis*. The final result of any analysis is only as good as the inputs on which it is based. Sensitivity analyses are an elaborated form of what-if simulations that ask a multitude of questions about the impacts of particular modeling decisions. Although rigorous sensitivity studies could be used to assess the robustness or fragility of the results, such studies are cumbersome to organize, computationally intense, and difficult to interpret.

- *Two-dimensional Monte Carlo*. Two-dimensional Monte Carlo simulation is a nesting of two ordinary Monte Carlo simulations (Hoffman and Hammonds, 99-0266 and Helton, 99-0265). By nesting one Monte Carlo simulation within another, analysts can discover how variability and uncertainty interact to create risk. Typically, the inner simulation represents natural variability of the underlying physical and biological processes, while the outer simulation represents the analyst's uncertainty about the particular parameters that should be used to specify inputs to the inner simulation.

- *Interval probabilities*. Probability bounds analysis (Frank et al., 99-0264; Williamson and Downs, 99-0272; Ferson and Long, 99-0263; Ferson, 99-0262) is a numerical approach that allows the calculation of bounds on arithmetic combinations of probability distributions when only bounds on the input distributions are given. The approach allows the analyst to decide what information is reliable. When the information about a distribution is very good, the bounds on the distribution will be very tight, approximating the precise distribution that is used in the Monte Carlo simulation. When the information is very poor, the bounds will tend to be much wider, representing weaker confidence about the specification of this distribution.

One or more of these methods may be used to assess the implications of uncertainty from measurement error, model uncertainty, and other kinds of incertitude on the Monte Carlo analyses conducted for this ERA.

7.4.3 Risk Description

The risk description is the part of the ecological risk assessment in which the risk assessors integrate and interpret the available information into conclusions about risks to the assessment endpoints (99-0033).

The risk description incorporates two primary elements. The first is the lines of evidence evaluation, which provides a process and framework for determining confidence in the risk estimate. The second is the determination of ecological adversity, which represents whether the valued structural or functional attributes of the ecological entities under consideration are altered, the degree of adversity to the entities, and if recovery is possible (99-0033).

7.4.3.1 Lines of Evidence

Evaluation of how well a measurement endpoint and its one or more lines of evidence represent an assessment endpoint is initially discussed in the weight-of-evidence portion of the Problem Formulation. However, it should be noted the while the results of the weight-of-evidence approach used to assign weights to individual measurement endpoints in the Problem Formulation Phase are an integral part of the lines of evidence process, the goal of the lines of evidence approach is to integrate all relevant findings of the risk assessment in an effort to determine the occurrence or potential for adverse ecological impacts. This is accomplished by evaluating the magnitude of response with respect to each measurement endpoint and the concurrence among the measurement endpoint(s) used to answer the question(s) posed by the assessment endpoint. In determining the magnitude of response in a measurement endpoint, two questions must be answered: 1) does the measurement endpoint indicate the presence or absence of harm, and 2) is the response observed low, medium, or high in magnitude of the response. When evaluating concurrence among measurement endpoints, there is an examination of the agreement or lack thereof among measurement endpoints as they relate to a specific assessment endpoint. Logical connection, interdependence, and correlations among measurement endpoints need to be considered. A graphical method that includes information on the measurement endpoints' weight and response provides an easy visual examination of agreements on divergences among the measurement endpoints. Developing lines of evidence also provides a structure under which a conclusion regarding confidence in the risk estimate can be made. The following three categories of factors will be considered when evaluating the individual lines of evidence (99-0033):

- Adequacy and quality of data—Influences confidence in the results of a study and the conclusions that may be drawn from it. For example: 1) Were the data quality objectives clearly presented and met by the experimental design? 2) Were the natural variabilities in the ecological parameters under evaluation understood well enough to result in a study yielding data sufficiently sensitive and robust to identify stressor-related perturbations?

- Degree and type of uncertainty associated with the evidence—Essential to understanding the limitations and assumptions of the approaches used in the risk assessment before a complete description of risks and their ecological significance is developed.

- Relationship of the evidence to the risk assessment questions—Determines the relative importance of the evidence to the assessment endpoint evaluated. Lines of evidence that establish a cause-and-effect relationship based on a definitive mechanism instead of associations only, and those that are directly related to the risk hypotheses are most likely of greatest importance.

Agreement between different lines of evidence increases confidence in the conclusions derived in the risk estimation. When lines of evidence disagree, it is important to distinguish between true inconsistencies and those related to uncertainty and variability associated with each measurement endpoint. The evaluation process involves more than just listing the evidence that supports or refutes the risk estimate. The ERA must present in detail the considerations and interpretations involved in evaluating all lines of evidence. As with assigning qualitative significance ratings to the measurement endpoints, professional judgment is required when evaluating the various results and conflicting lines of evidence.

7.4.3.2 Determining Ecological Significance

The determination of ecological significance evaluates the responses observed in the measurement endpoints and those expected in the assessment endpoints and considers whether any expected changes will adversely affect local species population structure and function. The goal of the interpretation of ecological significance is to provide the risk manager with a broader ecological perspective with which to evaluate the results of the risk assessment. Moreover, the interpretation of ecological significance assists in providing the basis for remedial action, and later, during the evaluation of remedial alternatives, in understanding the tradeoffs that may occur after evaluating the effects from the remedial alternatives themselves when compared the effects from the contaminants.

The following criteria are proposed by EPA’s Risk Assessment Forum for evaluating potential adverse changes in assessment endpoints (99-0033).

- Nature and intensity of effects.
- Spatial and temporal scale.
- Potential for recovery.

The extent to which these criteria are evaluated depends on the scope and complexity of the risk assessment. In evaluating the nature and intensity of effects, the risk assessment distinguishes adverse ecological changes that are different from those expected as part of normal ecosystem variability, or that result in little or no significant alteration of the system.

Spatial and temporal scales also will be considered in assessing the significance of effects. The duration, extent, and pattern of stressors will be considered in the context of the surrounding landscape. Depending on the types of effects, habitats, and potential receptors present, effects to small areas of critical habitat may be as, if not more, ecologically significant than impacts to larger, less critical areas. The duration of any effect is dependent on the persistence of the stressors, as well as how often receptors may come in contact with the stressors. Long-term effects can potentially result in the complete alteration of the biological community that was present prior to the introduction of the stressor. Even short-term effects can be ecologically significant if exposure occurs during critical life stages of receptors, or results in an acute response.

The final consideration in evaluating ecological significance is the rate and extent to which ecosystem recovery is possible. Recovery is defined as the rate and extent of return of a population or community to a condition that existed before the introduction of stressors (99-0033).

Relative to these criteria, this discussion will evaluate the ecological significance of any adverse response observed or predicted. It is important to realize that decisions regarding the need for remediation or how remediation should be conducted are not risk assessment issues and will not be discussed in the ERA. These issues are part of the risk management process that requires consideration of other factors such as feasibility and community acceptance, which are not within the purview of the risk assessment process. However, risk assessment approaches are often integral tools of the risk management process and the data which is used in the risk assessment may be critical in the determination of cleanup concentrations.

8. SUPPLEMENTAL INVESTIGATION REPORT

A Draft SI Report will be prepared to integrate and evaluate the data from the additional investigations outlined in this Work Plan and any subsequent addenda with the data from historical and ongoing investigations conducted by GE and its consultants. The purpose of the SI Report is to use this integrated data set to develop a comprehensive conceptual model for the Lower River that can be used to guide the selection of remedial alternatives to be evaluated during the detailed CMS analysis. The SI Report will address:

- Physical characteristics of the study area.
- Contaminant source area characterization.
- Nature and extent of contamination.
- Contaminant migration pathways.
- Contaminant persistence in the environment.
- Potential human and ecological receptors.

The SI Report will also include the complete human health and ecological risk characterization, and the identification of chemical- and location-specific ARARs. A general outline for the SI Report is presented in Table 8-1.

A Final SI Report will be prepared incorporating the resolution of agency comments on the Draft SI Report.

Table 8-1

General Outline for Supplemental Investigation Report

EXECUTIVE SUMMARY

1 INTRODUCTION

1.1 Purpose of Report
1.2 Site Background
  1.2.1 Site Description
  1.2.2 Site History
  1.2.3 Previous Investigations
1.3 Report Organization

2 STUDY AREA INVESTIGATION

2.1 Includes field activities associated with site characterization. These may include physical and chemical monitoring of some, but not necessarily all, of the following:
  2.1.1 Surface Features
  2.1.2 Contaminant Source Investigations
  2.1.3 Meteorological Investigations
  2.1.4 Surface Water and Sediment Investigations
  2.1.5 Geological Investigations
  2.1.6 Soil and Vadose Zone Investigations
  2.1.7 Groundwater Investigations
  2.1.8 Human Population Surveys
  2.1.9 Ecological Investigations
2.2 If technical memoranda documenting field activities were prepared, they may be included in an appendix and summarized in this report chapter.

3 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

3.1 Includes results of field activities to determine physical characteristics. These may include some, but not necessarily all, of the following:
  3.1.1 Surface Features
  3.1.2 Meteorology
  3.1.3 Surface Water Hydrology
  3.1.4 Geology
  3.1.5 Soils
  3.1.6 Hydrogeology
  3.1.7 Demography and Land Use
  3.1.8 Ecology

Table 8-1

General Outline for Supplemental Investigation Report (Continued)

4 NATURE AND EXTENT OF CONTAMINATION

- 4.1 Presents the results of site characterization. These may include natural chemical components in some, but not necessarily all, of the following media:
  - 4.1.1 Contaminant Sources
  - 4.1.2 Soils and Vadose Zone
  - 4.1.3 Groundwater
  - 4.1.4 Surface Water and Sediment
  - 4.1.5 Air

5 CONTAMINANT FATE AND TRANSPORT

- 5.1 Potential Routes of Migration (i.e., air, groundwater, etc.)
- 5.2 Contaminant Persistence
  - 5.2.1 If they are applicable (i.e., for organic contaminants), describe estimated persistence in the study area environment and physical, chemical, and/or biological factors of importance of the media of interest.
- 5.3 Contaminant Migration
  - 5.3.1 Discuss factors affecting contaminant migration for the media of importance (e.g., sorption onto soils, solubility in water, movement of groundwater, etc.).
  - 5.3.2 Discuss modeling methods and results, if applicable.

6 HUMAN HEALTH RISK ASSESSMENT

- 6.1 Introduction
- 6.2 Hazard Identification
- 6.3 Dose-Response Assessment
- 6.4 Exposure Assessment
- 6.5 Risk Characterization
- 6.6 Uncertainty Analysis

7 ECOLOGICAL RISK ASSESSMENT

- 6.2.1 Introduction
- 6.2.2 Problem Formulation
- 6.2.3 Analysis Phase
- 6.2.4 Risk Characterization

8 SUMMARY AND CONCLUSIONS

- 8.1 Summary
  - 8.1.1 Nature and Extent of Contamination
  - 8.1.2 Fate and Transport
  - 8.1.3 Risk Assessment
- 8.2 Conclusions
  - 8.2.1 Data Limitations and Recommendations for Future Work
  - 8.2.2 Recommended Remedial Action Objectives

Table 8-1

General Outline for Supplemental Investigation Report (Continued)

APPENDICES
A—INVESTIGATORS' WORK PLANS
B—ANALYTICAL DATA AND QA/QC EVALUATION RESULTS
C—RISK ASSESSMENT METHODS

9. SCHEDULE

The planned schedule to complete the tasks outlined in this Work Plan is summarized in Exhibit 9-1. The individual activities are scheduled to overlap and/or occur back-to-back as much as possible to complete the work as early as practical and as efficiently as possible.

Several aspects of the schedule are not completely within WESTON's control, including timely access to GE property, potential weather delays due to the onset of winter, permitting requirements, and document review periods. Any one or several of these aspects could cause delays in the project schedule outlined in Exhibit 9-1.

Activity Description	Early Start	Early Finish
Systematic Soil & Sediment Sampling		
REACH 1		
Sediment Sampling (500)	16DEC98A	18DEC98A
REACH 2		
Sediment Sampling (666)	11NOV98A	15DEC98A
REACH 5		
Riverbank/Floodplain Sampling (3063)	22FEB99A	31MAR99A
Sediment Sampling (1665)	01APR99A	11JUN99A
Riverbank/Floodplain Sampling (continued)	14JUN99A	30JUL99A
REACH 6		
Sediment Sampling (486)	03MAY99A	21MAY99A
Riverbank/Floodplain Sampling (86)	14JAN99A	27JAN99A
REACH 7		
Sediment Sampling (510)	01AUG99A	30SEP99A
Floodplain Sampling (648)	01AUG99A	30OCT99A
REACH 8		
Sediment Sampling (215)	24MAY99A	31MAY99A
Floodplain Sampling (36)	01FEB99A	05FEB99A
REACH 9		
Sediment Sampling (153)	31MAY99A	04JUN99A
Floodplain Sampling (350)	01NOV99A	30NOV99A
Discrete Soil & Sediment Sampling		
Residential Areas		
Riverbank/Floodplain Sampling (770)	15FEB99A	12MAR99A
Sediment Sampling (100)	26APR99A	30APR99A
Riverbank/Floodplain Sampling (continued)	14JUN99A	09JUL99A
Recreational Areas		
Riverbank/Floodplain Sampling (225)	15MAR99A	09APR99A
Sediment Sampling (70)	03MAY99A	07MAY99A
Commercial/Industrial Areas		
Riverbank/Floodplain Sampling (140)	12APR99A	16APR99A
Agricultural Areas		
Floodplain Sampling (300)	19JUL99A	06AUG99A
Other		
Aggrading Bars (245)	08MAR99A	19MAR99A
Former Meanders (54)	01MAR99A	05MAR99A
Vernal Pools (280)	01FEB99A	30APR00
Impoundments (60)	01AUG99A	14AUG99A
Run of River Cores (148)	10MAY99A	14MAY99A
Benthic Macroinvertebrate Sed & Sed Tox (71)	01MAR99A	28MAY99A
Frog Locations (40)	17MAY99A	21MAY99A
Tree Swallow Sediment Sampling (170)	01MAR99A	05MAR99A
Fish Locations (12)	22FEB99A	26FEB99A
Soil Invertebrate Locations (40)	01APR00*	30JUN00

Start Date 21OCT98
Finish Date 31MAY01
Data Date 02FEB00
Run Date 22FEB00 10:46

Early Bar
Progress Bar
Critical Activity

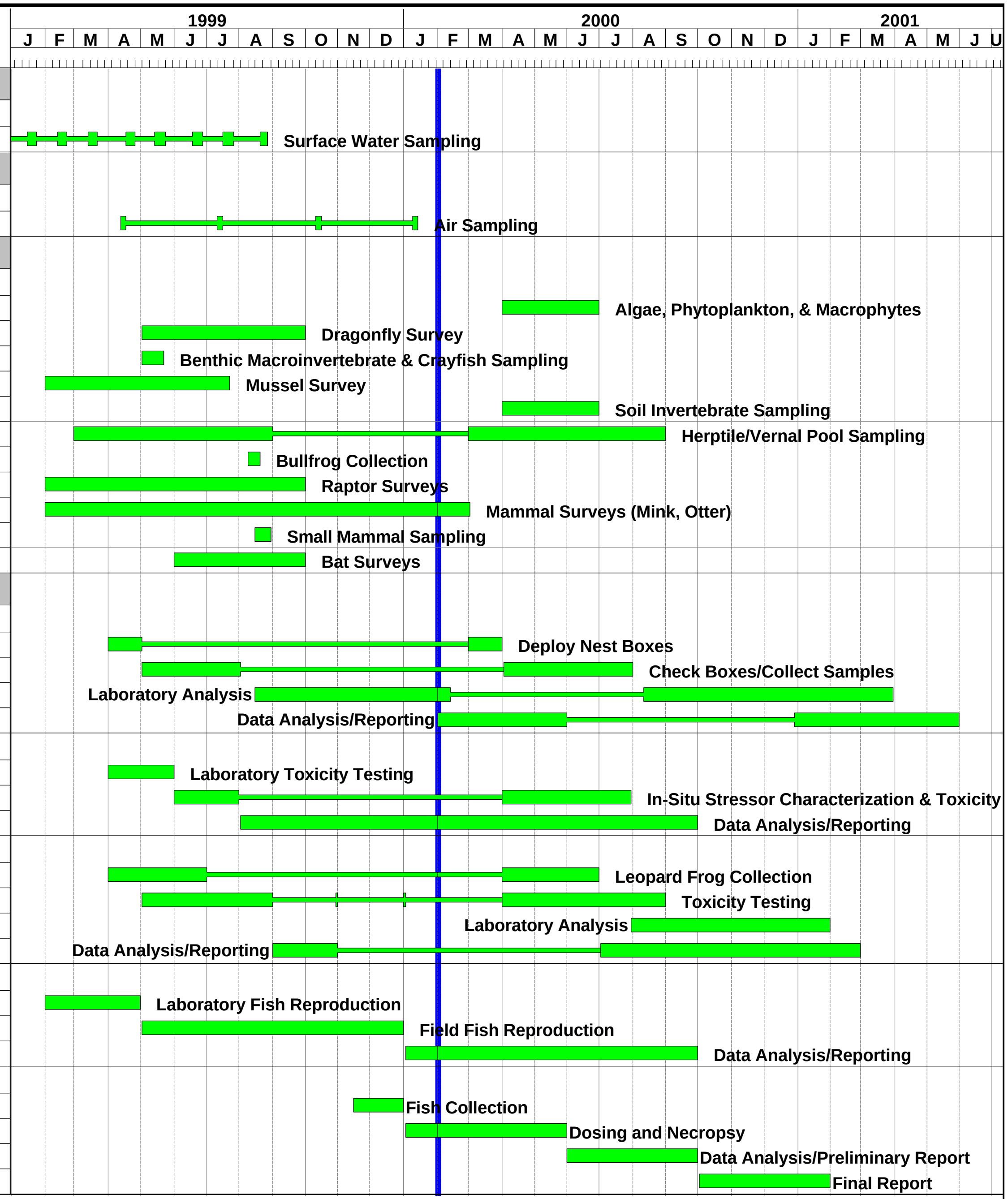
PITB

EXHIBIT 9-1 PROJECT SCHEDULE DRAFT
GE/HOUSATONIC RIVER PROJECT
ROY F. WESTON, INC

MANAGERS DESIGNERS/CONSULTANTS

Date	Revision	Checked	Approved

Activity Description	Early Start	Early Finish
Surface Water Sampling		
Surface Water Sampling	27AUG98A	27AUG99A
Air Sampling		
Air Sampling	12APR99A	14JAN00A
Biological Investigations		
Algae, Phytoplankton, & Macrophytes	01APR00*	30JUN00
Dragonfly Survey	03MAY99A	01OCT99A
Benthic Macroinvertebrate & Crayfish Sampling	03MAY99A	21MAY99A
Mussel Survey	01FEB99A	23JUL99A
Soil Invertebrate Sampling	01APR00*	30JUN00
Herptile/Vernal Pool Sampling	01MAR99A	31AUG00
Bullfrog Collection	09AUG99A	20AUG99A
Raptor Surveys	01FEB99A	30SEP99A
Mammal Surveys (Mink, Otter)	01FEB99A	01MAR00
Small Mammal Sampling	15AUG99A	29AUG99A
Bat Surveys	01JUN99A	30SEP99A
Investigators Study Plans		
Tree Swallow Study		
Deploy Nest Boxes	01APR99A	31MAR00
Check Boxes/Collect Samples	03MAY99A	31JUL00
Laboratory Analysis	16AUG99A	30MAR01
Data Analysis/Reporting	01FEB00A	31MAY01
Invertebrate Toxicity Testing		
Laboratory Toxicity Testing	01APR99A	31MAY99A
In-Situ Stressor Characterization & Toxicity	01JUN99A	30JUL00
Data Analysis/Reporting	02AUG99A	29SEP00
Amphibian Toxicity Testing		
Leopard Frog Collection	01APR99A	30JUN00
Toxicity Testing	03MAY99A	31AUG00
Laboratory Analysis	31JUL00	30JAN01
Data Analysis/Reporting	01SEP99A	28FEB01
Fish Health and Toxicity Testing		
Laboratory Fish Reproduction	01FEB99A	30APR99A
Field Fish Reproduction	03MAY99A	31DEC99A
Data Analysis/Reporting	03JAN00A	29SEP00
Mink Toxicity Study		
Fish Collection	15NOV99A	31DEC99A
Dosing and Necropsy	03JAN00A	31MAY00
Data Analysis/Preliminary Report	01JUN00	29SEP00
Final Report	02OCT00	30JAN01



Start Date	21OCT98
Finish Date	31MAY01
Data Date	02FEB00
Run Date	22FEB00 10:46

Early Bar
Progress Bar
Critical Activity

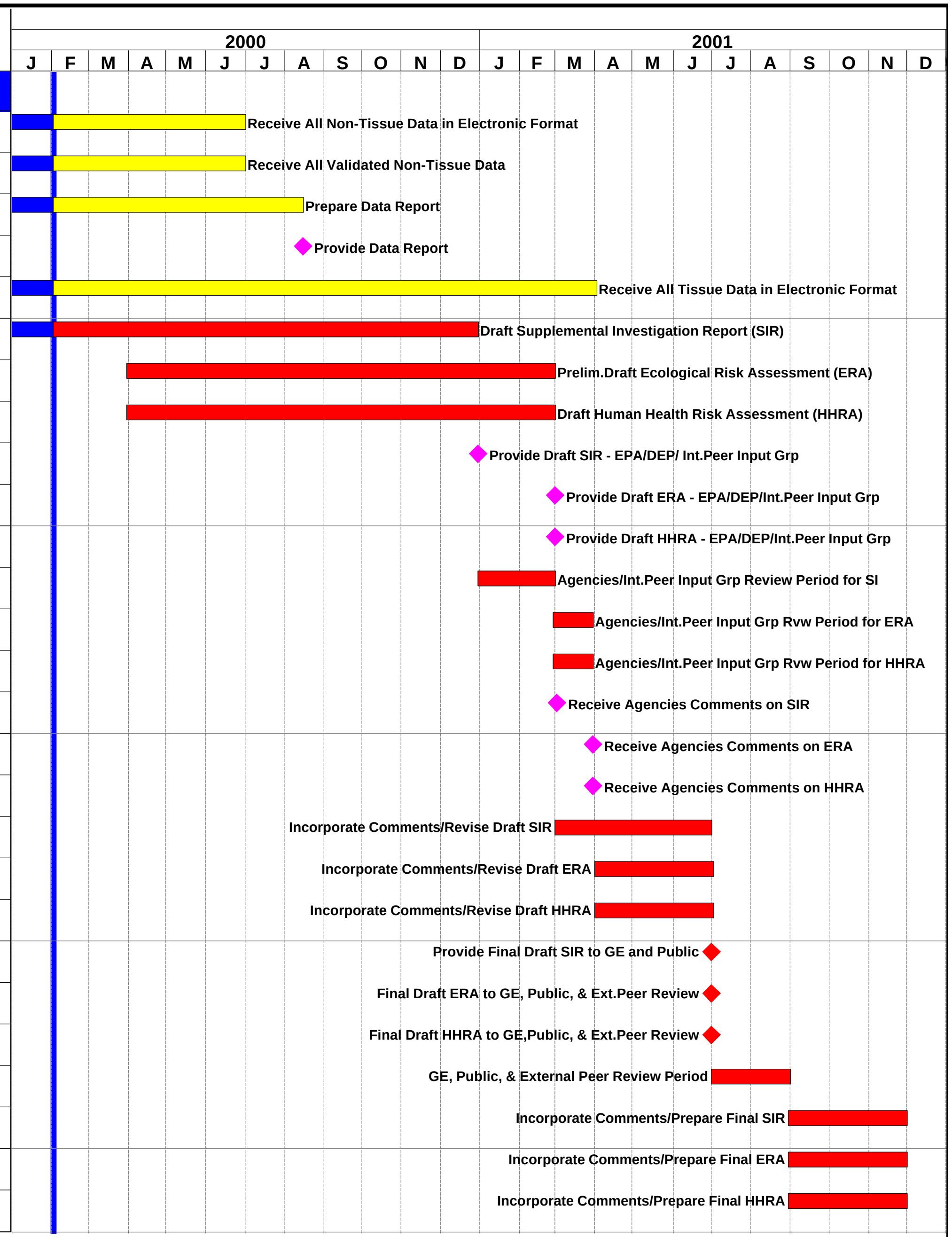
PITB

EXHIBIT 9-1 PROJECT SCHEDULE DRAFT
GE/HOUSATONIC RIVER PROJECT
ROY F. WESTON, INC

MANAGERS DESIGNERS/CONSULTANTS

Date	Revision	Checked	Approved

Activity Description	Calendar Days	Early Start	Early Finish
Reporting			
Receive All Non-Tissue Data in Electronic Format	361	01JUL99A	30JUN00
Receive All Validated Non-Tissue Data	270	01OCT99A	30JUN00
Prepare Data Report	485	01JUN99A	15AUG00
Provide Data Report	0		15AUG00
Receive All Tissue Data in Electronic Format	670	01JUN99A	01APR01
Draft Supplemental Investigation Report (SIR)	426	30OCT99A	30DEC00
Prelim.Draft Ecological Risk Assessment (ERA)	333	30MAR00	28FEB01
Draft Human Health Risk Assessment (HHRA)	333	30MAR00	28FEB01
Provide Draft SIR - EPA/DEP/ Int.Peer Input Grp	0		30DEC00
Provide Draft ERA - EPA/DEP/Int.Peer Input Grp	0		28FEB01
Provide Draft HHRA - EPA/DEP/Int.Peer Input Grp	0		28FEB01
Agencies/Int.Peer Input Grp Review Period for SI	59	31DEC00	28FEB01
Agencies/Int.Peer Input Grp Rvw Period for ERA	31	28FEB01	30MAR01
Agencies/Int.Peer Input Grp Rvw Period for HHRA	31	28FEB01	30MAR01
Receive Agencies Comments on SIR	0		01MAR01
Receive Agencies Comments on ERA	0		30MAR01
Receive Agencies Comments on HHRA	0		30MAR01
Incorporate Comments/Revise Draft SIR	122	01MAR01	30JUN01
Incorporate Comments/Revise Draft ERA	92	01APR01	01JUL01
Incorporate Comments/Revise Draft HHRA	92	01APR01	01JUL01
Provide Final Draft SIR to GE and Public	0	01JUL01	
Final Draft ERA to GE, Public, & Ext.Peer Review	0	01JUL01	
Final Draft HHRA to GE,Public, & Ext.Peer Review	0	01JUL01	
GE, Public, & External Peer Review Period	61	01JUL01	31AUG01
Incorporate Comments/Prepare Final SIR	92	31AUG01	30NOV01
Incorporate Comments/Prepare Final ERA	92	31AUG01	30NOV01
Incorporate Comments/Prepare Final HHRA	92	31AUG01	30NOV01



Start Date	01JAN99
Finish Date	30NOV01
Data Date	02FEB00
Run Date	22FEB00 10:45

Early Bar
Progress Bar
Critical Activity

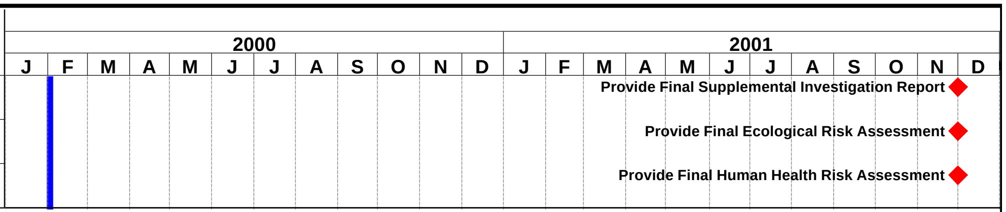
PI11 Sheet 1 of 2

EXHIBIT 9-1 PROJECT SCHEDULE - DRAFT
GE/HOUSATONIC RIVER PROJECT
ROY F. WESTON, INC

WESTON® MANAGERS DESIGNERS/CONSULTANTS

Date	Revision	Checked	Approved

Activity Description	Calendar Days	Early Start	Early Finish
Provide Final Supplemental Investigation Report	0	01DEC01	
Provide Final Ecological Risk Assessment	0	01DEC01	
Provide Final Human Health Risk Assessment	0	01DEC01	



10. REFERENCES

00-0274 GE Monthly Status Reports Massachusetts Contingency Plan, EPA EE/CA Corrective Action Activities. June 1996 – May 1997.

00-0275 WESTON (Roy F. Weston, Inc.). 1998. *Source Area Characterization Report*.

00-0309 TechLaw, Inc. 4 May 1998. *Preliminary Report: Wetland Characterization and Function-Value Assessment, Housatonic River from Newell Street to Woods Pond.*

00-0313 WESTON (Roy F. Weston, Inc.) 12 January 1999. *Final Health and Safety Plan GE/ Housatonic River Site Pittsfield, Massachusetts.* U.S. Department of the Army New England District, Corps of Engineers.

00-0315 Ballew, M. (EPA) and M. Harvey (ORS, DEP). 1998. Memorandum (May 14, 1998) to Bryan Olson (EPA) and Anna G. Symington (BWSC, DEP) Concerning Evaluation of Human Health Risks from Exposure to Elevated Levels of PCBs in Housatonic River Sediment, Bank Soils and Floodplain Soils in Reaches 3-1 to 4-6 (Newell Street to the Confluence of the East and West Branches).

00-0316 Landrum, P.F., National Oceanic and Atmospheric Administration. 1998. Personal Communication to the Internal Peer Review Group Meeting, 17 December 1998.

00-0334 WESTON (Roy F. Weston, Inc.). March 1999. *Final Field Sampling Plan.*

00-0377 Woodlot Alternatives, Inc. May 1999. *Housatonic River and Riparian Community Characterization: Lyman Street to the Confluence.*

00-0388 United States of America, State of Connecticut, and Commonwealth of Massachusetts, Plaintiffs vs. General Electric Company, Defendant. October 1999. C*onsent Decree-Main Document.*

00-0389 United States of America, State of Connecticut, and Commonwealth of Massachusetts, Plaintiffs vs. General Electric Company, Defendant. October 1999. *Consent Decree—Appendix E—Statement of Work for Removal Actions Outside the River.*

00-0390 United States of America, State of Connecticut, and Commonwealth of Massachusetts, Plaintiffs vs. General Electric, Defendant. October 1999. *Consent Decree—Appendices G Through W.*

00-0458 WESTON (Roy F. Weston, Inc.). February 2000. *Final Quality Assurance Project Plan.*

00-0459 WESTON (Roy F. Weston, Inc.). 1999. *Environmental Information Management Systems Data Management Plan.*

01-0014 Geraghty & Miller. 1988. *Evaluation of Groundwater Conditions, Unkamet Brook Area.*

01-0019 BBL (Blasland, Bouck & Lee, Inc.). 1996. *MCP Supplemental Phase II/RCRA Facility Investigation Report for Lyman Street/U.S. EPA Area 5A Site.*

01-0020 BBL (Blasland, Bouck & Lee, Inc.). 1995. *MCP Supplemental Phase II Scope of Work and Proposal for RCRA Facility Investigation of Unkamet Brook Area/U.S. EPA Area 1.*

01-0021 BBL (Blasland, Bouck & Lee, Inc.). 1995. *MCP Interim Phase II Report and Current Assessment Summary for Unkamet Brook Area/U.S. EPA Area 1,* Volumes I, II, III, V, and XII.

01-0022 O'Brien & Gere Engineers, Inc. 1995. *Phase I Report (MCP)/Current Assessment Summary, Hill 78 Area/Area 2.*

01-0024 BBL (Blasland, Bouck & Lee, Inc.). 1994. *MCP Interim Phase II Report and Current Assessment Summary for East Street Area 2/U.S. EPA Area 4.* Volumes I, II, III, IV, V, VI, VII, IX, X, and XII.

01-0027 BBL (Blasland, Bouck & Lee, Inc.). February l994. *MCP Phase I Report for Lyman Street Parking Lot (Oxbow Area D) and Current Assessment Summary for U.S. EPA Area 5a.* Volumes I, II, III, and IV.

01-0140 BBL (Blasland, Bouck & Lee, Inc.). May 1994. *Sampling and Analysis Plan/Data Collection and Analysis Quality Assurance Plan.*

01-0147 BBL (Blasland, Bouck & Lee, Inc.). 1998. *Report on Supplemental Characterization Activities –Building 68 Area.*

01-0161 Geraghty & Miller. 1991. *Phase I Limited Site Investigation Current Assessment Summary Report Hill 78 Area, Pittsfield, MA.* Volume I.

01-0196 Golder Associates. May 1995. *Addendum to MCP Phase II Scope of Work for Lyman Street Site and Proposal for RCRA Facility Investigation for U.S. EPA Area 5A.*

02-0007 Massachusetts Water Resources Commission. 1975. *The Housatonic River - 1974 Water Quality Analysis*.

02-0016 The Connecticut Agricultural Experimentation Station. 1982. *Polychlorinated Biphenyls in Housatonic River Sediments in Massachusetts and Connecticut: Determination, Distribution, and Transport*.

02-0030 Stewart Laboratories, Inc. 1982. *Housatonic River Study 1980 and 1982.* Volumes I and II.

02-0038 BBL (Blasland, Bouck & Lee, Inc.). 1992. *Addendum to MCP Interim Phase II Report/Current Assessment Summary for Housatonic River, Volume I of II.*

02-0048 ChemRisk. 1994. *Evaluation of the Terrestrial Ecosystem of the Housatonic River Valley*. Prepared for General Electric Company, Pittsfield, Massachusetts.

02-0062 Blasland & Bouck Engineers. September 1986. *Addendum—Housatonic River Study—135-Day Interim Report.*

02-0071 BBL (Blasland, Bouck & Lee, Inc.). December 1991. *MCP Interim Phase II Report/Current Assessment Summary for Housatonic River.* Volumes I, II, and III.

02-0089 USGS (U.S. Geological Survey). 1994. *Water Resources Data, Massachusetts and Rhode Island, Water Year 1994.* USGS Water-Data Report MA-RI-94-1, pp. 149-150.

02-0090 LMS (Lawler, Matusky & Skelly Engineering). September 1991. *Ambient Trend Monitoring and PCB Fate and Transport Model.*

02-0098 HEC. (Harrington Engineering and Construction, Inc., 1996. *Report on the Preliminary Investigation of Corrective Measures for Housatonic River and Silver Lake Sediment.* Prepared for General Electric Company.

02-0101 Chadwick & Associates, Inc. 1994. *Aquatic Ecology Assessment of the Housatonic River, Massachusetts, 1993*. Prepared for General Electric Company, Pittsfield, Massachusetts.

02-0102 Chadwick & Associates, Inc. 1993. *Fisheries Investigation of the Housatonic River, Massachusetts, 1993.* Prepared for General Electric Company, Pittsfield, Massachusetts.

02-0135 Woodlot Alternatives, Inc. June 1998. *Housatonic River Meander Survey Mapping Project*.

02-0161 WESTON (Roy F. Weston, Inc.). 1998. *Preliminary Work Plan for Engineering Evaluation/Cost Analysis and Remedial Investigation for OU 2 Housatonic River*.

02-0166 ChemRisk. 4 February 1996. *Proposal for Human Health Risk Assessment of the Housatonic River.*

02-0188 AQUA TERRA Consultants. 14 October 1999. *Modeling Study of PCB Contamination in the Housatonic River: Modeling Framework Design*.

04-0004 BBL (Blasland, Bouck & Lee, Inc.). 1996. *Supplemental Phase II/RCRA Facility Investigation Report for Housatonic River and Silver Lake.* January 1996. Report, Study. 375 pages, (AR No. 02.02.2, Doc. No. 000019).

04-0007 BBL (Blasland, Bouck & Lee, Inc.). 1996. *Supplemental Phase II/RCRA Facility Investigation for Housatonic River and Silver Lake Analytical Data for September 1994 through December 1995.* Vol. I of IV.

05-0003 Geraghty & Miller, Inc. April 1989. *Supplemental Investigation of Soil and Groundwater Conditions at the Newell Street Site, General Electric Company, Pittsfield, Massachusetts.*

05-0005 BBL (Blasland, Bouck & Lee, Inc.). March 1994. *MCP Interim Phase II Report for Newell Street Parking Lot Site and Current Assessment Summary for U.S. EPA Area 5B.* Volumes I, II, III, and IV of IV.

05-0062 TechLaw, Inc. March 1999. *Final Preliminary Ecological Characterization, Newell Street to Woods Pond.*

06-0001 BBL (Blasland, Bouck & Lee, Inc.). February 1996. *MCP Phase I and Interim Phase II Report for Former Housatonic River Oxbow Areas A, B, C, J, and K* (Vol. I of II).

07-0001 WESTON (Roy F. Weston, Inc.). 1998. *Work Plan for Engineering Evaluation/Cost Analysis (EE/CA).*

07-0028 WESTON (Roy F. Weston, Inc.). August 1999. *Final Comprehensive Data Report-the Source Reach (the First 1/2 Mile).*

99-0002 EPA (U.S. Environmental Protection Agency), Office of Emergency and Remedial Response. 1989. *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A).* Interim Final. EPA/540/1-89/002.

99-0003 EPA (U.S. Environmental Protection Agency), Office of Solid Waste and Emergency Response. 1992. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Office of Emergency and Remedial Response, Hazardous Site Evaluation Division, Intermittent Bulletin Volume 1, Number 1. Publication 9285.7-081.

99-0005 EPA (U.S. Environmental Protection Agency), New England. 1995. “Risk Updates,” Number 3.

99-0006 EPA (Environmental Protection Agency), Office of Research and Development, Office of Emergency and Remedial Response. 1997. *Health Effects Assessment Summary Tables, FY-1997 Update.* 9200.6-303(97-1); EPA 540/R-97-036; PB97-921199.

99-0007 EPA (Environmental Protection Agency), Office of Research and Development, National Center for Environmental Assessment. 1997. *Exposure Factors Handbook, Volume I—General Factors.* (Update to *Exposure Factors Handbook*, EPA/600/8-89/043-May 1989). EPA/600/P-95-002Fa.

99-0010 EPA (Environmental Protection Agency), Office of Solid Waste and Emergency Response. 1998. *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part D, Standardized Planning, Reporting and Review of Superfund Risk Assessments).* Interim. EPA 540-R-97-033; OSWER 9285.7-01D; PB97-963305.

99-0011 EPA (Environmental Protection Agency). 1998. "Substance File List." Integrated Risk Information System (IRIS), http://www.epa.gov/ngispgm3/iris/index.html.

99-0013 DiToro, D.M., C.S. Zarba, D.J. Hansen et al. 1991. "Technical Basis for Establishing Sediment Quality Criteria for Nonionic Organic Chemicals Using Equilibrium Partitioning." *Environ. Toxicol. Chem,* 10:1541-1583.

99-0014 Long, E.G., D.D. MacDonald, S.L. Smith et al. 1995. "Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." *Environ. Management,* 19:81-97.

99-0015 Persaud, D., R. Jaagumagi, and A. Hayton. 1996. *Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario*. Ontario Ministry of Environment and Energy. Queens Printer for Ontario.

99-0016 EPA (U.S. Environmental Protection Agency). 1992. *A SAB Report: Review of Sediment Criteria Development Methodology for Non-Ionic Organic Contaminants.* Washington, DC. EPA-SAB-EPEC-93-002.

99-0017 ATSDR (Agency for Toxic Substances and Disease Registry). 1995. *Toxicology Profile for Polychlorinated Biphenyls.* Draft Publication for Comment (Update). U.S. Department of Health and Human Services, Public Health Service. Prepared by Research Triangle Institute.

99-0018 EPA (U.S. Environmental Protection Agency). 1993. *Technical Basis For Deriving Sediment Quality Criteria For Nonionic Organic Contaminants For The Protection Of Benthic Organisms By Using Equilibrium Partitioning.* Washington, DC. EPA-822-R-93/011.

99-0030 Bailey, R.G. 1995. *Description of the Ecoregions of the United States,* 2nd ed. Rev. and Expanded (1st ed. 1980). Misc. Publ. No. 1391 (rev.), Washington, DC: USDA Forest Service. 108 pp. With separate map at 1:7,500,000.

99-0031 EPA (U.S. Environmental Protection Agency), Office of Research and Development, National Center for Environmental Assessment. 1996. *PCBs: Cancer Dose-Response Assessment and Application to Environmental Mixtures.* EPA/600/P-96/001F.

99-0032 EPA (U.S. Environmental Protection Agency). 1992. *Framework for Ecological Risk Assessment*. Risk Assessment Forum, Washington, DC. EPA/603-R-92/001.

99-0033 EPA (U.S. Environmental Protection Agency). 1998. *Guidelines for Ecological Risk Assessment*. Risk Assessment Forum, Washington DC. EPA/630/R-95/002F.

99-0037 Sheehan, P.J. and O.L. Loucks. 1994. "Issue Paper on Effects Characterization." In: *Ecological Risk Assessment Issue Papers.* U.S. Environmental Protection Agency, Washington, DC. EPA/630/R-94/009.

99-0037 Suter, G.W. II, J.W. Gillet, and S.B. Norton. 1994. "Issue Paper on Characterization of Exposure." In: *Ecological Risk Assessment Issue Papers.* U.S. Environmental Protection Agency, Washington, DC. EPA/630/R-94/009.

99-0038 EPA (U.S. Environmental Protection Agency). 1993. *A Review of Ecological Assessment Case Studies from a Risk Assessment Perspective.* Risk Assessment Forum. EPA/630/R-92/005.

99-0040 EPA (U.S. Environmental Protection Agency), Office of Research and Development. 1993. *Wildlife Exposure Factors Handbook.* Volumes I and II. EPA/600/R-93/187a, EPA/600/R-93/187b.

99-0041 Menzie, C., M. Henning, J. Cura, K. Finkelstein, J. Gentile, J. Maughan, D. Mitchell, S. Petron, B. Potocki, S. Svirsky, and P. Tyler. 1996. "Special Report of the Massachusetts Weight-of-Evidence Approach for Evaluating Ecological Risks." *Human and Ecological Risk Assessment*, 2(2):227-304.

99-0042 Suter, G.W. II. 1989. "Ecological Endpoints." In: *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference Document*. W. Warren-Hicks, B.R. Parkhurst, and S.S. Baker, Jr., Editors. EPA 600/3-89/013.

99-0043 Suter, G.W. II. 1993. *Ecological Risk Assessment.* Lewis Publishers, Chelsea, MI.

99-0044 EPA (U.S. Environmental Protection Agency). 1994. "Field Studies for Ecological Risk Assessment." *ECO Update,* Intermittent Bulletin, Vol. 2, No. 3.

99-0045 Shaffer, H.B., R.A. Alford, B.D. Woodward, S.J. Richards, R.G. Altig, and C. Gason. 1994. "Quantitative Sampling of Amphibian Larvae." In: *Measuring and Monitoring Biological Diversity, Standard Methods for Amphibians,* pp. 130-141.

99-0046 Massachusetts Natural Heritage and Endangered Species Program. 1997. *Massachusetts Natural Heritage Atlas, 1997-98 Edition.* Massachusetts Division of Fisheries and Wildlife, Westborough, Massachusetts.

99-0047 Bellrose, F.C. 1976. *Ducks, Geese and Swans of North America.* The Stackpole Co., Harrisburg, Pennsylvania.

99-0048 Smith, D.G. 1995. *Keys to the Freshwater Macroinvertebrates of Massachusetts.* Second Edition. Privately published by D.G. Smith, Sunderland, Massachusetts.

99-0049 EPA (U.S. Environmental Protection Agency). 1990. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*. Office of Research and Development, Washington, DC. EPA/600/4-90/030.

99-0050 Burton, G.A., M.K. Nelson, and C. G. Ingersoll. 1992. "Freshwater Benthic Toxicity Tests." In: *Sediment Toxicity Assessment*. G.A. Burton, Jr., Editor. Lewis Publishers, Chelsea, MI.

99-0050 Chapman, P.M., E.A. Power, and G. A. Burton. 1992. "Integrative Assessments in Aquatic Ecosystems." In: *Sediment Toxicity Assessment*. G.A. Burton, Jr., Editor. Lewis Publishers, Chelsea, MI.

99-0052 Thomas, N.K., J.O. Lamberson, and R.C. Swartz. 1992. "Bulk Sediment Toxicity-Test Approach." In: *Sediment Classification Methods Compendium*. U.S. Environmental Protection Agency, Office of Water. EPA 823-R-92-006.

99-0053 Lee, K.E. 1985. *Earthworms: Their Ecology and Relationships with Soils and Land Use*. Academic Press Australia.

99-0054 Mayfield, H. 1975. "Suggestions for Calculating Nest Success." *Wilson Bulletin*, 87:456-466.

99-0055 EPA (U.S. Environmental Protection Agency), Great Lakes National Program Office. 1996. *Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod Hyalella Azteca and the Midge Chironomus Riparius: National Biological Service Final Report for the U.S. Environmental Protection Agency Great Lakes National Program Office (GLNPO) Assessment and Remediation of Contaminated Sediment (ARCS) Project*. EPA 905-R96-008.

99-0057 EPA (U.S. Environmental Protection Agency). May 1998. *Region 9 PRGs.*

99-0060 Safe, S.H. 1994. "Polychlorinated Biphenyls (PCBs): Environmental Impact, Biochemical and Toxic Responses, and Implications for Risk Assessment." *Critical Reviews in Toxicology,* 242(2):87-149.

99-0062 Massachusetts Division of Fish and Wildlife. 1986. *Birds of the Housatonic Valley Wildlife Management Area.*

99-0063 MADEP (Massachusetts Department of Environmental Protection), MADEP Technical Services Branch. 1996. *Massachusetts Surface Water Quality Standards.*

99-0065 Ankley, G.T., G.L. Phipps, E.N. Leonard, D.A. Benoit, V.R. Mattson, P.A. Kosian, A.M. Cotter, J.R. Dierkes, D.J. Hansen, and J.D. Mahony. 1991. "Acid-Volatile Sulfide as a Factor Mediating Cadmium and Nickel Bioavailability in Contaminated Sediments." *Environ. Toxicol. Chem.*, 10:1299-1307.

99-0066 Cairns, M.A., A.V. Nebeker, J.H. Gakstatter, and W. Griffis. 1984. "Toxicity of Copper-Spiked Sediments to Freshwater Invertebrates." *Environ. Toxicol. Chem.*, 3:435-446.

99-0067 Eisler, R. and A.A. Belisle. 1996. *Planar PCB Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review*. Contaminant Hazard Reviews Report 31.

99-0068 EPA (U.S. Environmental Protection Agency). 1998. *Report from the Workshop on the Application of 2,3,7,8-TCDD Toxicity Equivalency Factors to Fish and Wildlife, January 20-22, 1998.* Submitted to Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, DC. Submitted by Eastern Research Group, Inc., Lexington, MA.

99-0069 Hill, A.B. 1965. "The Environment and Disease: Association or Causation." *Proc. Royal Soc. Med.*, 58:295-300.

99-0071 Kemble, N.E., W.G. Brumbaugh, E.L. Brunson, F.J. Dwyer, C.G. Ingersoll, D.P. Monds, and D.F. Woodward. 1994. "Toxicity of Metal-Contaminated Sediments from the Upper Clark Fork River, MT, to Aquatic Invertebrates in Laboratory Exposures." *Environ. Toxicol. Chem*., 12:1985-1998.

99-0072 Maughan, J.T. 1993. *Ecological Assessments of Hazardous Waste Sites*. Van Nostrand Reinhold, New York, NY.

99-0075 Nebeker, A.V., S.T. Onjukka, M.A. Cairns, and D.F. Krawczyk. 1986. "Survival of *Daphnia Magna* and *Hyalella Azteca* in Cadmium Spiked Water and Sediment." *Environ. Toxicol. Chem.*, 5:433-438.

99-0076 Norton, S.B., D.J. Rodier, J.H. Gentile, W.H. van der Schalie, W.P. Wood, and M.W. Slimak. 1992. "A Framework for Ecological Risk Assessment at the EPA." *Environ. Toxicol. Chem.*, 11:1663-1672.

99-0077 Pennak, R.W. 1978. *Fresh-Water Invertebrates of the United States.* 2nd Edition. John Wiley & Sons, New York, NY.

99-0079 Safe, S. 1990. "Polychlorinated Biphenyls (PCBs), Dibenzo-p-Dioxins (PCDDs), Dibenzofurans (PCDFs), and Related Compounds: Environmental and Mechanistic Considerations Which Support the Development of Toxic Equivalency Factors (TEFs)." *Critical Reviews in Toxicology,* 21:51-88.

99-0081 Suter, G.W. II and J.B. Mabrey. 1994. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1994 Revision*. Environmental Restoration Program, Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-96/R1.

99-0083 EPA (U.S. Environmental Protection Agency). 1992. *Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene.*

99-0084 EPA (U.S. Environmental Protection Agency). 1992. *Guidance for Data Usability in Risk Assessment, Part A.* Publication 9285.7-09A.

99-0085 WESTON (Roy F. Weston, Inc.). June 1998. *Upper Reach — Housatonic River Ecological Risk Assessment* (Final).

99-0088 EPA (U.S. Environmental Protection Agency). 1992. Guidance on Risk Characterization for Risk Managers and Risk Assessors. Memorandum from F. Henry Habicht, III, Deputy Administrator to Assistant Administrators and Regional Administrators. Office of the Administrator, Washington, DC.

99-0089 EPA (U.S. Environmental Protection Agency). 1991. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Office of Solid Waste and Emergency Response, Washington, DC. OSWER Directive 9285.603.

99-0090 EPA (U.S. Environmental Protection Agency). 1991. *Risk Assessment Guidance for Superfund, Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals).* Interim. Office of Emergency and Remedial Response, Washington, DC. Publication 9285.7-01B.

99-0097 Rosenblatt, D., L. Dache, and D. Cogley. 1982. “An Environmental Late Model Leading to Preliminary Pollutant Limit Values for Human Health Effects.” In: *Environmental Risk Analysis for Chemicals.* R. A. Conway, Editor. Van Nostrand Reinhold.

99-0104 Cowardin, L.M., V. Carter, F.C. Golet, and E.T. La Roe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States.* Performed for the Office of Biological Services, U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS-79/31.

99-0106 EPA (U.S. Environmental Protection Agency). 1996. *Proposed Guidelines for Carcinogenic Risk Assessment.* Office of Research and Development, Washington, DC. EPA/600/P-92/003C.

99-0110 EPA (U.S. Environmental Protection Agency). 1991. *Water Quality Criteria Summary*. Office of Science and Technology, Health and Ecological Criteria Division, Ecological Risk Assessment Branch, Human Risk Assessment Branch, Washington, DC. May 1991.

99-0111 Stephan, C.E., D.I. Mount, D.J. Hansen et al. 1985. *Guidelines for Deriving Numerical National Criteria for the Protection of Aquatic Organisms and Their Uses*. National Technical Information Service, Springfield, VA. PB85-227049.

99-0113 Wright, A. 24 September 1998. Personal Communication from Adam Wright, Massachusetts Department of Environmental Protection.

99-0116 EPA (U.S. Environmental Protection Agency). 1993. *Great Lakes Water Quality Initiative Criteria Documents in the Protection of Wildlife (Proposed): DDT, Mercury, 2,3,7,8-TCDD, and PCBs.* Office of Sciences and Technology, Washington, DC.

99-0117 Sample, B.E., D.M. Opresko, and G.W. Suter II. June 1996. *Toxicological Benchmarks for Wildlife: 1996 Revision.* Prepared by Risk Assessment Program, Lockheed Martin Energy Systems, Inc., Oak Ridge, TN. Prepared for U.S. Dept. of Energy.

99-0119 Dourson, M.L. and J.F. Stara. 1983. “Regulatory History and Experimental Support of Uncertainty (Safety) Factors.” *Reg. Tox. and Pharm*., 3:224-238.

99-0120 Bondon, A. and F. Ribeyre. 1989. *Aquatic Ecotoxicology: Fundamental Concepts and Methodologies.* Volume I.

99-0123 EPA (U.S. Environmental Protection Agency). November 1998. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance Dermal Risk Assessment Interim Guidance.* (Draft) Office of Emergency and Remedial Response, Washington, DC. Peer Consultation Workshop.

99-0127 EPA (U.S. Environmental Protection Agency). July 1998. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.* Volumes One, Two, and Three.

99-0128 EPA (U.S. Environmental Protection Agency). September 1986. “Guidelines for Carcinogen Risk Assessment.” *Federal Register*, 51(185):33992-34003.

99-0136 EPA (U.S. Environmental Protection Agency). 1991. *Removal Program Representative Sampling Guidance, Volume 1: Soil.* Prepared by the U.S. EPA Committee on Representative Sampling for the Removal Program. OSWER Directive 9360.4-10.

99-0137 EPA (U.S. Environmental Protection Agency). 1979. *Quantitative Techniques for the Assessment of Lake Quality.* U.S. EPA Office of Water, Washington, DC. EPA 440-5-79-015.

99-0138 EPA (U.S. Environmental Protection Agency), Environmental Response Team. 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments.* Interim Final. EPA 540-R-97-006.

99-0139 EPA (U.S. Environmental Protection Agency, Region III). 1998. Memorandum (10/1/98) from Jennifer Hubbard, Toxicologist, EPA Region III, Superfund Technical Support Section to RBC Table Users Concerning Risk-Based Concentration Table.

99-0140 Landrum, P.F., D.C. Gossiaux, and J. Kukkonen. 1997. "Sediment Characteristics Influencing the Bioavailability of Nonpolar Organic Contaminants to *Diporeia spp.*" *Chemical Speciation and Bioavailability*, 9 (2).

99-0141 Ankley, G.T., D.A. Benoit, R.A. Hoke, E.N. Leonard, C.W. West, G.L. Phipps, V.R. Mattson, and L.A. Anderson. 1993. "Development and Evaluation of Test Methods for Benthic Invertebrates and Sediments: Effects of Flow Rate and Feeding on Water Quality and Exposure Conditions." *Archives of Environmental Toxicology and Chemistry*, 25:12-19.

99-0142 West, C.W., V.R. Mattson, E.N. Leonard, G.L. Phipps, and G.T. Ankley. 1993. "Comparison of the Relative Sensitivity of Three Benthic Invertebrates to Copper Contaminated Sediments from the Keweenaw Waterway." *Hydrobiologia*, 262:57-63.

99-0143 Ankley, G.T., D.A. Benoit, J.C. Balough, T.B. Reynoldson, K.E. Day, and R.A. Hoke. 1994. "Evaluation of Potential Confounding Factors in Sediment Toxicity Tests with Three Freshwater Benthic Invertebrates." *Environmental Toxicology and Chemistry*, 13:627-635.

99-0145 Quinney, T.E. and C.D. Ankney. 1985. "Prey Size Selection by Tree Swallows." *Auk*, 102:245-250.

99-0146 Bicknell, B.R., J.C. Imhoff, J.L. Kittle, Jr., A.S. Donigian, and R.C. Johnson. 1998. "Hydrological Simulation Program-Fortran User's Manual for Release 11." RPA/600/r-97/080.

99-0147 Hamrick, J.M. 1966. "User's Manual for the Environmental Fluid Dynamics Computer Code." Special Report No. 331 in *Applied Marine Science and Ocean Engineering*, Virginia Institute of Marine Science.

99-0148 TAMS Consultants, Inc. and Gradient Corporation. 1993. *Phase 2B Sampling and Analysis/Quality Assurance Project Plan Volume 1: Flow-Averaged Water-Column Sampling, Hudson River PCB Reassessment RI/FS.* U.S. EPA Work Assignment No. 013-2N84. Revision 1. Prepared for U.S. EPA Region II Alternative Remedial Contracting Strategy (ARCS) for Hazardous Waste Remedial Services.

99-0196 Burton, G.A. and P.F. Landrum. 1989. *Standard Guide for Sediment Collection, Storage, Characterization, and Manipulation for Toxicological Testing.* ASTM Guidance Document E-1391-94.

99-0220 Eisler, R. 1986. *Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Laurel MD. Biological Report 85 (1.7).

99-0241 Cogliano, V.J. 1998. "Assessing the Cancer Risk from Environmental PCBs." *Environmental Health Perspectives*, 106(6):317-323.

99-0246 Clark, J., K. Dickson, and J. Cairns. 1979. "Estimating Aufwuchs Biomass." In: *Methods and Measurement of Periphyton Communities: A Review*. R. Weitzel, Editor. American Society for Testing and Materials, W. Conshohochen, Pennsylvania.

99-0247 EPA (U.S. Environmental Protection Agency). 1997. *Revision to Rapid Bioassessment Protocols for Use in Streams and Rivers: Periphyton, Benthic, Macroinvertebrates, and Fish.* EPA841-D-97-002.

99-0248 Ruttner, F. 1953. *Fundamentals of Limnology*. University of Toronto Press., Toronto.

99-0249 Smith, R. l966. *Ecology and Field Biology*. Harper & Row, New York.

99-0250 USGS (U.S. Geological Survey). 1987. "Methods for Collection and Analysis of Aquatic, Biological, and Microbiological Samples. In: *Techniques of Water Resources Investigations of the United States Geological Survey.* L.J. Britton and P.E. Greeson, Editors.

99-0253 Shelton, L.R. and P.D. Capel. 1994. *Guidelines for Collecting and Processing Samples of Stream Bed Sediment for Analysis of Trace Elements and Organic Contaminants for the National Water-Quality Assessment Program*. U.S. Geological Survey Open-File Report 94-458.

99-0254 Thomann, R., J. Connolly, and T. Parkerton. 1992. "An Equilibrium Model of Organic Chemical Accumulation in Aquatic Food Webs with Sediment Interaction." *Environmental Toxicology and Chemistry*, ll:615-629.

99-0256 Porter, S.D., T.F. Cuffney, M.E. Gurtz, and M.R. Meader. 1993. *Methods for Collecting Algal Samples as Part of the National Water-Quality Assessment Program.* U.S. Geological Survey, Open-File Report 93-409.

99-0257 Sijm, D., K.W. Broersen, D.F. De Roode, and P. Mayer. 1998. "Bioconcentration Kinetics of Hydrophobic Chemicals in Different Densities of *Chlorella Pyrenoidosa*." *Environmental Toxicology and Chemistry*, 17(9): 1695-1704.

99-0259 Alefeld, G. and J. Herzberger. 1983. *Introduction to Interval Computations*. Academic Press, New York.

99-0260 Dubois, D. and H. Prade. 1988. *Possibility Theory: An Approach to Computerized Processing of Uncertainty*. Plenum Press, New York.

99-0261 Dwyer, P. 1951. *Linear Computations*. John Wiley, New York.

99-0262 Ferson, S. 1995. "Quality Assurance for Monte Carlo Risk Assessments." In: *Proceedings of the 1995 Joint ISUMA/NAFIPS Symposium on Uncertainty Modeling and Analysis*, pp. 14-19. IEEE Computer Society Press, Los Alamitos, California.

99-0263 Ferson, S. and T.F. Long. 1995. "Conservative Uncertainty Propagation in Environmental Risk Assessments." In: *Environmental Toxicology and Risk Assessment - Third Volume*. ASTM STP 1218. J.S. Hughes, G.R. Biddinger, and E. Mones, Editors. American Society for Testing and Materials, W. Conshohochen, Pennsylvania.

99-0264 Frank, M.J., R.B. Nelsen, and B. Schweizer. 1987. " Best-Possible Bounds for the Distribution of a Sum—A Problem of Kolmogorov." *Probability Theory and Related Fields*, 74:199-211.

99-0265 Helton, J.C. 1994. "Treatment of Uncertainty in Performance Assessments for Complex Systems." *Risk Analysis,* 14:483-511.

99-0266 Hoffman, F.O. and J.S. Hammonds. 1994. "Propagation of Uncertainty in Risk Assessments: The Need to Distinguish Between Uncertainty Due to Lack of Knowledge and Uncertainty Due to Variability." *Risk Analysis*, 14(5):707-712.

99-0267 Iman, R.L. and W.J. Conover. 1980. "Small Sample Sensitivity Analysis Techniques for Computer Models, with an Application to Risk Assessment." *Communications in Statistics*, A9:1749-1842.

99-0268 Iman, R.L., J.C. Helton, and J.E. Campbell. 1981. "An Approach to Sensitivity Analysis of Computer Models, Part 2. Ranking of Input Variables, Response Surface Validation, Distribution Effect and Technique Synopsis." *Journal of Quality Technology*, 13:232-240.

99-0269 Kaufmann, A. and M.M. Gupta. 1985. *Introduction to Fuzzy Arithmetic: Theory and Applications*. Van Nostrand Reinhold, New York.

99-0270 Moore, R.E. 1966. *Interval Analysis*. Prentice-Hall, Englewood Cliffs, New Jersey.

99-0271 Neumaier, A. 1990. *Interval Methods for Systems of Equations.* Cambridge University Press, Cambridge.

99-0272 Williamson, R.C. and T. Downs. 1990. "Probabilistic Arithmetic I: Numerical Methods for Calculating Convolutions and Dependency Bounds." *International Journal of Approximate Reasoning,* 4:89-158.

99-0273 Zadeh, L. 1978. "Fuzzy Sets as a Basis for a Theory of Possibility." *Fuzzy Sets Systems,* 1:3-28.

99-0274 EPA (U.S. Environmental Protection Agency). 1996. *Soil Screening Guidance: User's Guide.* Second Edition. Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-96/018.

99-0275 Van den Berg, M. et al. 1998. "Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs for Humans and Wildlife." *Environmental Health Perspectives*, 106(12):775-792.

99-0276 GZA GeoEnvironmental, Inc. May 1991. *Sediment Sampling and Analysis Data Report—Rising Paper Company, Great Barrington, Massachusetts.* Newton Upper Falls, Massachusetts.

99-0278 Bratley, P., B.L. Fox, and L.E. Schrage. 1983. *Guide to Simulations*. Springer-Verlag, New York.

99-0279 Bukowski, J., L. Korn, and D. Wartenberg. 1995. "Correlated Inputs in Quantitative Risk Assessment: The Effects of Distributional Shape." *Risk Analysis,* 15:215-219.

99-0280 Cario, M.C. and B. L. Nelson. 1997. "Modeling and Generating Random Vectors with Arbitrary Marginal Distributions and Correlation Matrix. http://www.iems.nwu.edu/%7Enelsonb/norta4.ps.

99-0281 Clemen, R. and T. Reilly. 1999. "Correlations and Copulas for Decision and Risk Analysis." *Management Science,* 45:208-224.

99-0282 Cooke, R.M. 1991. *Experts in Uncertainty.* Oxford University Press, Cambridge.

99-0283 Cullen, A.C. and H.C. Frey. 1998. *Probabilistic Techniques in Exposure Assessment: A Handbook for Dealing with Variability and Uncertainty in Models and Inputs.* Plenum Press, New York

99-0284 Ferson, S. 1994. "Naive Monte Carlo Methods Yield Dangerous Underestimates of Tail Probabilities." In: *Proceedings of the High Consequence Operations Safety Symposium*, pp. 507–514. J.A. Cooper, Editor. Sandia National Laboratories. SAND94–2364.

99-0285 Fréchet, M. 1935. "Généralisations du Théorème des Probabilités Totales." *Fundamenta Mathematica,* 25:379-387.

99-0286 Fréchet, M. 1951. "Sur les Tableaux de Corrélation Dont les Marges Sont Données." *Ann. Univ. Lyon, Sect. A* 9:53-77.

99-0287 Grandy, W.T., Jr. and L.H. Schick. 1991. *Maximum Entropy and Bayesian Methods.* Kluwer Academic Publishers, Dordrecht.

99-0288 Hoeffding, W. 1940. "Masstabinvariante Korrelationstheorie." *Schriften des Matematischen Instituts und des Instituts für Angewandte Mathematik der Universität Berlin* 5 (Heft 3): 179-233 [translated in Hoeffding, W. 1940. Scale-Invariant Correlation Theory. *Collected Works of Wassily Hoeffding*. N.I. Fisher and P.K. Sen, Editors. Springer-Verlag, New York].

99-0289 Burgman, M.A., S. Ferson, and H.R. Akcakya. 1993. *Risk Assessment in Conservation Biology*. Chapman and Hall, London.

99-0291 Lee, R.C. and W.E. Wright. 1994. "Development of Human Exposure-Factor Distributions Using Maximum-Entropy Inference." *Journal of Exposure Analysis and Environmental Epidemiology,* 4:329-341.

99-0292 Lurie, P.M. and M.S. Goldberg. 1994. *A Method for Simulating Correlated Random Variables from Partially Specified Distributions*. Institute for Defense Analysis, Alexandria, VA. IDA Paper P-2998.

99-0293 Meyer, M.A. and J.M Booker. 1991. *Eliciting and Analyzing Expert Judgment: A Practical Guide.* Academic Press, New York.

99-0294 Morgan, M.G. and M. Henrion. 1990. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*. Cambridge University Press, Cambridge, UK.

99-0295 Nelsen, R.B. 1986. "Properties of a One-Parameter Family of Bivariate Distributions with Specified Marginals." *Communications in Statistics (Theory and Methods),* A15:3277-3285.

99-0296 Nelsen, R.B. 1987. "Discrete Bivariate Distributions with Given Marginals and Correlation." *Communications in Statistics (Simulation and Computation),* B16:199-208.

99-0297 Reinert, K.H., S.M. Bartell, and G.R. Biddinger. 1998. *Ecological Risk Assessment Decision-Support System: A Conceptual Design*. SETAC Press. Society for Environmental Toxicology and Chemistry, Pensacola, Florida.

99-0298 Scheuer, E.M. and D.S. Stoller. 1962. "On the Generation of Normal Random Vectors." *Technometrics*, 4:278-281.

99-0299 EPA (U.S. Environmental Protection Agency). 1997. *Guiding Principles for Monte Carlo Analysis*. Risk Assessment Forum, Washington, DC. EPA-630-R-97-001

99-0300 EPA (U.S. Environmental Protection Agency). 1994. *Peer Review Workshop: Report on Ecological Risk Assessment Issue Papers*. Risk Assessment Forum, Washington, DC.

99-0301 Voit, E.O., W.L. Balthis, and R.A. Holster. 1995. "Hierarchical MC/P Modeling with S-Distributions: Concepts and Illustrative Analysis of Mercury Contamination in King Mackerel." *Environmental International,* 21:627-635.

99-0302 Warren-Hicks, W.J. and D.R.J. Moore, Editors. 1998. *Uncertainty Analysis in Ecological Risk Assessment.* SETAC Press, Society for Environmental Toxicology and Chemistry, Pensacola, Florida.

99-0303 Whitt, W. 1976. "Bivariate Distributions with Given Marginals." *The Annals of Statistics,* 4:1280-1289.

99-0304 Birnbaum, LS. 1999. “TEFs: A Practical Approach to a Real-World Problem.” *Human and Ecological Risk Assessment,* 5(1):13-24.

99-0305 Hankinson, O. 1995. “The Aryl Hydrocarbon Receptor Complex.” *Annu. Rev. Pharmacol. Toxicol.,* 35:307-340.

99-0306 Poland, A. and J.C. Knutson. 1982. “2,3,7,8-Tetrachlorodibenzo-p-Dioxin and Related Halogenated Aromatic Hydrocarbons: Examinations of the Mechanism of Toxicity.” *Annu. Rev. Pharmacol. Toxicol.,* 22:517-554.

99-0308 Safe, S.H. 1997. “Limitations of the Toxic Equivalency Approach for Risk Assessment of TCDD and Related Compounds.” *Teratog. Carcinog. Mutagen,* 17:285-304.

99-0309 Safe, S.H. 1999. "Development and Application of TEFs." *Human and Ecological Risk Assessment,* 5(1):9-12.

99-0310 Stegeman, J.J. and M.E. Hahn. 1994. “Biochemistry and Molecular Biology of Monooxygenases: Current Perspectives on Forms, Functions and Regulation of Cytochrome P450 in Aquatic Species.” In: *Aquatic Toxicology*. D.C. Malins and G.K. Ostrander, Editors. Lewis Publishers, Boca Raton, Florida.

99-0311 Whitlock, J.P. 1993. “Mechanistic Aspects of Dioxin Action.” *Chem. Res. Toxicol.,* 6:754-763.

99-0312 WHO (World Health Organization). 1997. Meeting on the Derivation of Toxic Equivalency Factors (TEFs) for PCBs, PCDDs, PCDFs and Other Dioxin-Like Compounds for Humans and Wildlife. Geneva, Switzerland.

99-0313 Hallam, T.G., A.R. Lassiter, J. Li, and W. McKinney. 1990. “Toxicant-Induced Mortality in Models of Daphnia Populations.” *Environmental Toxicology and Chemistry,* 9:597-621.

99-0314 Norvitch, R.F. and M.E.S. Lamb. 1966. *Ground Water Basic Data Report No. 9*. Ground Water Series. Prepared by the U.S. Geological Survey in cooperation with the Massachusetts Water Resources Commission.

99-0315 Canadian Council of Ministers of the Environment. 1999. “Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Summary Tables.” In: *Canadian Environmental Quality Guidelines*. 1999. Canadian Council of Ministers of the Environment, Winnipeg.

99-0316 Suter, G.W. and C.L. Tsao. 1996. *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*. ES/ER/TM-96/R2.

99-0317 McCarty, L.A. and D. Mackay. 1993. "Enhancing Ecological Modeling and Assessment: Body Residues and Modes of Toxic Action." *Environmental Science and Technology*, 27(9):1719-1728.

99-0318 Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J.Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. "Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod. *Hyalella azteca* and the Midge *Chironomus riparius*." *Journal of Great Lakes Research*, 22(3):602-623.

99-0320 deZwann, A. and T.C.M. Wijsman. 1976. "Anaerobic Metabolism in Bivalvia (Mollusca): Characteristics of Anaerobic Metabolism." *Comp. Biochemistry and Physiology*, 54(B): 313-324.

99-0321 Hummel, H. et al. 1989. "The Glycogen Content in Stressed Marine Bivalves: The Initial Absence of a Decrease." *Comp. Biochemistry and Physiology*, 94(B): 729-733.

99-0322 Patterson, M.A., B.C. Parker, and R.J. Neves. 1997. "Effects of Quarantine Times on Glycogen Levels of Native Freshwater Mussels *(Bivalvia: Unionidae)* Previously Infested with Zebra Mussels." *Am. Malacol. Bull*, 14(1): 75-79.

99-0323 Salozar, S.M. 1996. *An In Situ Assessment of Mercury Contamination in the Sudbury River, Massachusetts, Using Bioaccumulation and Growth in Transplanted Freshwater Mussels.* NOAA Technical Memorandum. NOS ORCA 89. NOAA, Seattle, WA.

99-0324 Salazar, M.H. and S.M. Salazar. 1996. "Using Caged Bivalves to Characterize Exposure and Effects Associated with Pulp and Paper Mill Effluents." Proc. 5th IAWQ Symposium on Forest Industry Product Wastewaters, Vancouver, B.C.

99-0325 APHA (American Public Health Association). 1995. "Plankton." In: *Standard Methods for the Examination of Water and Wastewater*, pp. 10-2 - 10-26.

99-0326 Swackhammer, D. and R. Skogland. 1993. "Bioaccumulation of PCBs by Algae: Kinetics Versus Equilibrium." *Environ. Toxicol. Chem.,* 12:831-838.

99-0333 Frey, H.C. 1992. *Quantitative Analysis of Uncertainty and Variability in Environmental Policy Making.* Environmental Science and Engineering Fellows Program, American Association for the Advancement of Science, Washington, DC.

99-0336 Geraghty and Miller, Inc. 1992. *Soil Remediation Goals for Sprague Electric Brown Street Site*, *North Adams, MA*.

99-0337 EPA (U.S. Environmental Protection Agency). 1987. *Data Quality Objectives for Remedial Response Activities: Development Process.* Office of Emergency and Remedial Response and Office of Waste Programs Enforcement, Washington, D.C. PB88-131370.

99-0338 Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup, and Office of Research and Standards. April 1996. *Guidance for Disposal Site Risk Characterization in Support of the Massachusetts Contingency Plan.* Chapter 9, Method 3 "Environmental Risk Characterization." Interim Final Policy.

99-0339 EPA (U.S. Environmental Protection Agency). December 1991. "Ecological Assessment of Superfund Sites: An Overview." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (OS-230). *Eco Update*, Intermittent Bulletin, Volume 1, Number 2. Publication 9345.0-05I.

99-0340 EPA (U.S. Environmental Protection Agency). September 1991. "The Role of BTAGs in Ecological Assessment." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (OS-230). *Eco Update*, Intermittent Bulletin, Volume 1, Number 1. Publication 9345.0-05I.

99-0341 EPA (U.S. Environmental Protection Agency). March 1992. "The Role of Natural Resource Trustees in the Superfund Process." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (OS-230). *Eco Update*, Intermittent Bulletin, Volume 1, Number 3. Publication 9345.05I.

99-0342 EPA (U.S. Environmental Protection Agency). May 1992. "Developing a Work Scope for Ecological Assessment." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (OS-230). *Eco Update,* Intermittent Bulletin, Volume 1, Number 4. Publication 9345.0-05I.

99-0343 EPA (U.S. Environmental Protection Agency). September 1994. "Using Toxicity Tests in Ecological Risk Assessment." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (OS-230). *Eco Update*, Intermittent Bulletin, Volume 2, Number 1. Publication 9345.0-05I, EPA 540-F-94-012, PB94-963303.

99-0344 Sample, B.E. and C.A. Arenal. 1999. "Allometric Models for Interspecies Extrapolation of Wildlife Toxicity Data." *Bull. Environ. Contam. Toxicol.,* 62:653-663.

99-0345 EPA (U.S. Environmental Protection Agency). 1995. "Final Water Quality Guidance for the Great Lakes System." *Federal Register*, 60(56): 15366+, 23 March 1995.

99-0346 EPA (U.S. Environmental Protection Agency). 1998. "National Recommended Water Quality Criteria." *Federal Register*, 63(237):68354+, 10 December 1998.

99-0347 Thompson, K.M. and J.D. Graham. 1996. "Going Beyond the Single Number: Using Probabilistic Risk Assessment to Improve Risk Management." *Human and Ecological Risk Assessment*, 2(4): 1008-1034.

99-0348 EPA (U.S. Environmental Protection Agency). January 1996. "Ecotox Thresholds." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response. *Eco Update*, Intermittent Bulletin, Volume 3, Number 2. Publication 9345.0-12FSI, EPA 540/F-95/038, PN95-963324.

99-0349 EPA (U.S. Environmental Protection Agency). September 1994. "Selecting and Using Reference Information in Superfund Ecological Risk Assessments." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (5204G). *Eco Update,* Intermittent Bulletin, Volume 2, Number 4. Publication 9345.0-10I, EPA 540-F-94-050, PB94-963319.

99-0350 EPA (U.S. Environmental Protection Agency). September 1994. "Field Studies for Ecological Risk Assessment." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (5204G). *Eco Update,* Intermittent Bulletin, Volume 2, Number 3. Publication 9345.0-05I. EPA 540-F-94-014, PB94-963305.

99-0351 EPA (U.S. Environmental Protection Agency). September 1994. "Catalogue of Standard Toxicity Tests for Ecological Risk Assessment." Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Hazardous Site Evaluation Division (5204G). *Eco Update*, Intermittent Bulletin, Volume 2, Number 2. Publication 9345.0-05I, EPA 540-F-94-013, PB94-963304.

99-0352 Barbour, H., T. Simmons, P. Swain, and H. Woolsey. 1998. *Our Irreplaceable Heritage, Protecting Biodiversity in Massachusetts.* Massachusetts Heritage and Endangered Species Program and the Massachusetts Chapter of the Nature Conservancy. 83 pp.

99-0353 Bickford, W.E. and U.J. Dymon. 1990. *An Atlas of Massachusetts River Systems, Environmental Designs for the Future.* University of Massachusetts Press, Amherst, MA. 87 pp.

99-0354 Weatherbee, P.B. 1996. *Flora of Berkshire County, Massachusetts.* The Studley Press, Inc., Dalton, MA. 123 pp.

99-0355 Caswell, H. 1989. *Matrix Population Models: Construction, Analysis, and Interpretation.* Sinauer Associates, Inc. Publishers, Sunderland, PA.

99-0356 Winston, G.W., B.S. Shane, and C.B. Henry. 1988. "Hepatic Monooxygenase Induction and Promutagen Activation in Channel Catfish from a Contaminated River Basin." *Ecotoxicol. Environ. Saf.,* 6:258-271.

99-0357 Ankley, G.T., G.J. Niemi, K.B. Lodge et al. 1993. “Uptake of Planar Polychlorinated Biphenyls and 2,3,7,8-Substituted Polychlorinated Dibenzofurans and Dibenzo-p-dioxins by Birds Nesting in the Lower Fox River and Green Bay, Wisconsin.” *Arch. Environ. Contam. Toxicol.,* 24(3):332-344.

99-0358 Bysshe, J.J. 1990. “Bioconcentration Factor in Aquatic Organisms.” In: *Handbook of Chemical Property Estimation Methods: Environmental Behavior of Organic Compounds.”* W.J. Lyman, Editor. American Chemical Society, Washington, DC.

99-0359 Callahan, M.A., M.W. Slimak, N.W. Gabel et al. 1979. *Water-Related Environmental Fate of 129 Priority Pollutants.* EPA 440/4-79-029a. U.S. Environmental Protection Agency, Washington, D.C.

99-0360 Cockerham, L.G. and B.S. Shane. 1994. *Basic Environmental Toxicology.* CRC Press, Boca Raton, FL.

99-0361 Leifer, A., R.H. Brink, G.C. Thom et al., 1983. *Environmental Transport and Transformation of Polychlorinated Biphenyls.* U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, Office of Pest Working Hazard, Washington, DC. EPA No. 560/5-83-025.

99-0362 Mackay, D. 1989. “Modeling the Long-Term Behavior of an Organic Contaminant in a Large Lake Application of PCBs in Lake Ontario.” *S. Great Lakes Res.,* 15:283-297.

99-0363 Moore, D.R.J. and S.L. Walker. 1991. *Canadian Water Quality Guidelines for Polychlorinated Biphenyls in Coastal and Estuarine Waters.* Scientific Series No. 186. Environment Canada, Ottawa, Canada.

99-0364 Porte, C. and J. Albaiges. 1994. “Bioaccumulation Patterns of Hydrocarbons and Polychlorinated Biphenyls in Bivalves, Crustaceans, and Fish.” *Arch. Environ. Contam. Tox.,* 26(3):273-81.

99-0365 Pruell, R.J., N.I. Rubinstein, B.K. Taplin et al. 1993 “Accumulation of Polychlorinated Organic Contaminants from Sediment by Three Benthic Marine Species.” *Arch. Environ. Contam. Tox.,* 24(3):290-297.

99-0366 Rohrer, T.K., J.C. Forney, and J.H. Hartig. 1982. “Organochlorine and Heavy Metal Residues in Standard Fillets of Coho and Shinook Salmon of the Great Lakes—1980.” *J Great Lakes Res.,* 8:623-634.

99-0367 Safe, S., S. Bendiera, T. Sawyer et al. 1985. “PCBs: Structure-Function Relationships and Mechanisms of Action.” *Environ. Health Perspect.,* 60:47-56.

99-0368 Secor. C.L., E.L. Mills, J. Harshbarger et al. 1993. *Bioaccumulation of Toxicants, Element and Nutrient Composition and Soft Tissue Histology of Zebra Mussels (Dreissena polymorpha) from New York Waters.* Chemosphere, 26 (8):1559-1575.

99-0369 Sugiura, K. 1992. "Microbial Degradation of Polychlorinated Biphenyls in Aquatic Environments." *Chemosphere*, 24(7):881-890.

99-0370 Hoffman, D.J., C.P. Rice, and T.J. Kubiak. 1996. PCBs and Dioxins in Birds. In: *Environmental Contaminants in Wildlife—Interpreting Tissues Concentrations*, pp. 165-207. W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood, Editors. SETAC Special Publications Series. CRC Press, Boca Raton, FL.

99-0371 Tillitt, D.E., and P.J. Wright. 1997. Dioxin-Like Embryotoxicity of a Lake Michigan Lake Trout Extract to Developing Lake Trout. *Organhalogen Cmpds.*, 34:221-225.

99-0372 Tillitt, D.E., R.W. Gale, J.C. Meadows, J.L. Zajicek, P.H. Peterman, S.N. Heaton, P.D. Jones, S.J. Bursian, T.J. Kubiak, J.P. Giesy, and R.J. Aulerich. 1996. "Dietary Exposure of Mink to Carp from Saginaw Bay. 3. Characterization of Dietary Exposure to Planar Halogenated Hydrocarbons, Dioxin Equivalents, and Biomagnification." *Environ. Sci. Technol.*, 30: 283-291.

99-0373 Bayne, B.L. 1976. "Aspects of Reproduction in Bivalve Molluscs." In: *Estuarine Processes*, pp. 432-448, M.L. Wiley, Editor. Academic Press, New York..

99-0374 Bayne, B.L., D.A. Brown, K. Burns, D.R. Dixon, A. Ivanovici, D.R. Livingstone, D.M. Lowe, and M.N. Moore. 1985. *The Effects of Stress and Pollution in Marine Animals*. Praeger, New York.

99-0375 Bruner, K.A., S.W. Fisher, and P.F. Landrum. 1994. "The Role of the Zebra Mussel, *Dreissena polymorpha*, in Contaminant Cycling. II. Zebra Mussel Contaminant Accumulation from Algae and Suspended Particles, and Transfer to the Benthic Invertebrate, *Gambarus fasciatus*." *Journal of Great Lakes Research*, 20: 735-750.

99-0376 Gabbott, P.A. 1983. "Developmental and Seasonal Metabolic Activities in Marine Molluscs." In: *The Mollusca, Vol. 2, Environmental Biochemistry and Physiology*, pp. 165-217. P.W. Hochachka, Editor. Academic Press, New York.

99-0377 Helm, M.M, D.L. Holland, and R.R. Stephenson. 1973. "The Effect of Supplementary Algae Feeding of a Hatchery Breeding Stock of *Ostrea edulis L.* on Larval Vigor." *Journal of the Marine Biological Association* (U.K.), 53: 673-684.

99-0378 Koenig, B.G. and C.D. Metcalf. 1990. "The Distribution of PCB Congeners in Bivalves, *Elliptio complanata*, Introduced into the Otanabee River, Peterborough, Ontario." *Chemosphere*, 21(12): 1441-1449.

99-0379 Metcalf, C.D. and M.N. Charlton. 1990. "Freshwater Mussels as Biomonitors for Organic Industrial Contaminants and Pesticides in the St. Lawrence River." *Science and the Total Environment*, 98: 595-615.

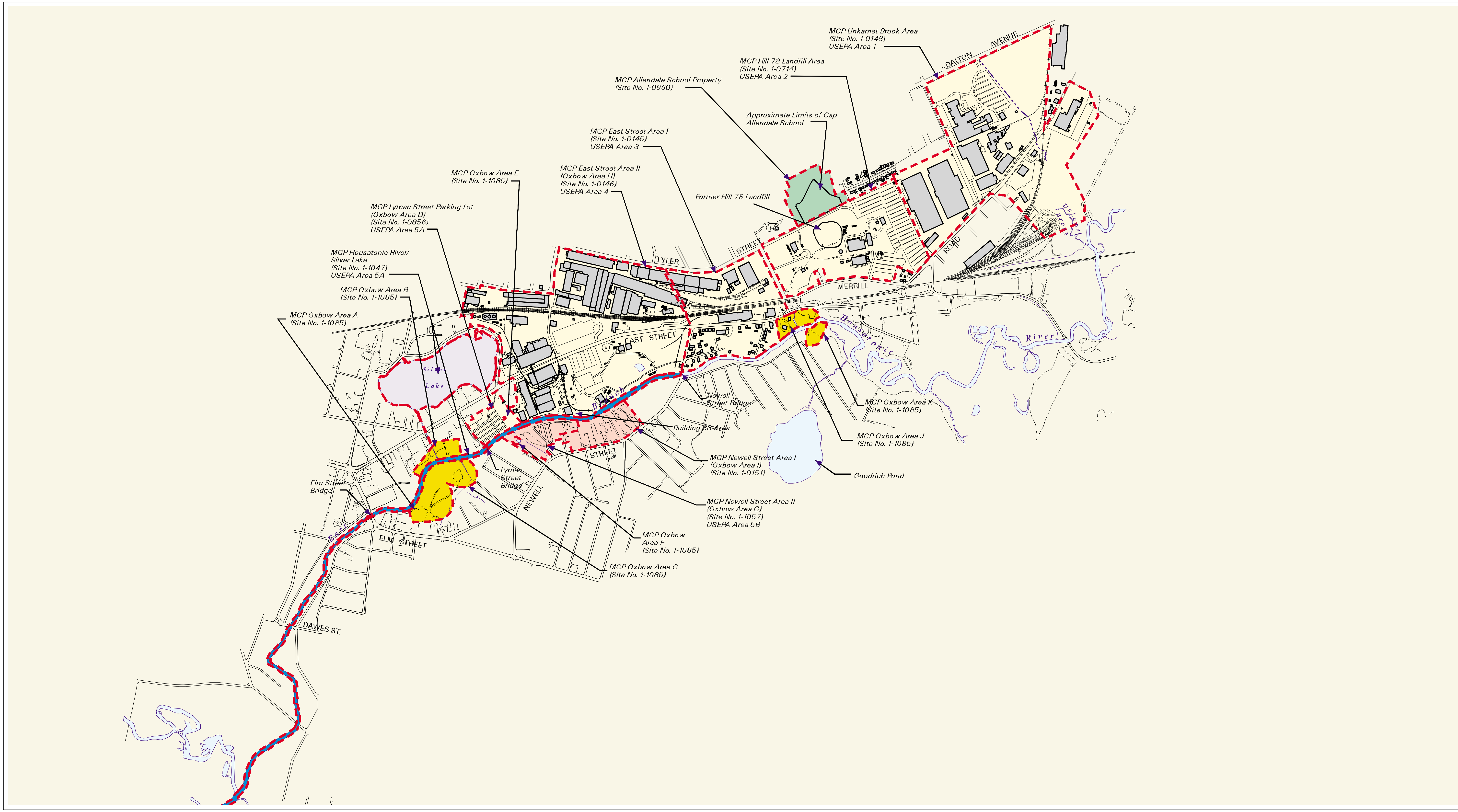
99-0380 Phillips, D.J.H. and P.S. Rainbow. 1993. *Biomonitoring of Trace Aquatic Contaminants*. Elsevier Applied Science, London.

99-0381 deKock, W.C. and K.J.M. Kramer. 1994. Chapter 3. "Active Biomonitoring (ABM) by Translocation of Bivalve Molluscs." In: *Biomonitoring of Coastal Waters and Estuaries*, pp. 51-84. K.J.M. Kramer, Editor. CRC Press, Boca Raton, Florida.

99-0382 Levings, C.D. and N.G. McDaniel. 1976. *Industrial Disruption of Invertebrate Communities on Beaches of Howe Sound, B.C.* Tech Report No. 663. Fish. Mar. Ser. Envir. Can. 92 pp.

99-0383 Wu, R.S.S. and C.D. Levings. 1980. “Mortality, Growth, and Fecundity of Transplanted Mussel and Barnacle Populations Near a Pulp Mill Outfall.” *Mar. Pollut. Bull.*, 11:11-15.

99-0384 Tillitt, D.E. 1999. “The Toxic Equivalents Approach for Fish and Wildlife.” *Human and Ecological Risk Assessment*, 5(1):25-32.



LEGEND

- O.U. #1 - GE Facility
- O.U. #2 - Housatonic River
- O.U. #3 - Allendale School
- O.U. #4 - Silver Lake
- O.U. #5 - Newell Street
- O.U. #6 - Oxbows A, B, C, J, and K

N

Scale in Feet

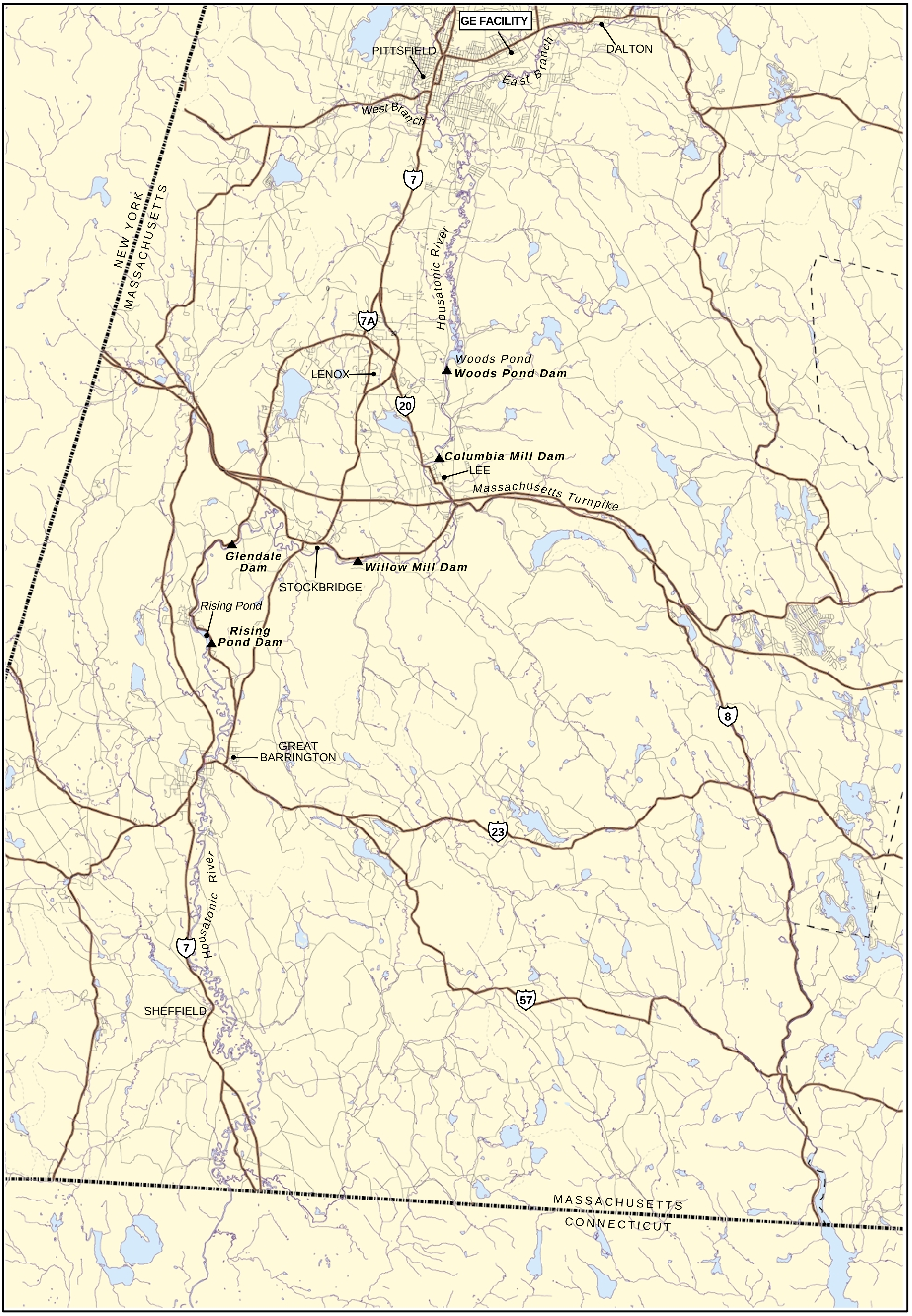
700 0 700 1400 2100 2800

Map produced by WESTON, adapted from Geographic Information System (GIS) database provided by TechLaw Inc.

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 1-1
LOCATIONS OF OPERABLE UNITS

/proj2/gepitt/amls/base18.aml ..17 Nov 99 16:22:26 Wednesday



LEGEND

▲ Approximate Location of Dam

MASSACHUSETTS

LOCATION AREA

0 6000 12000 18000

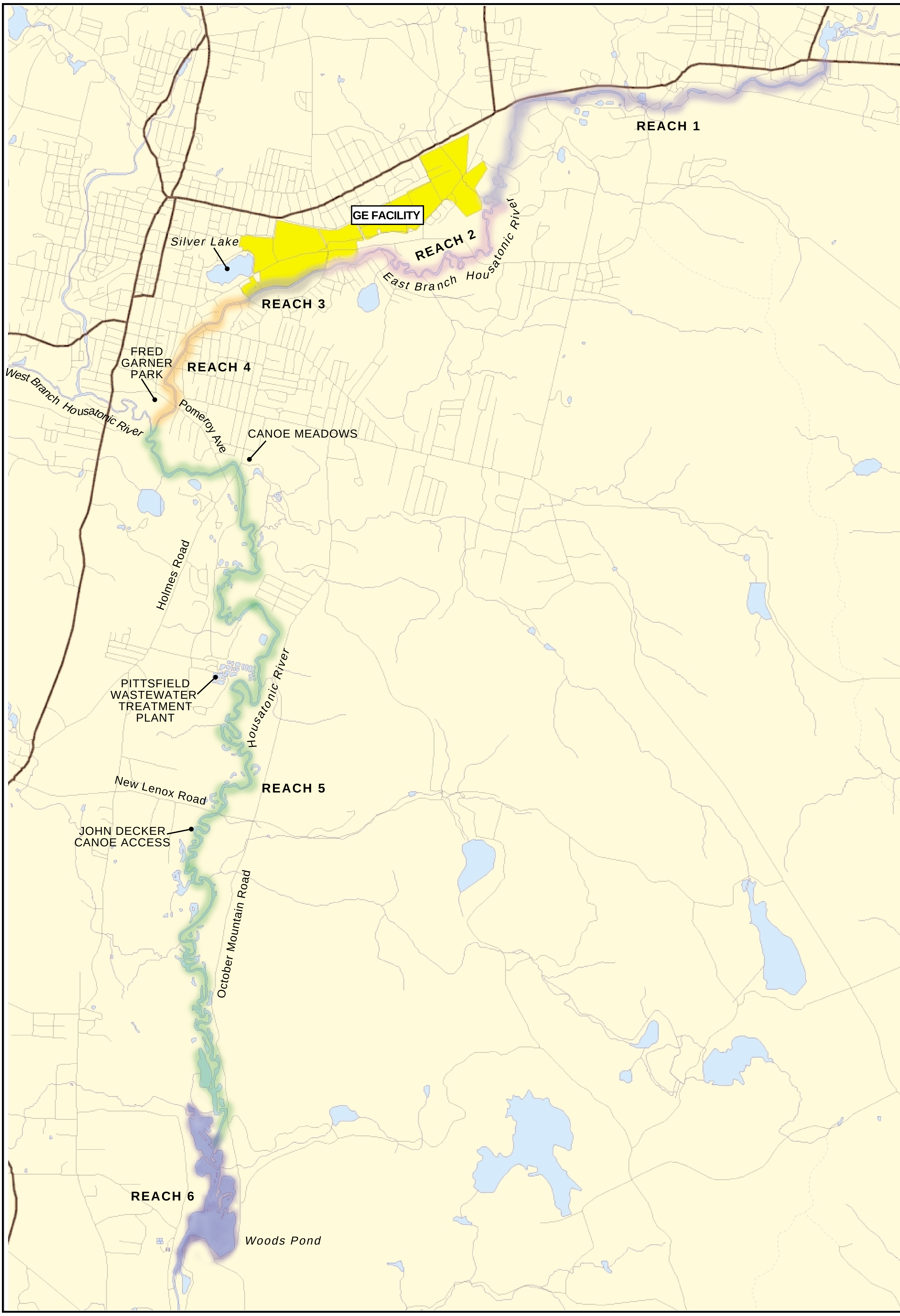
Scale In Feet

N

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 1-2
SITE LOCATION MAP

99P-2830-1



LEGEND

Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6

0 1750 3500 5250

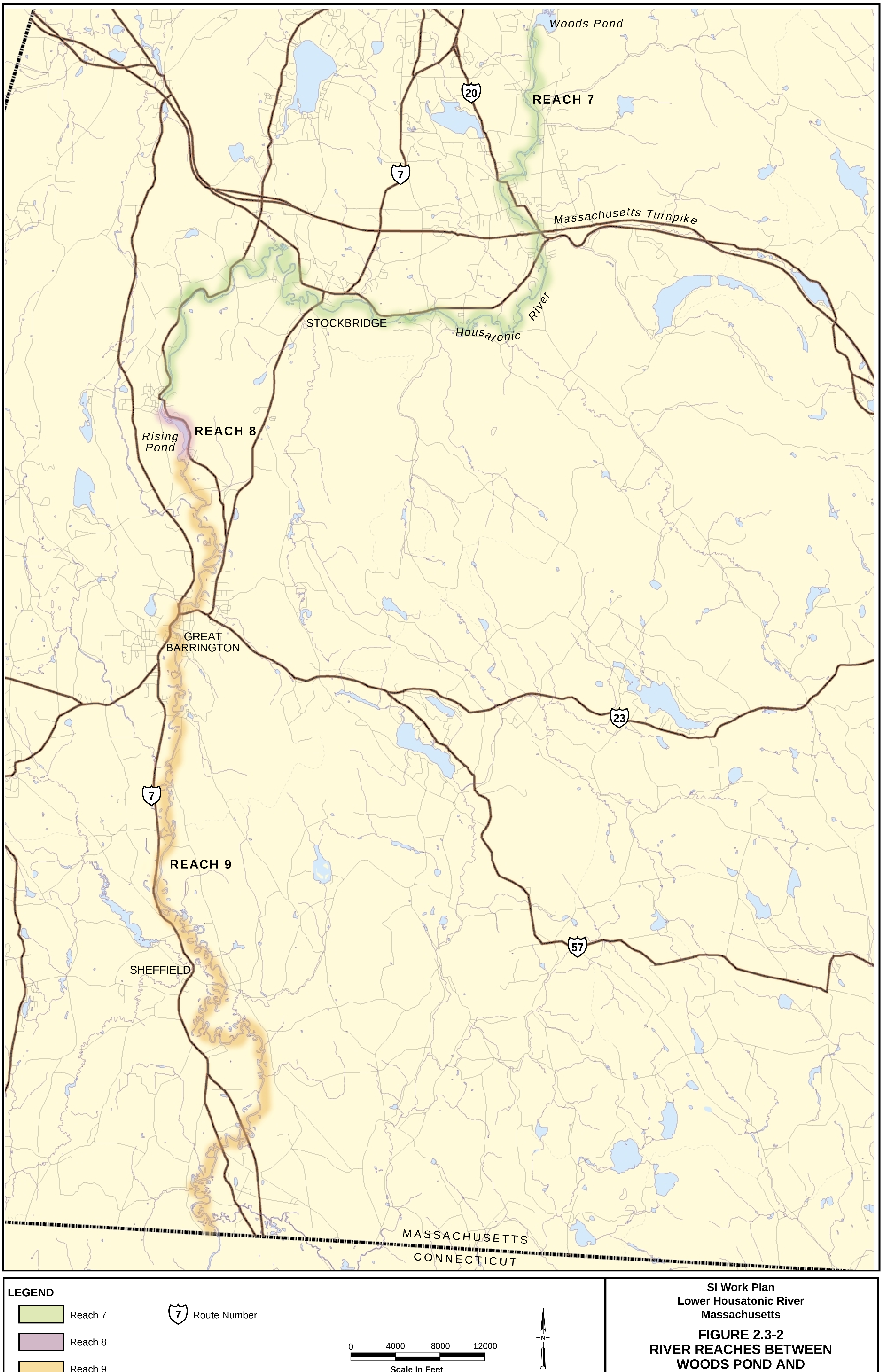
Scale In Feet

N

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 2.3-1
RIVER REACHES
BETWEEN DALTON AND WOODS POND

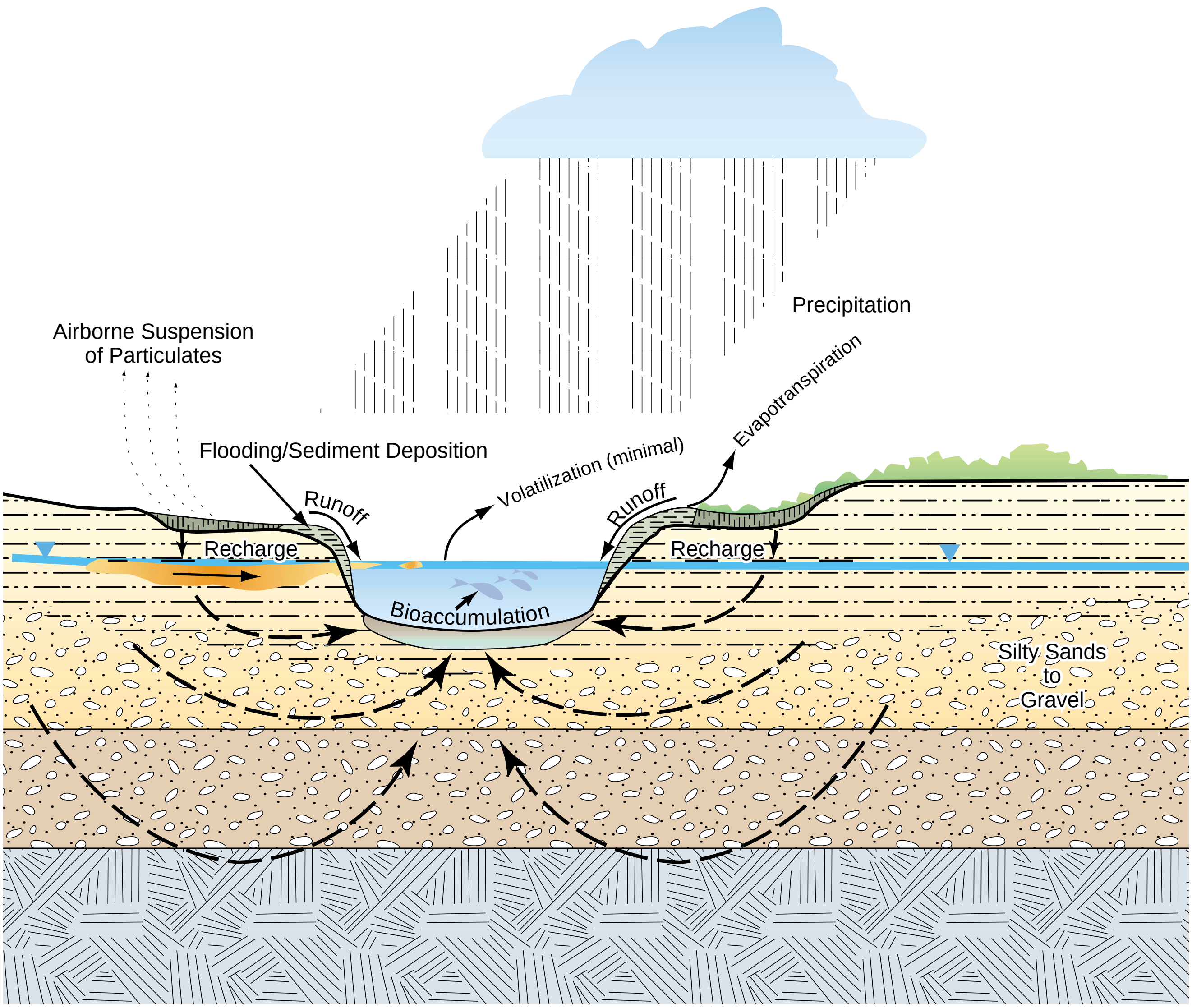
99P-2830-2



SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 2.3-2
RIVER REACHES BETWEEN WOODS POND AND CONNECTICUT BORDER

99P-2830-3



LEGEND

- Surface Water
- Sediment
- Bank Soils
- Floodplain Soils
- Vegetation
- Alluvium
- Glacial Till
- Bedrock - Stockbridge Formation (Calcitic Marble)
- LNAPL Seep
- Water Elevation
- Groundwater Flow

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 3.2-1
POTENTIAL CONTAMINANT MIGRATION PATHWAYS

99P-2830-4

LEGEND

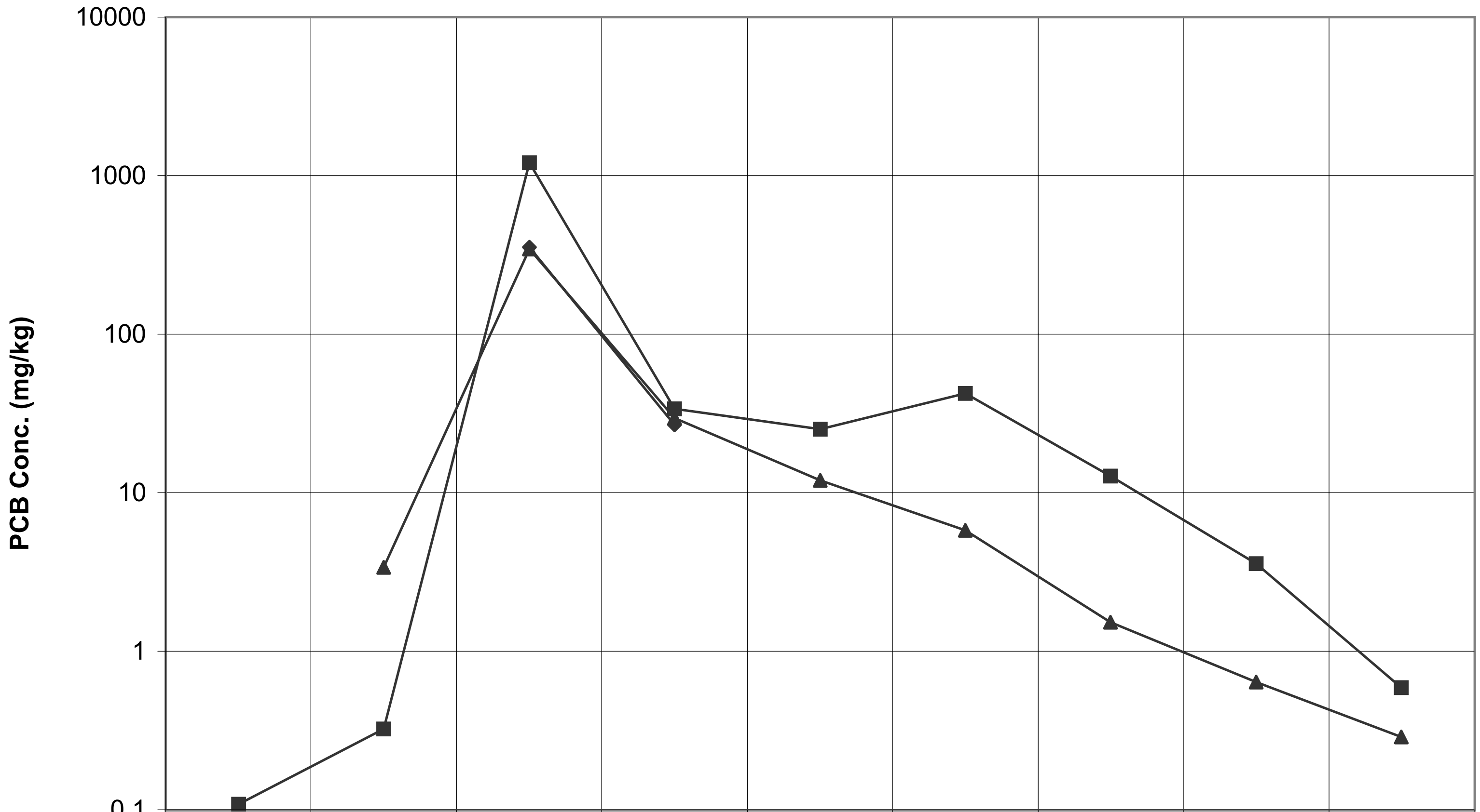
- Subsurface DNAPL, LNAPL Plumes
- Bank Soils Impacted by Fill Material and Flooding
- Bank Soils Impacted by Flooding and Sediment Deposition
- Sediment Depositional Area
- Sediment Transport
- Floodplain Soils

99P-2830-5

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 3.2-2
GENERIC PLAN VIEW
OF CONTAMINANT TRANSPORT PROCESSES

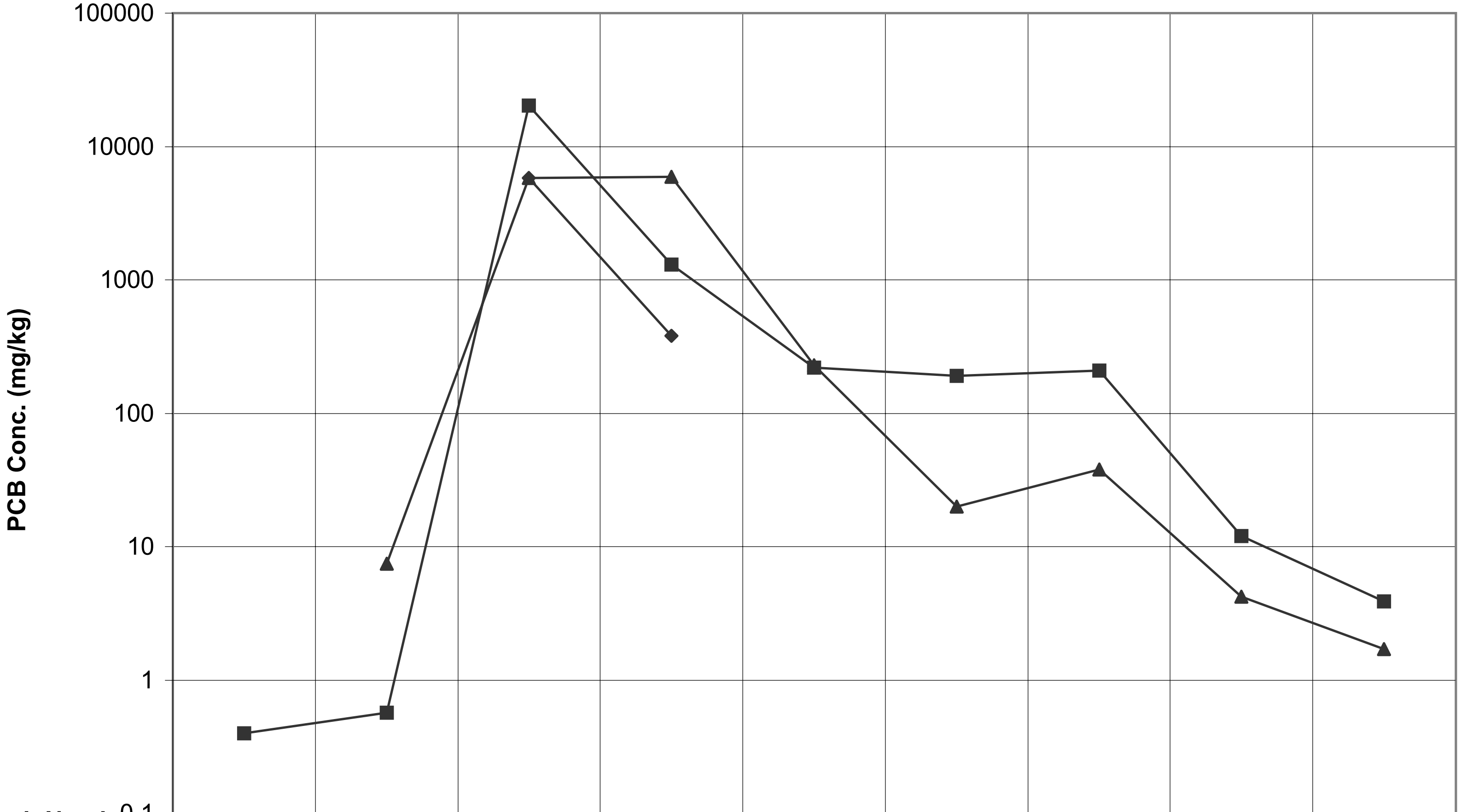
Figure 3.2-3
Average PCB Concentrations in 0 - 0.5 Foot Interval
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
Bank Samples			352	27					
Sediment Samples	0.108	0.324	1210	33.8	25.1	42.4	12.7	3.57	0.59
Floodplain Samples		3.38	343	29.7	12.0	5.78	1.53	0.637	0.289

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

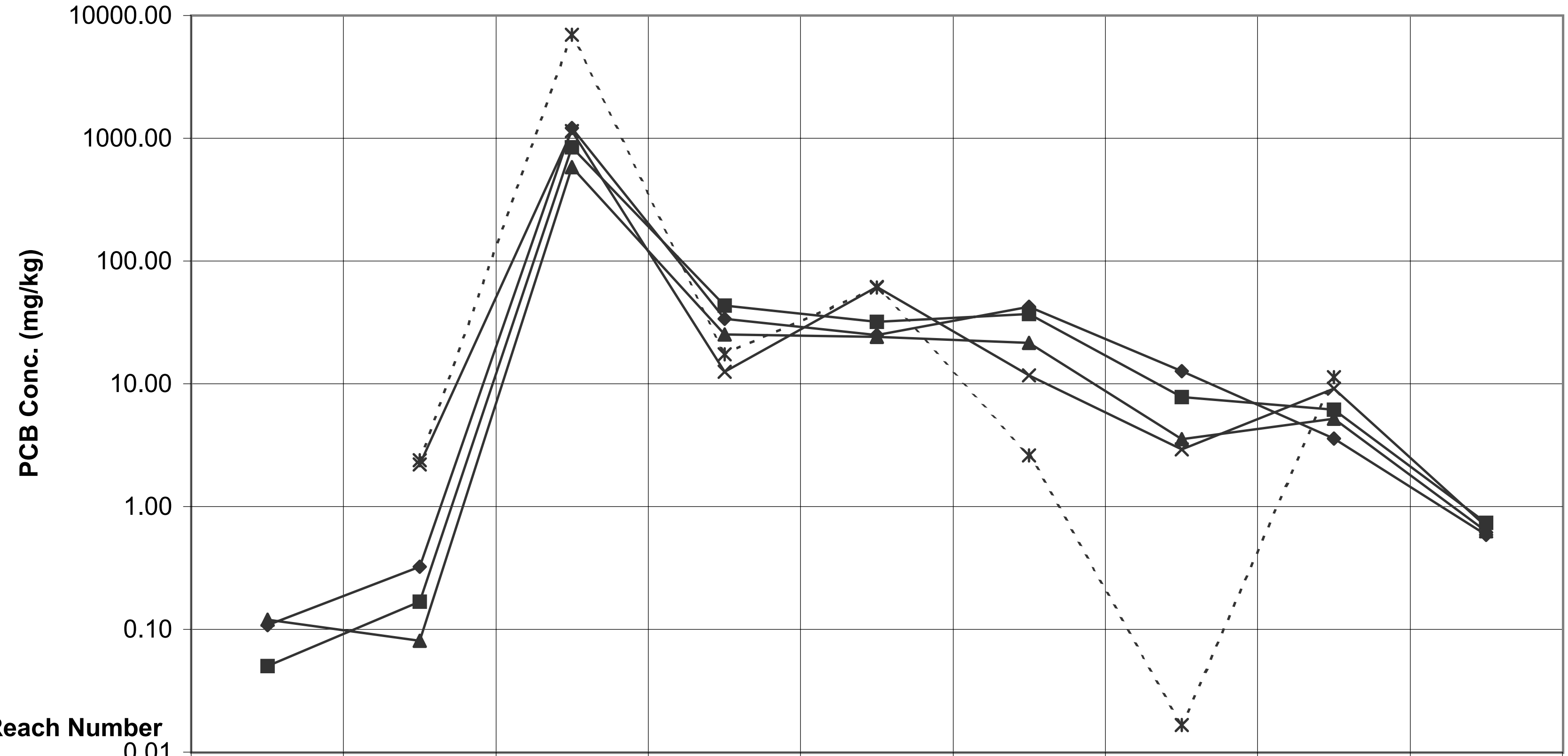
Figure 3.2-4
Maximum PCB Concentrations in 0 - 0.5 Foot Interval
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
Bank Samples			5800	380					
Sediment Samples	0.4	0.57	20200	1300	220	190	210	12	3.9
Floodplain Samples		7.43	5793	5904	230	20	38	4.2	1.7

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

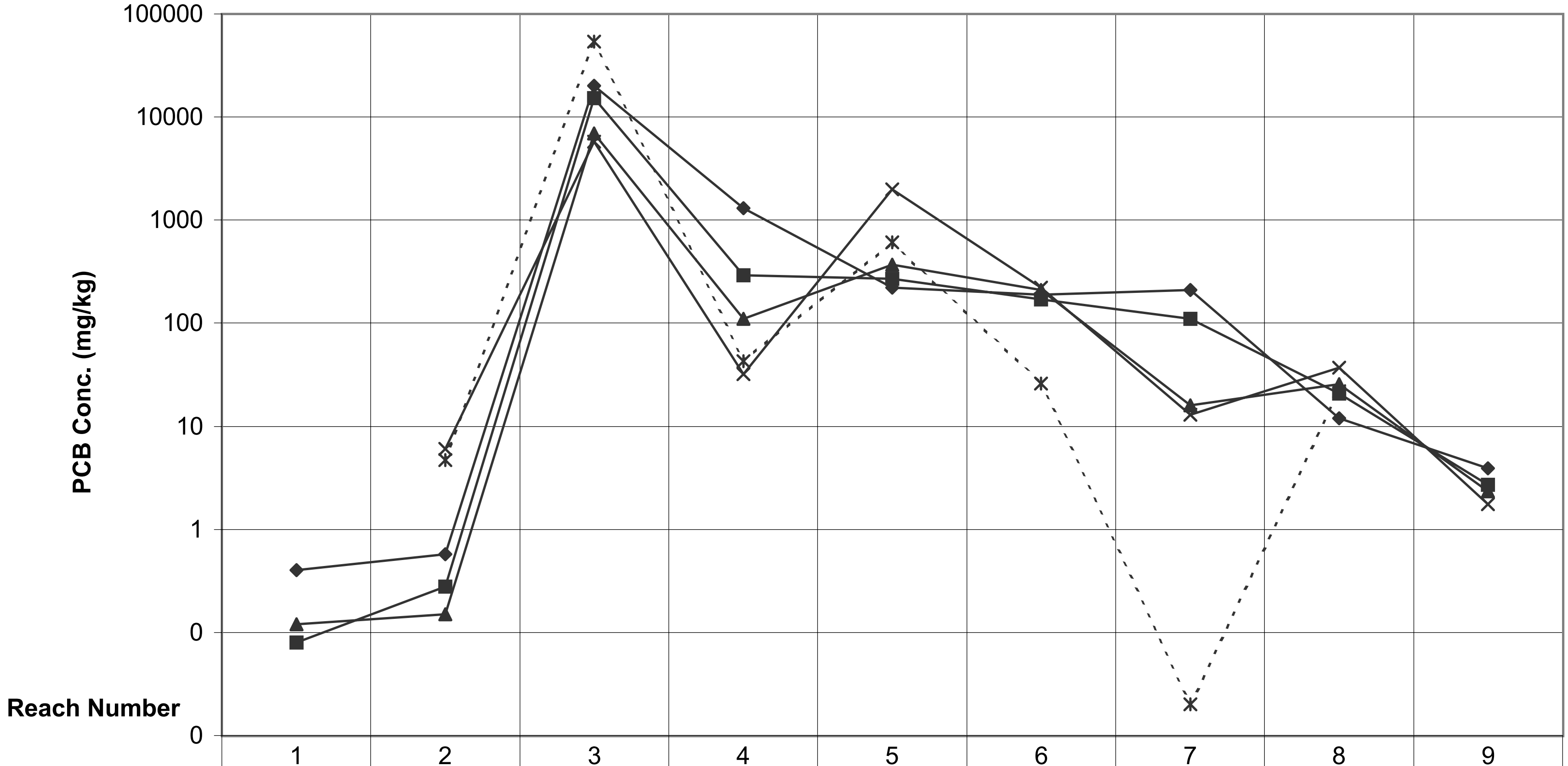
Figure 3.3-1
Average PCB Concentrations in Sediment
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
0-0.5 Feet	0.108	0.324	1210	33.8	25.1	42.4	12.7	3.57	0.59
0.5-1.0 Feet	0.05	0.168	848	43.5	31.9	37.2	7.77	6.14	0.741
1.0-2.0 Feet	0.12	0.081	582	25.1	24.1	21.5	3.56	5.19	0.632
2.0-3.0 Feet		2.20	1150	12.6	61.6	11.8	2.92	9.2	0.691
3+ Feet		2.38	7000	17.3	60.8	2.6	0.0167	11.38	

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

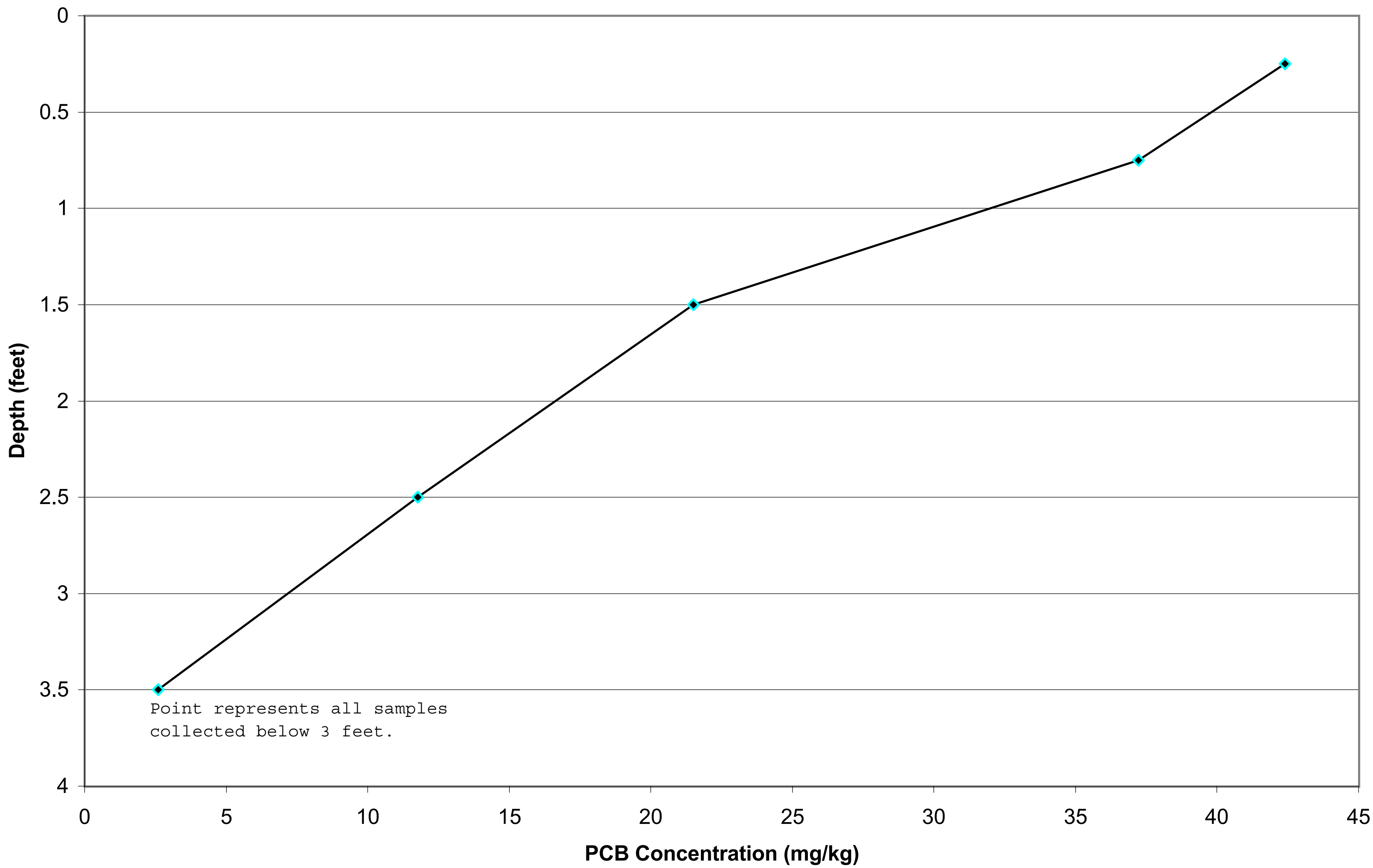
Figure 3.3-2
Maximum PCB Concentrations in Sediment
Lower Housatonic River
Pittsfield, MA



	1	2	3	4	5	6	7	8	9
0-0.5 Feet	0.4	0.57	20200	1300	220	190	210	12	3.9
0.5-1.0 Feet	0.08	0.28	15300	290	270	170	110	20.7	2.7
1.0-2.0 Feet	0.12	0.15	6950	110	370	210	16	25.5	2.33
2.0-3.0 Feet		6	5790	32	2000	220	13	37	1.76
3+ Feet		4.7	54000	43	610	26	0.02	22	

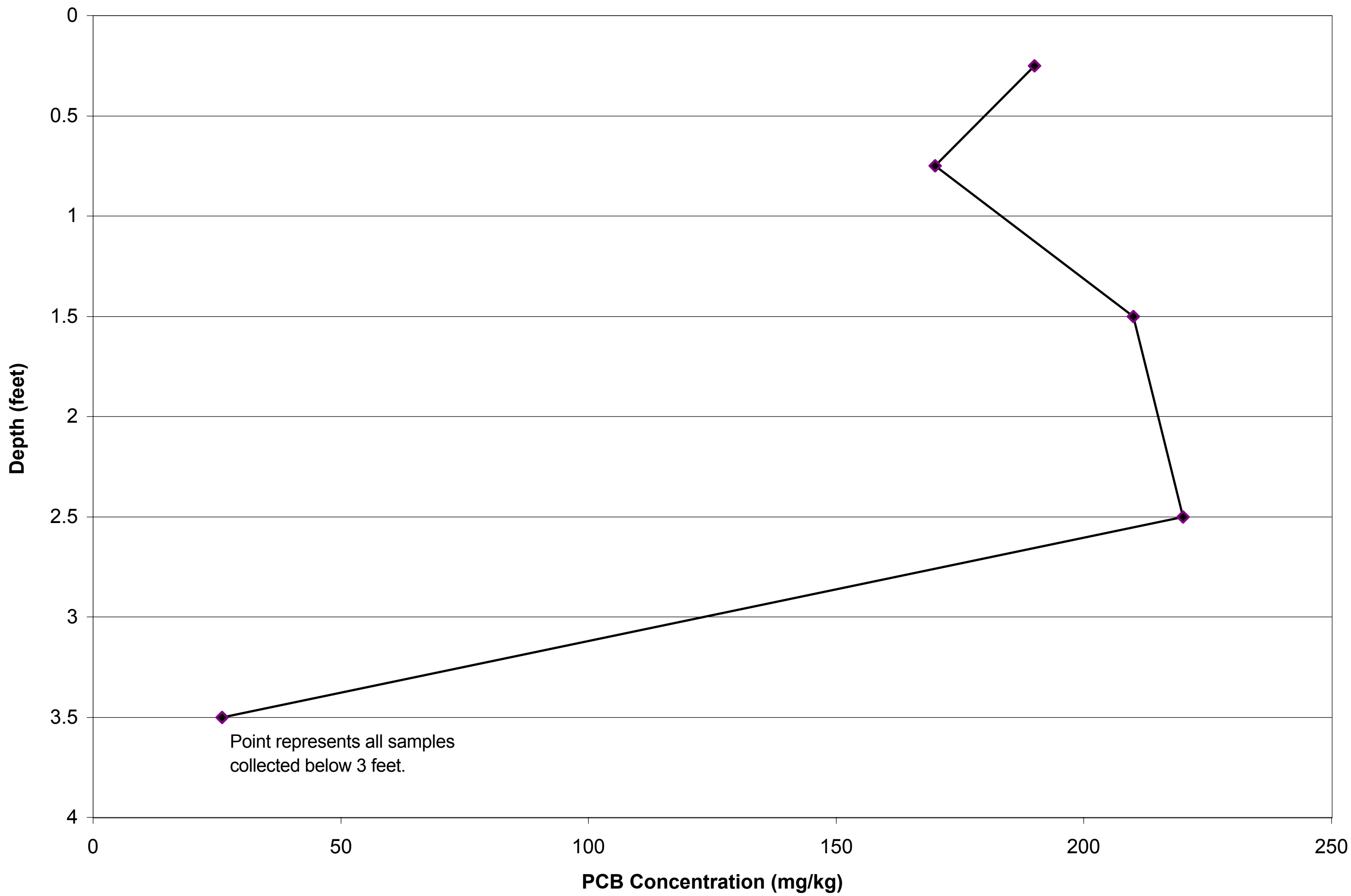
Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

Figure 3.3-3
Average PCB Concentrations in Woods Pond Sediments
Housatonic River - Historical Data
Pittsfield, MA



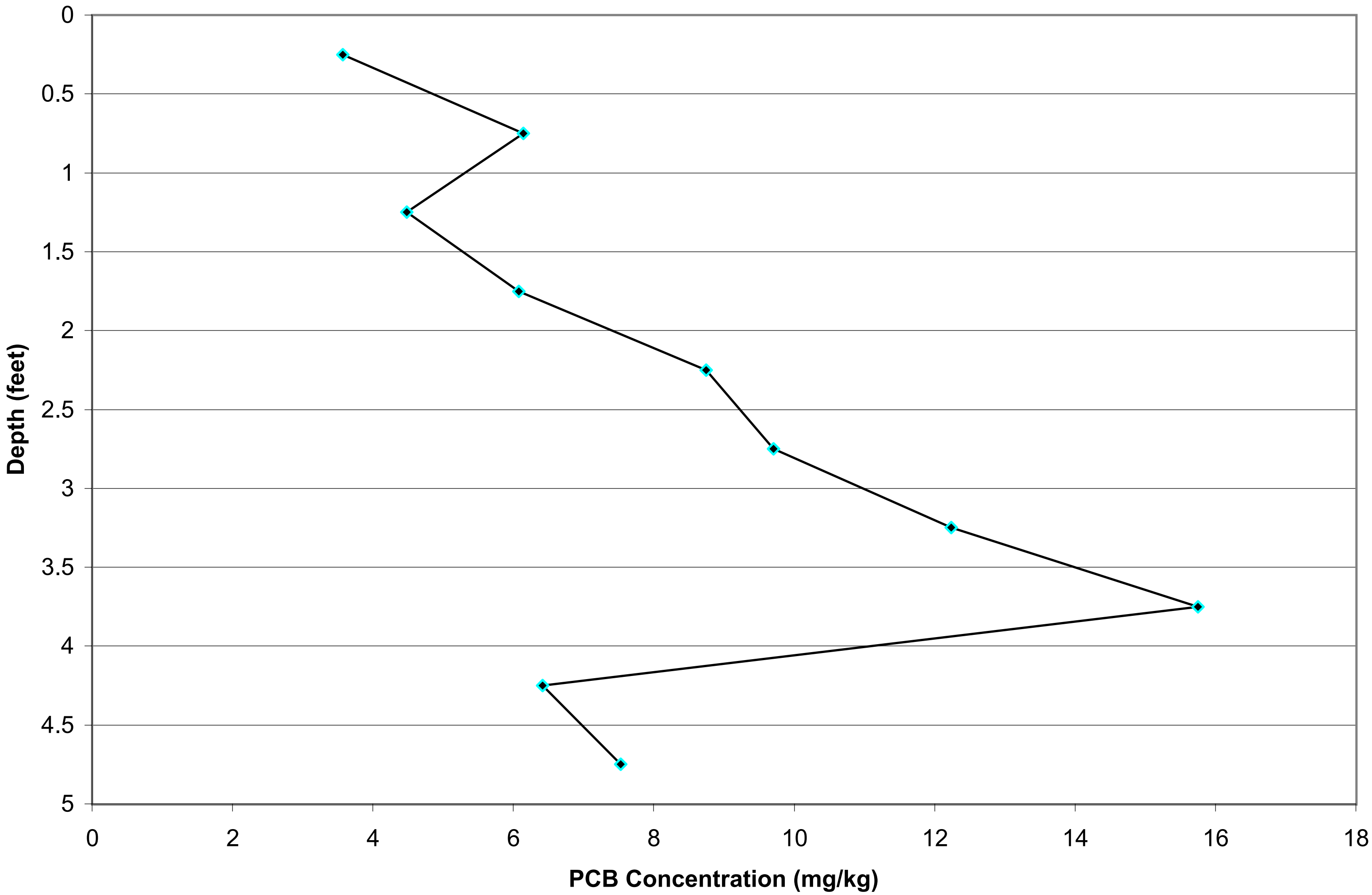
Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.

Figure 3.3-4
Maximum PCB Concentrations in Woods Pond Sediments
Housatonic River - Historical Data
Pittsfield, MA



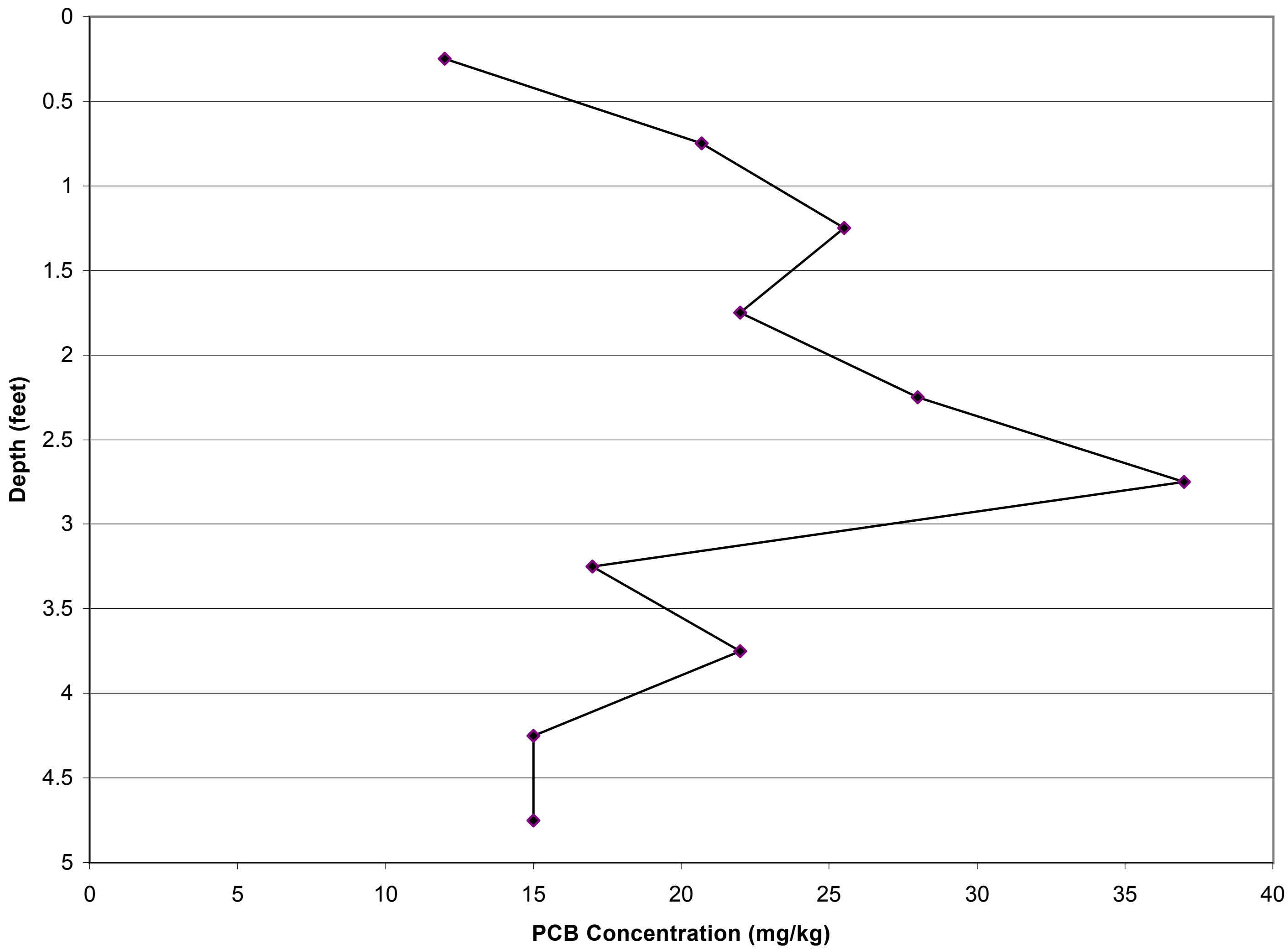
Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

Figure 3.3-5
Average PCB Concentrations In Rising Pond Sediments
Housatonic River - Historical Data
Pittsfield, MA



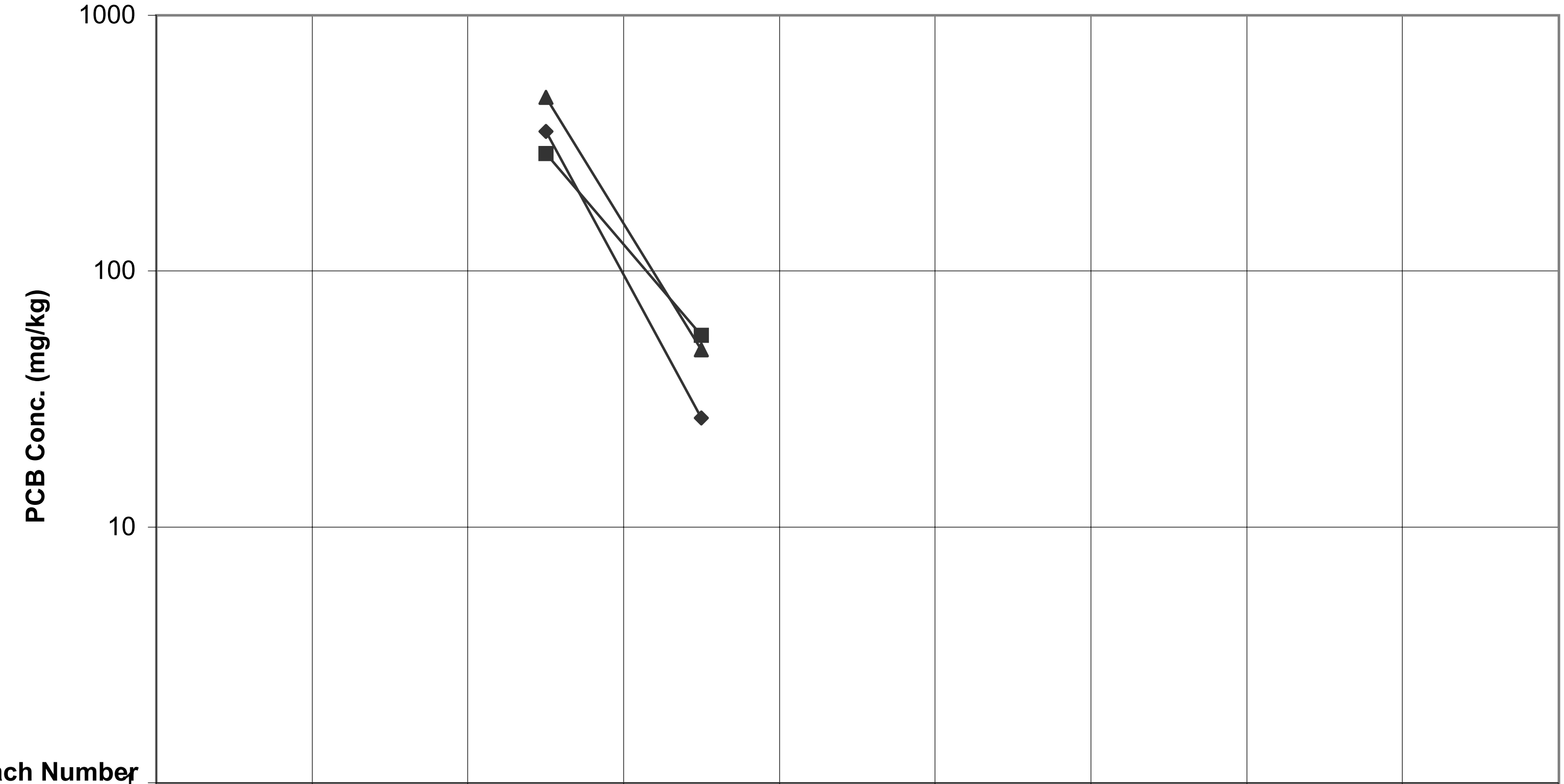
Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

Figure 3.3-6
Maximum PCB Concentrations in Rising Pond Sediments
Housatonic River - Historical Data
Pittsfield, MA



Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

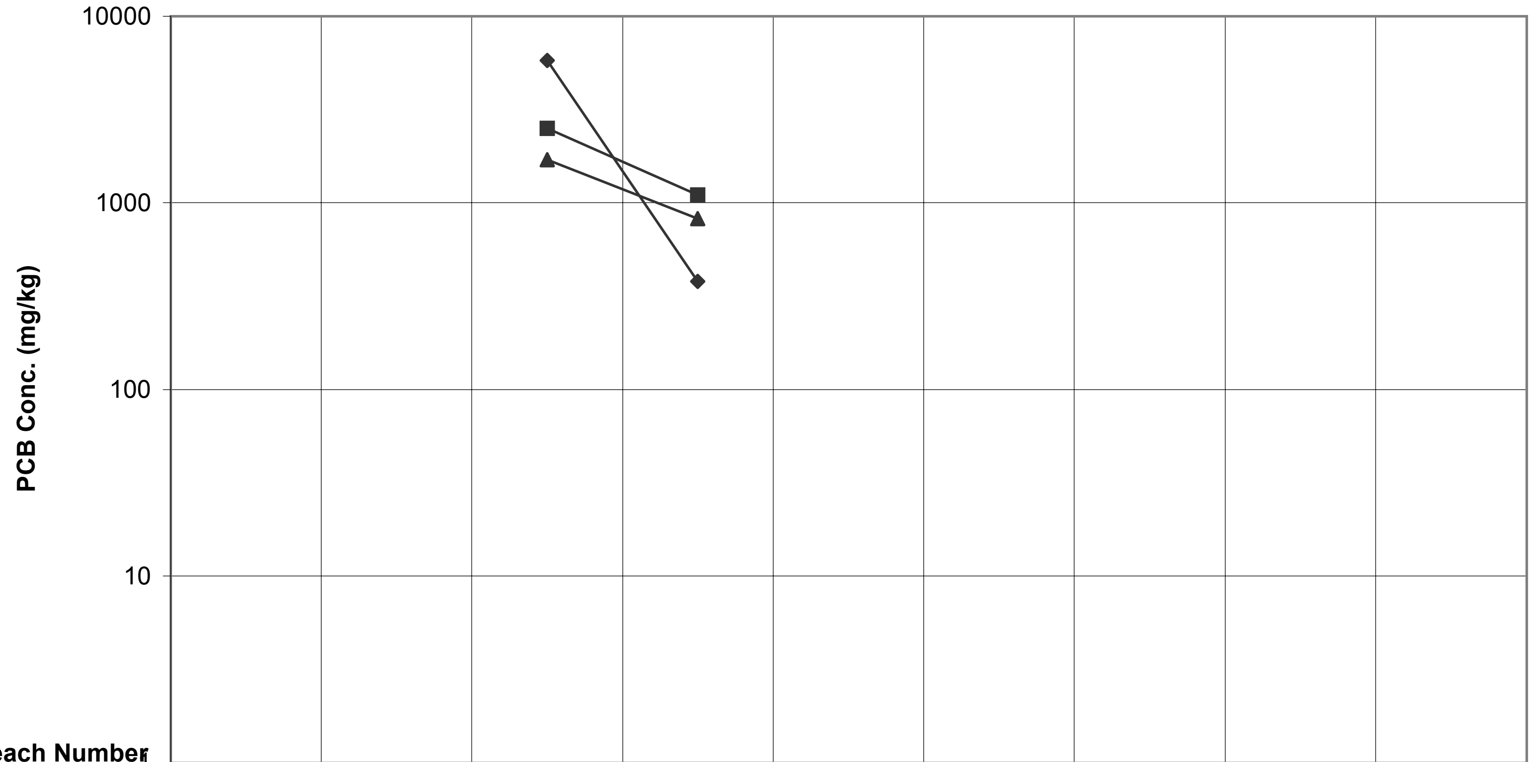
Figure 3.3-7
Average PCB Concentrations in River Bank Soils
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
0-0.5 Feet			352	27					
1.0-1.5 Feet			288	56					
2.0-2.5 Feet			478	49					

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

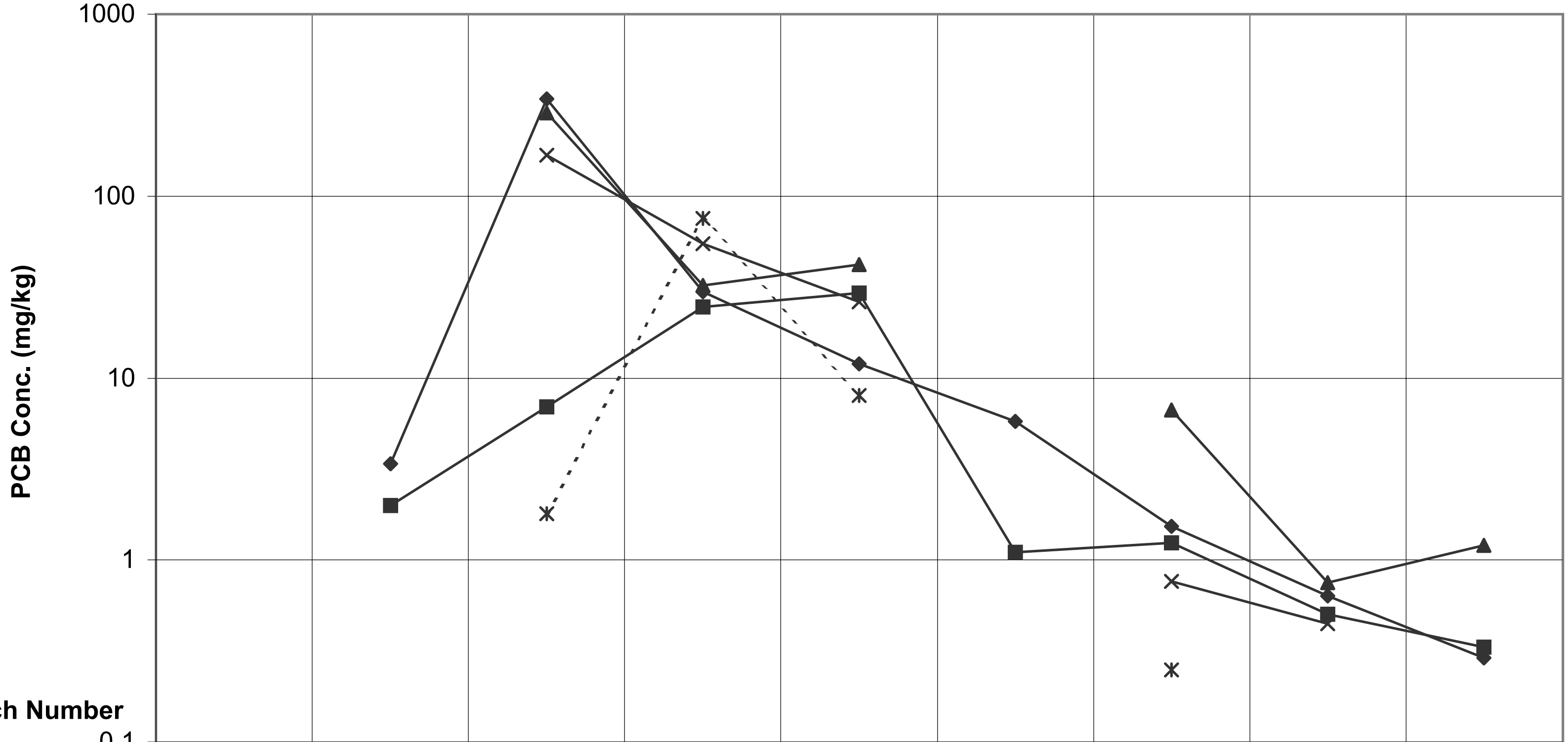
Figure 3.3-8
Maximum PCB Concentrations in River Bank Soils
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
0-0.5 Feet			5800	380					
1.0-1.5 Feet			2500	1100					
2.0-2.5 Feet			1700	820					

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

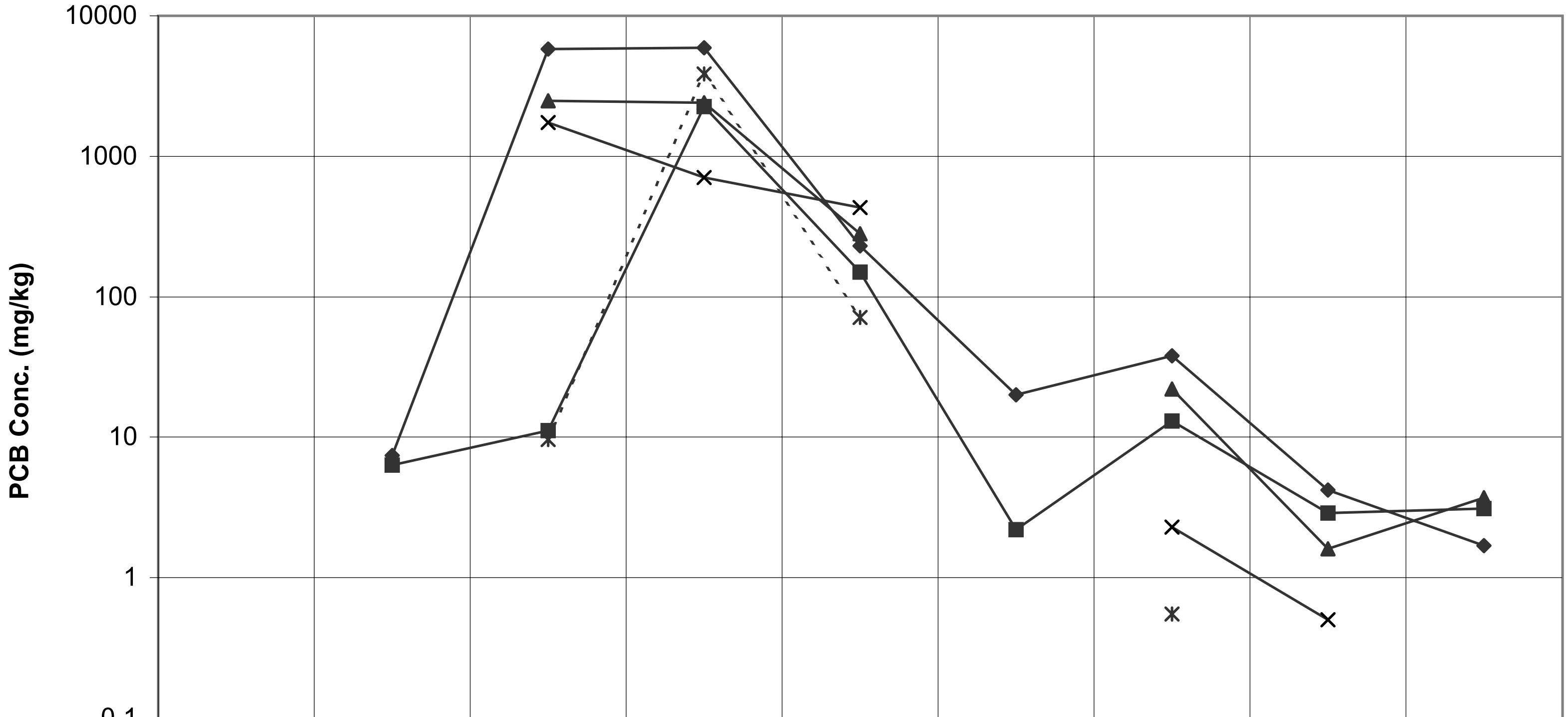
Figure 3.3-9
Average PCB Concentrations in Floodplain Soils
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
0-0.5 Feet		3.38	343	29.7	12.0	5.78	1.53	0.637	0.289
0.5-1.0 Feet		2	6.95	24.6	29.3	1.10	1.25	0.503	0.333
1.0-2.0 Feet			287	32.4	41.9		6.69	0.753	1.209
2.0-3.0 Feet			167	54.6	26.3		0.762	0.445	
3+ Feet			1.80	75.5	8.05		0.248		

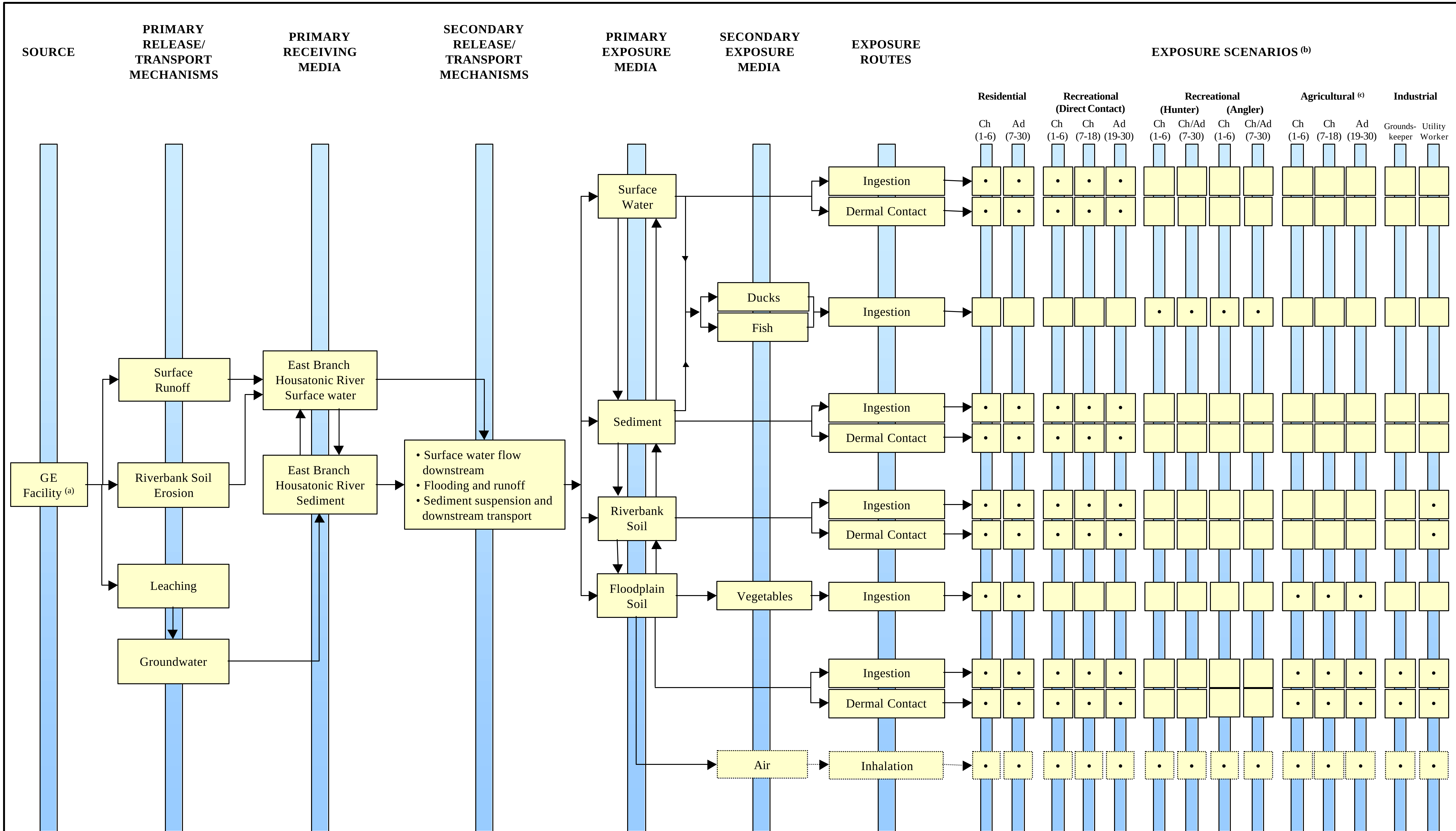
Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.

Figure 3.3-10
Maximum PCB Concentrations in Floodplain Soils
Lower Housatonic River
Pittsfield, MA



Reach Number	1	2	3	4	5	6	7	8	9
0-0.5 Feet		7.43	5793	5904	230	20	38	4.2	1.7
0.5-1.0 Feet		6.32	11.1	2250	150	2.2	13	2.9	3.1
1.0-2.0 Feet			2477	2410	280		22	1.6	3.7
2.0-3.0 Feet			1744	704	430		2.3	0.5	
3+ Feet			9.6	3850	71		0.55		

Sources: Blasland, Bouck & Lee, 1998, Housatonic River Sediment and Floodplain Investigation Maps.
EPA Region 1 Database, 1998. GE database, May 1999.



= Complete exposure pathway

= Incomplete exposure pathway

= May not be evaluated quantitatively.

(a) = Includes all facility-related sources such as site soils, Unkamet Brook, Silver Lake, former oxbows, fill areas, etc.

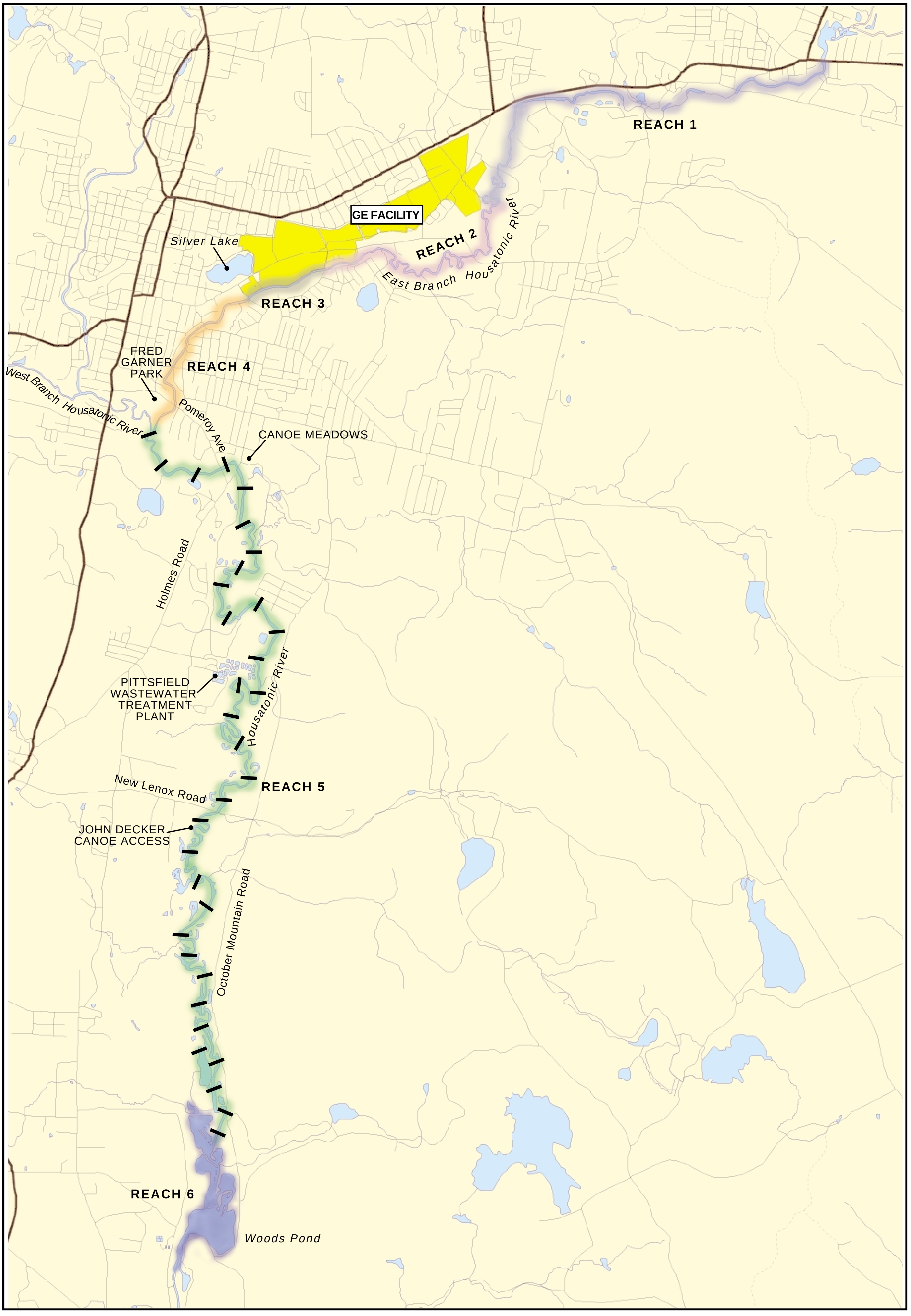
(b) = Numbers in parentheses indicate age range (years).

(c) = Consumption of dairy products from cattle raised on contaminated floodplain soil is not included on this figure, but may be evaluated if further investigation shows this to be a significant pathway.

Ch = Child

Ad = Adult

Figure 4-1
Conceptual Site Model
Baseline Human Health Risk Assessment



LEGEND

Reach 1
Reach 2
Reach 3
Reach 4
Reach 5
Reach 6
Proposed Transect

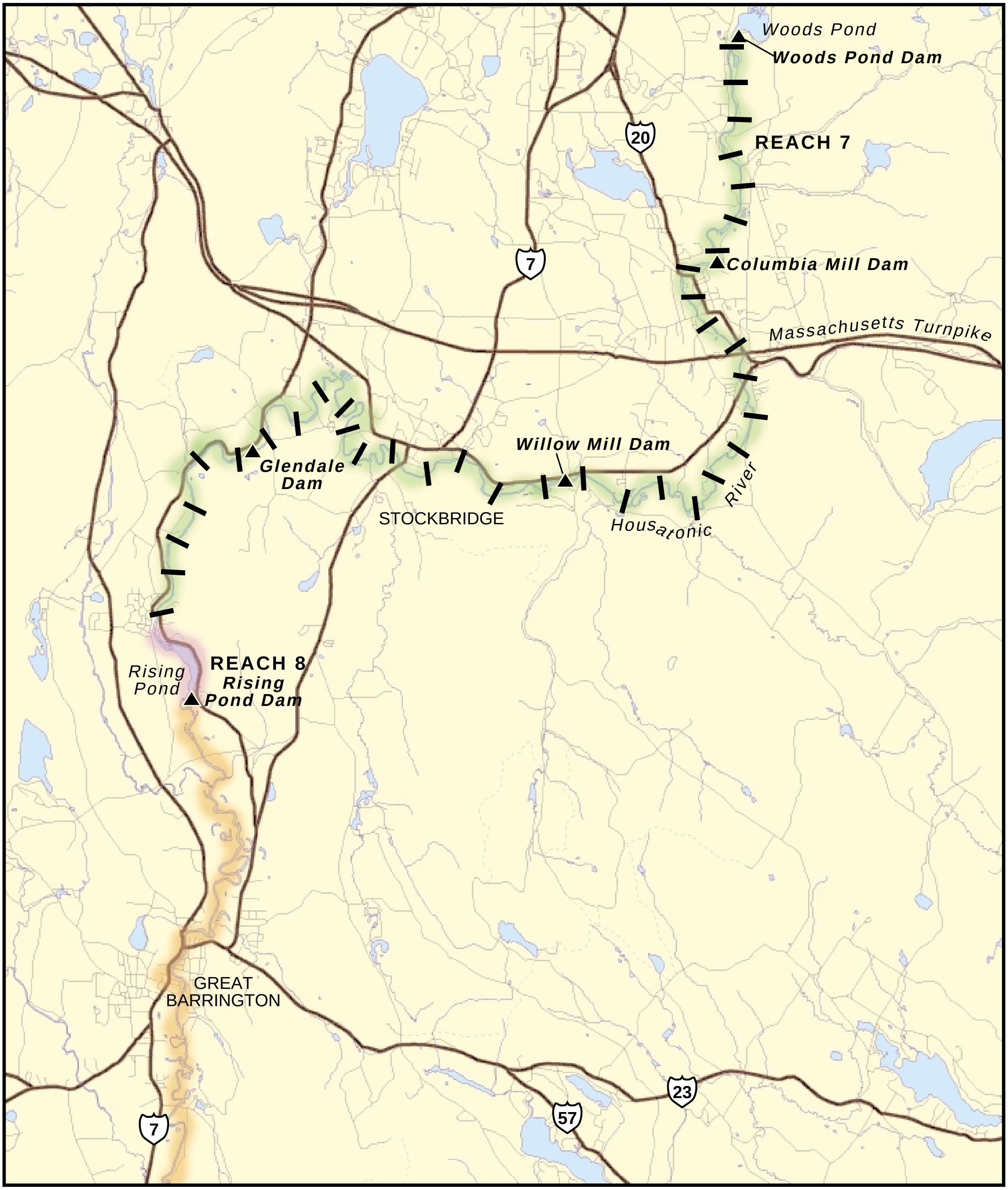
0 1750 3500 5250
Scale In Feet

N

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-1
PROPOSED TRANSECT FREQUENCY—REACH 5

99P-2830-6



LEGEND

- Reach 7
- Reach 8
- Reach 9
- 7 Route Number
- ▲ Approximate Location of Dam
- Proposed Transect

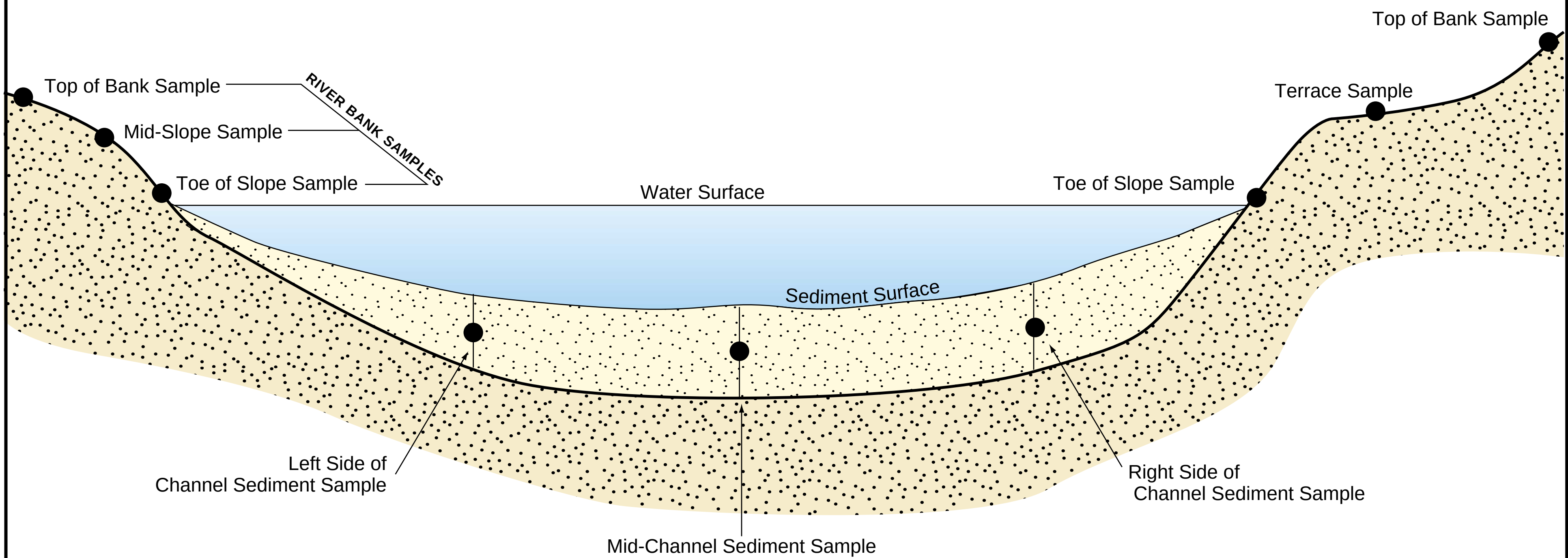
0 4000 8000 12000
Scale In Feet

N

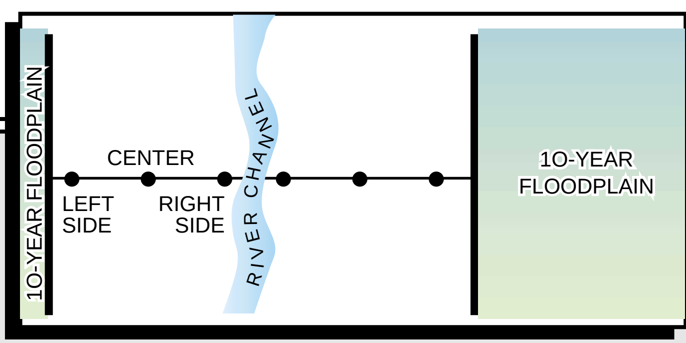
99P-2830-7

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-2
PROPOSED TRANSECT FREQUENCY AND DAM LOCATIONS
REACH 7



PLAN VIEW OF FLOODPLAIN SAMPLE LOCATIONS



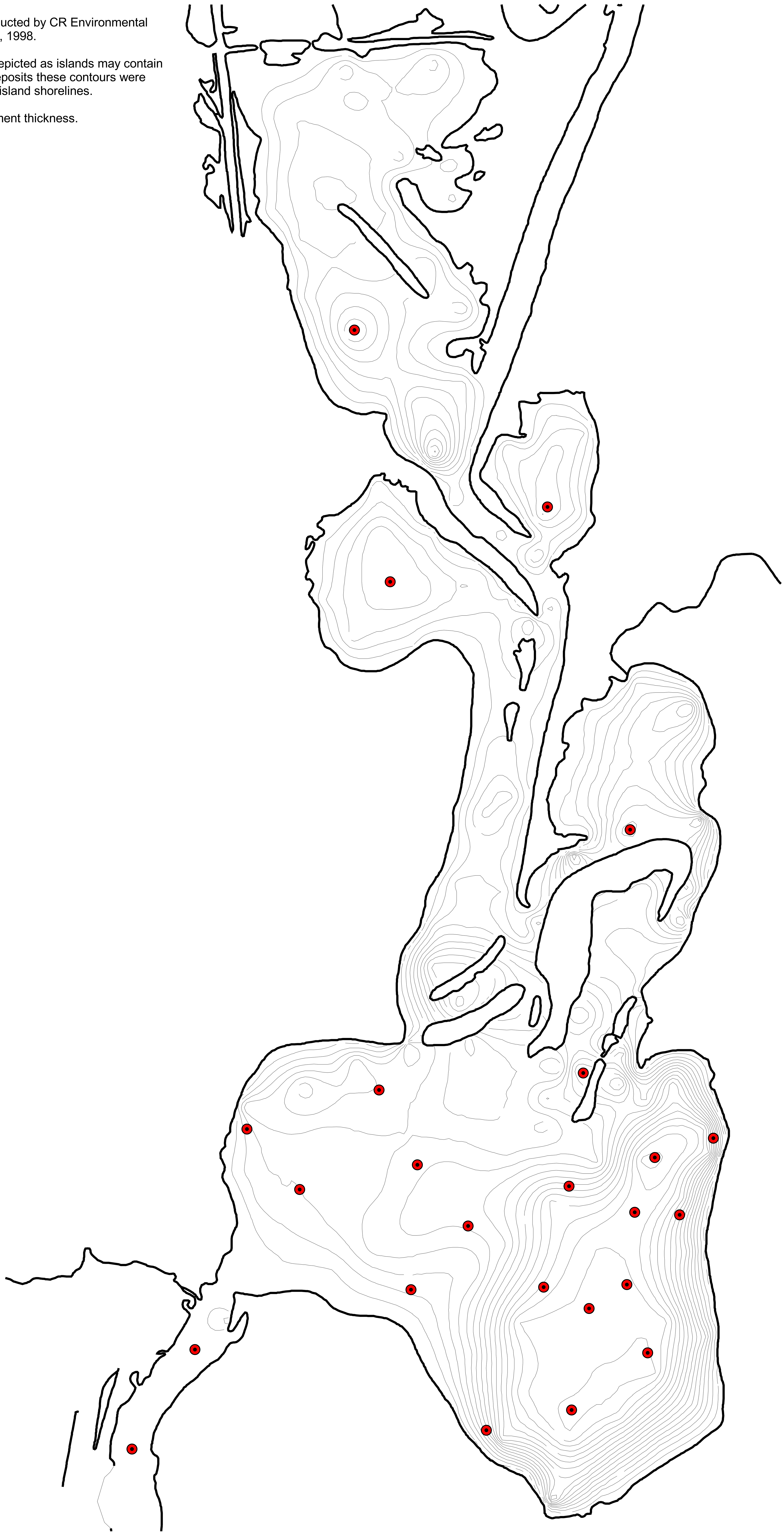
SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-3
TYPICAL SEDIMENT, BANK, AND FLOODPLAIN SAMPLE LOCATIONS ALONG RIVER TRANSECT

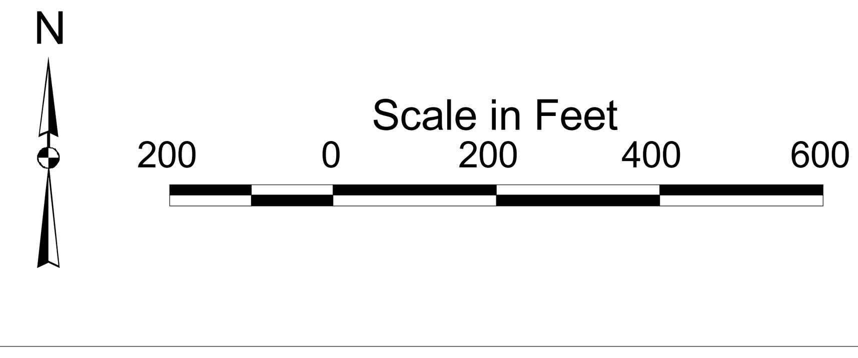
99P-2830-8

NOTES:

1. Sediment profiling conducted by CR Environmental between December 1-3, 1998.
2. Because some areas depicted as islands may contain substantial sediment deposits these contours were allowed to terminate at island shorelines.
3. Contours indicate sediment thickness. Contour interval: 1 foot.



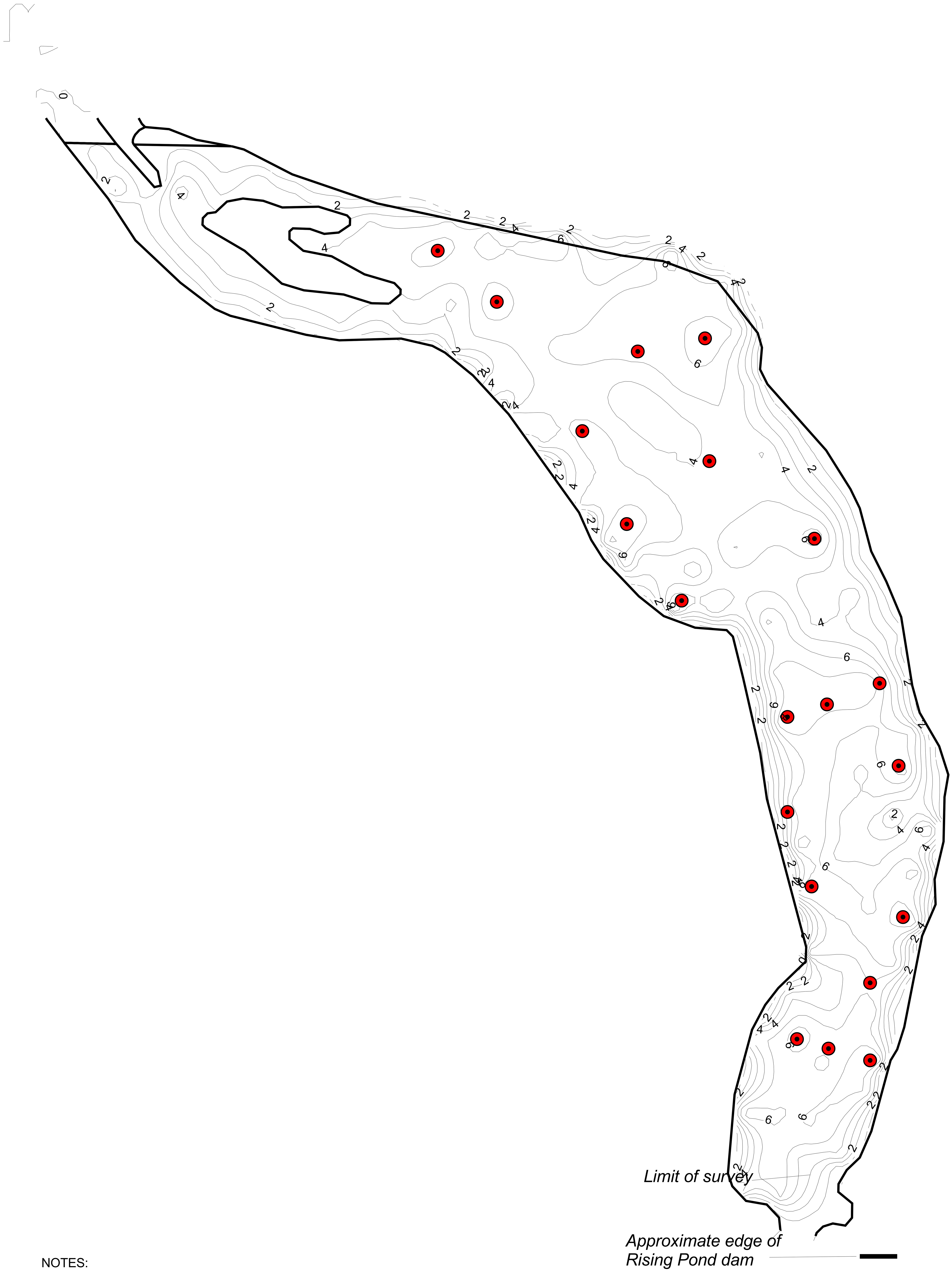
Core locations



SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-4
PROPOSED SEDIMENT CORING LOCATIONS FOR WOODS POND AND ADJACENT BACKWATER AREAS

| d:/gepitt/aprs/sedcore2.apr | Layout - Woods Pond Sed. | o:\gepitt\aprs\swi-workplan\in\woods_sed_thickness.eps | 9:53 AM, 10/19/1999 |



NOTES:

1. Sediment profiling conducted by CR Environmental between December 4-5, 1998.

2. Because some areas depicted as islands may contain substantial sediment deposits these contours were allowed to terminate at island shorelines.

3. Contours indicate sediment thickness.
Contour interval: 1 foot.

● Core locations

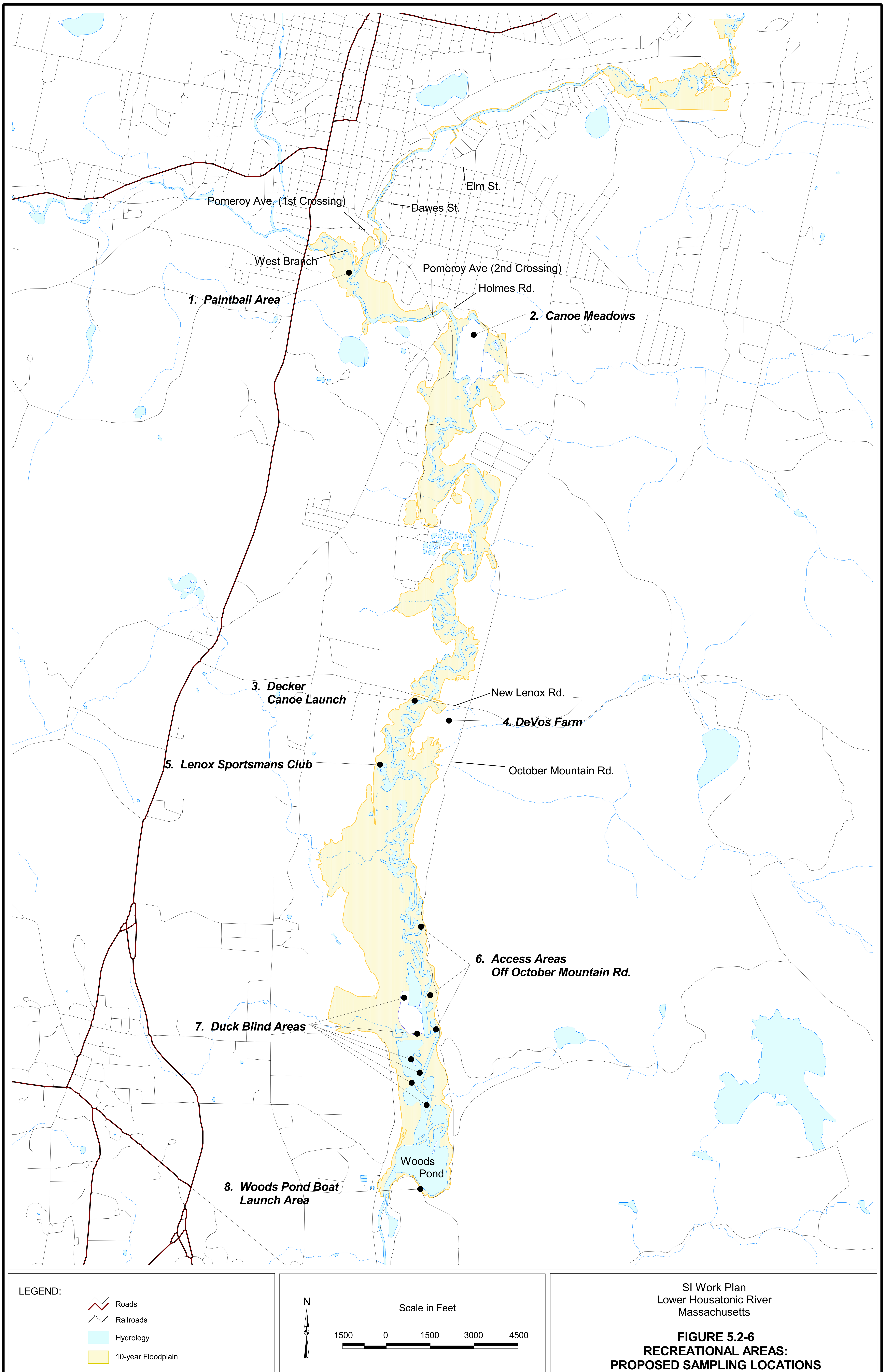
N

Scale in Feet

150 0 150 300 450

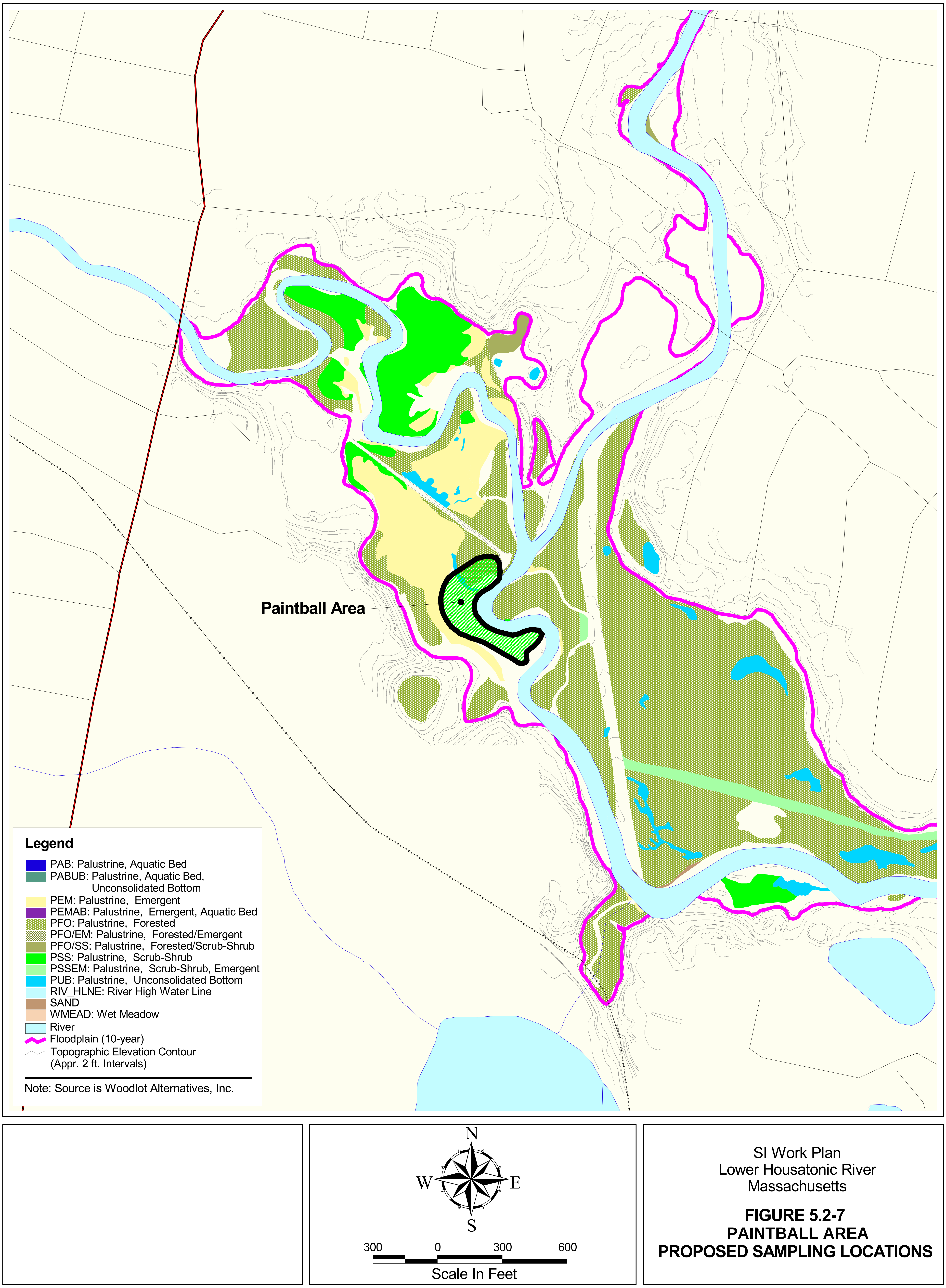
SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-5
PROPOSED SEDIMENT CORING LOCATIONS FOR RISING POND



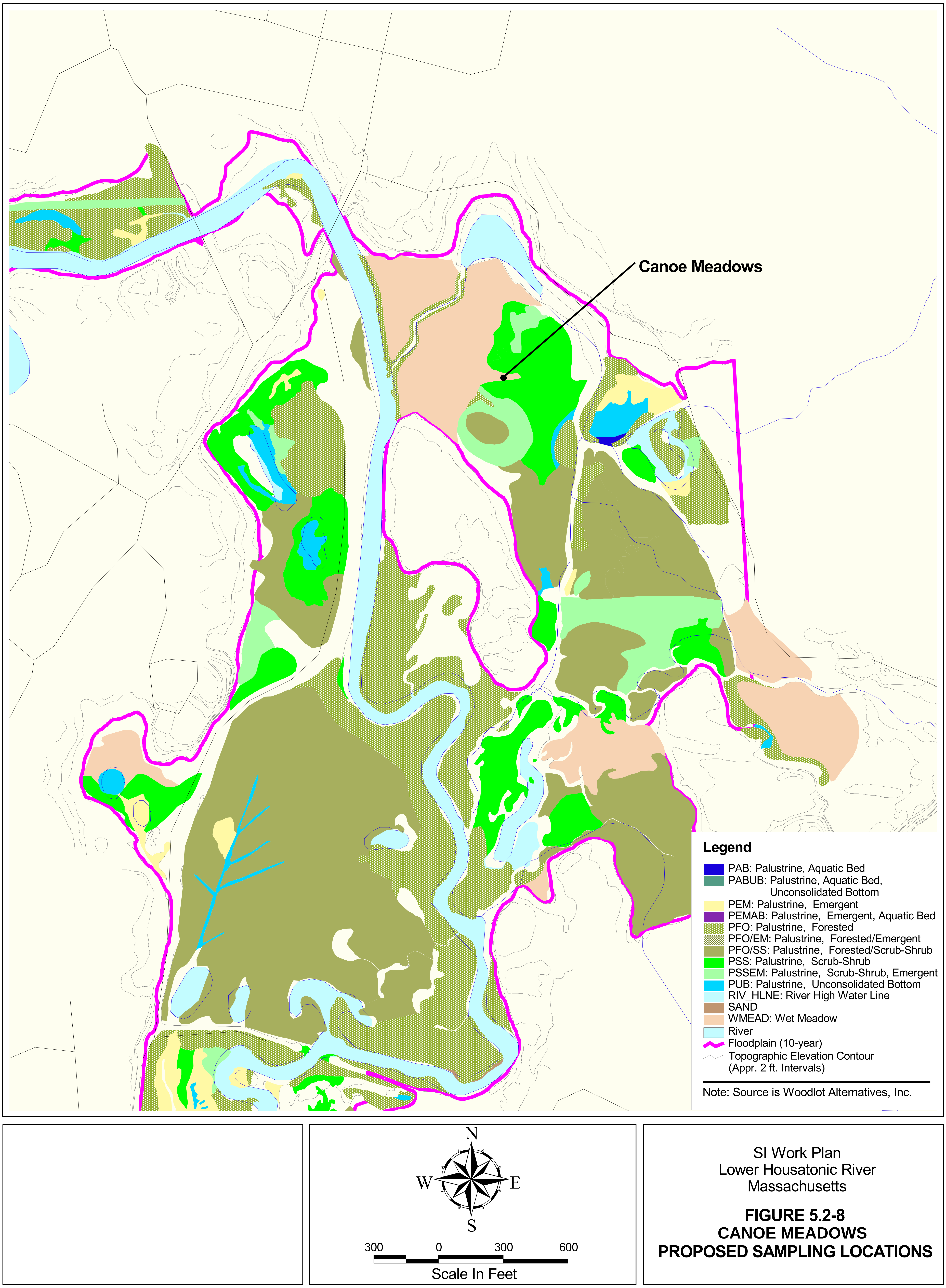
SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-6
RECREATIONAL AREAS:
PROPOSED SAMPLING LOCATIONS



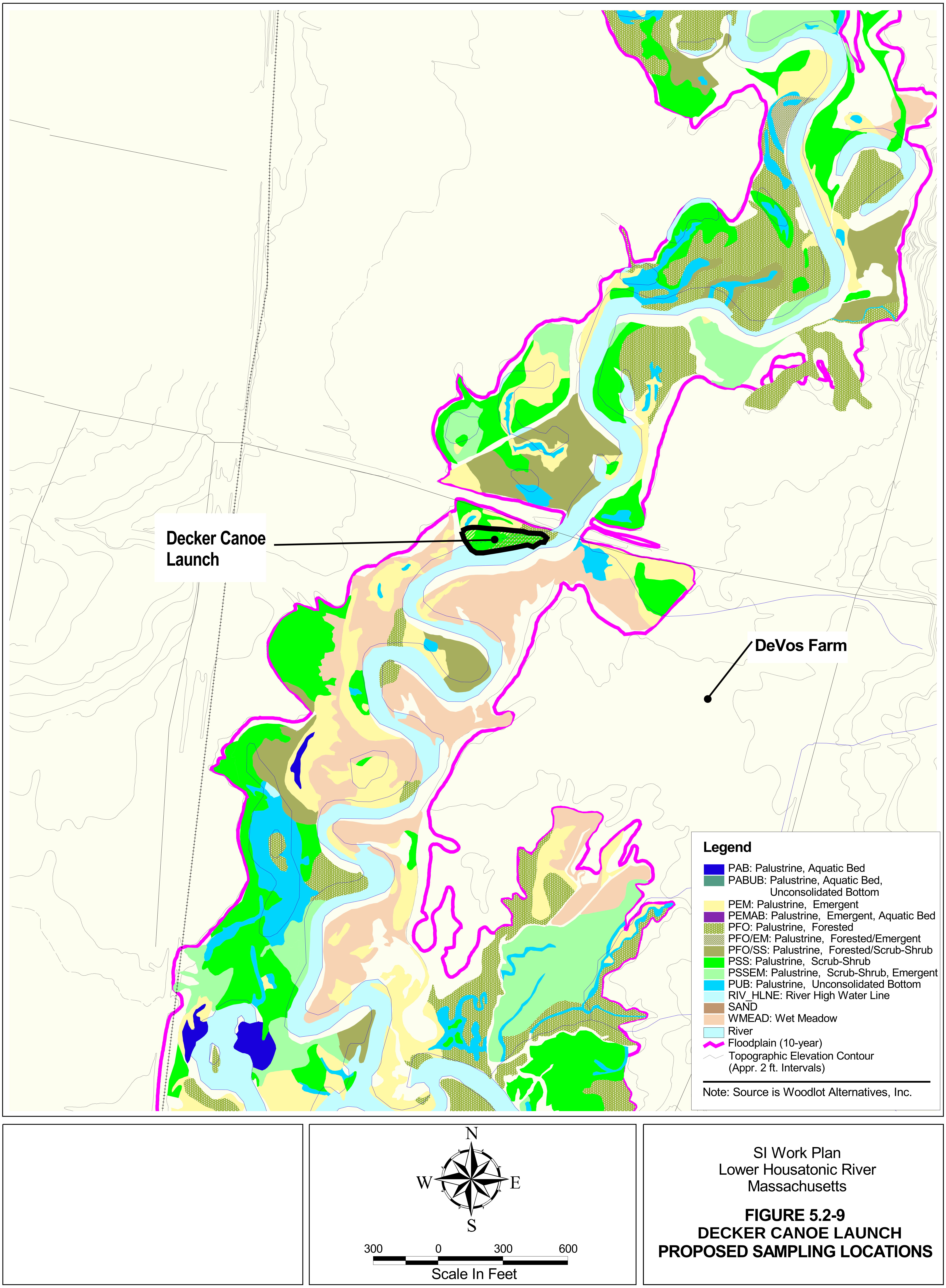
SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-7
PAINTBALL AREA
PROPOSED SAMPLING LOCATIONS



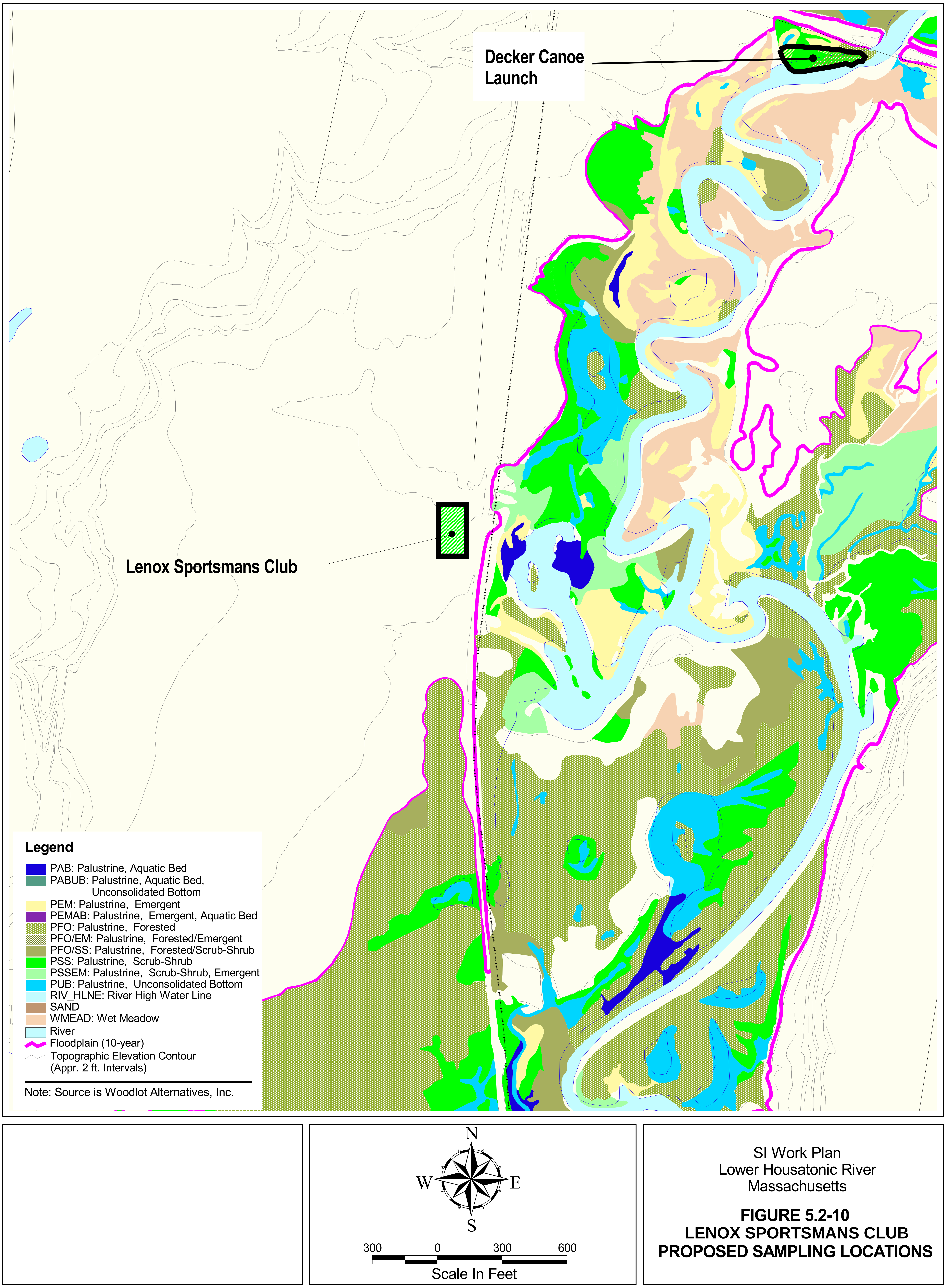
SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-8
CANOE MEADOWS
PROPOSED SAMPLING LOCATIONS



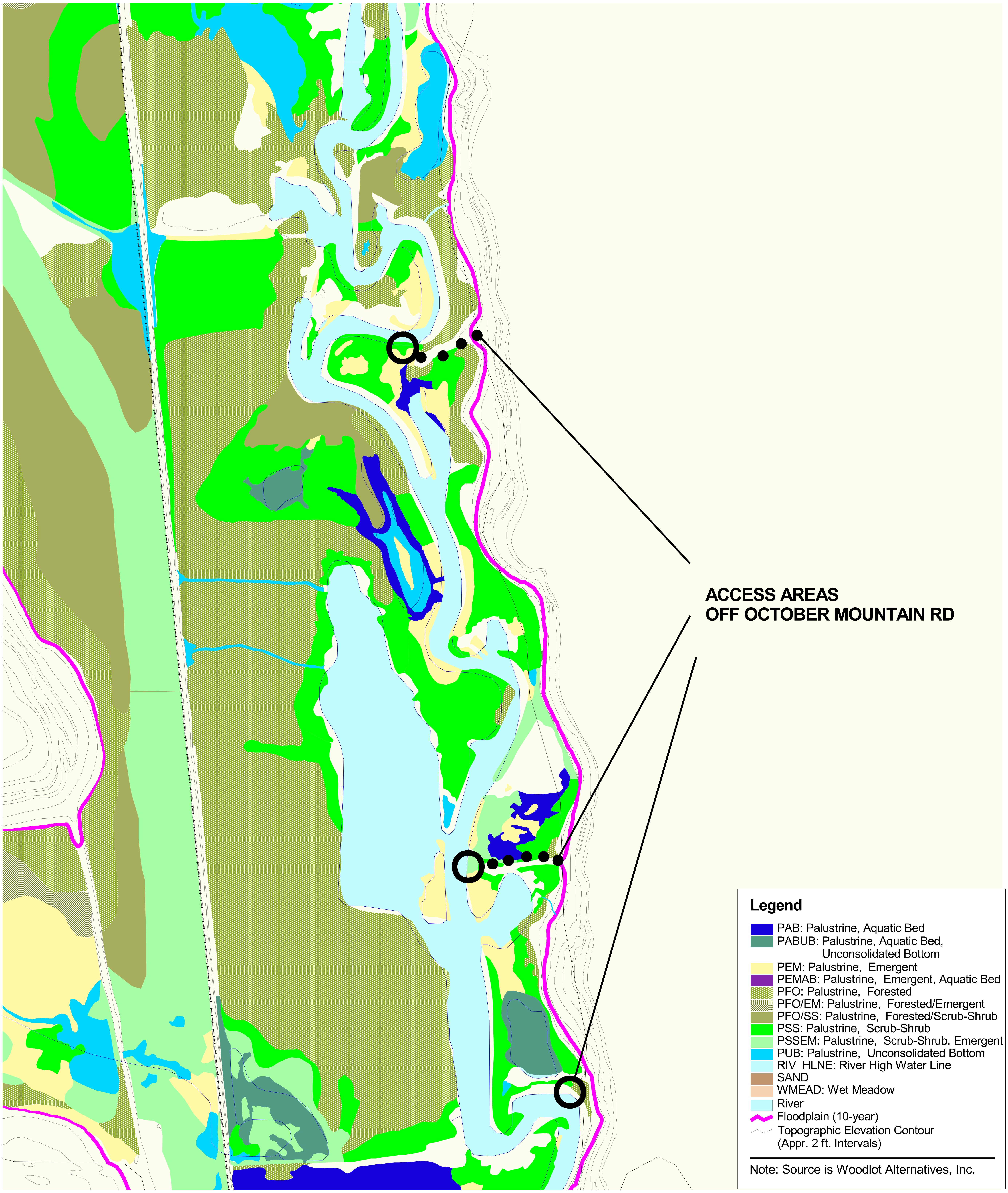
SI Work Plan
Lower Housatonic River
Massachusetts

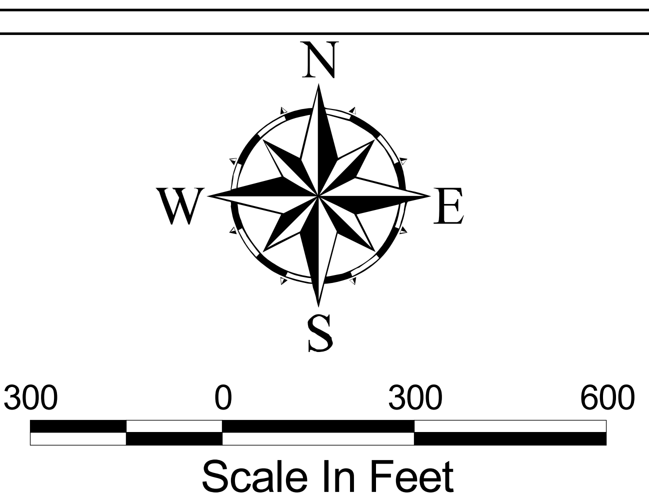
FIGURE 5.2-9
DECKER CANOE LAUNCH
PROPOSED SAMPLING LOCATIONS



SI Work Plan
Lower Housatonic River
Massachusetts

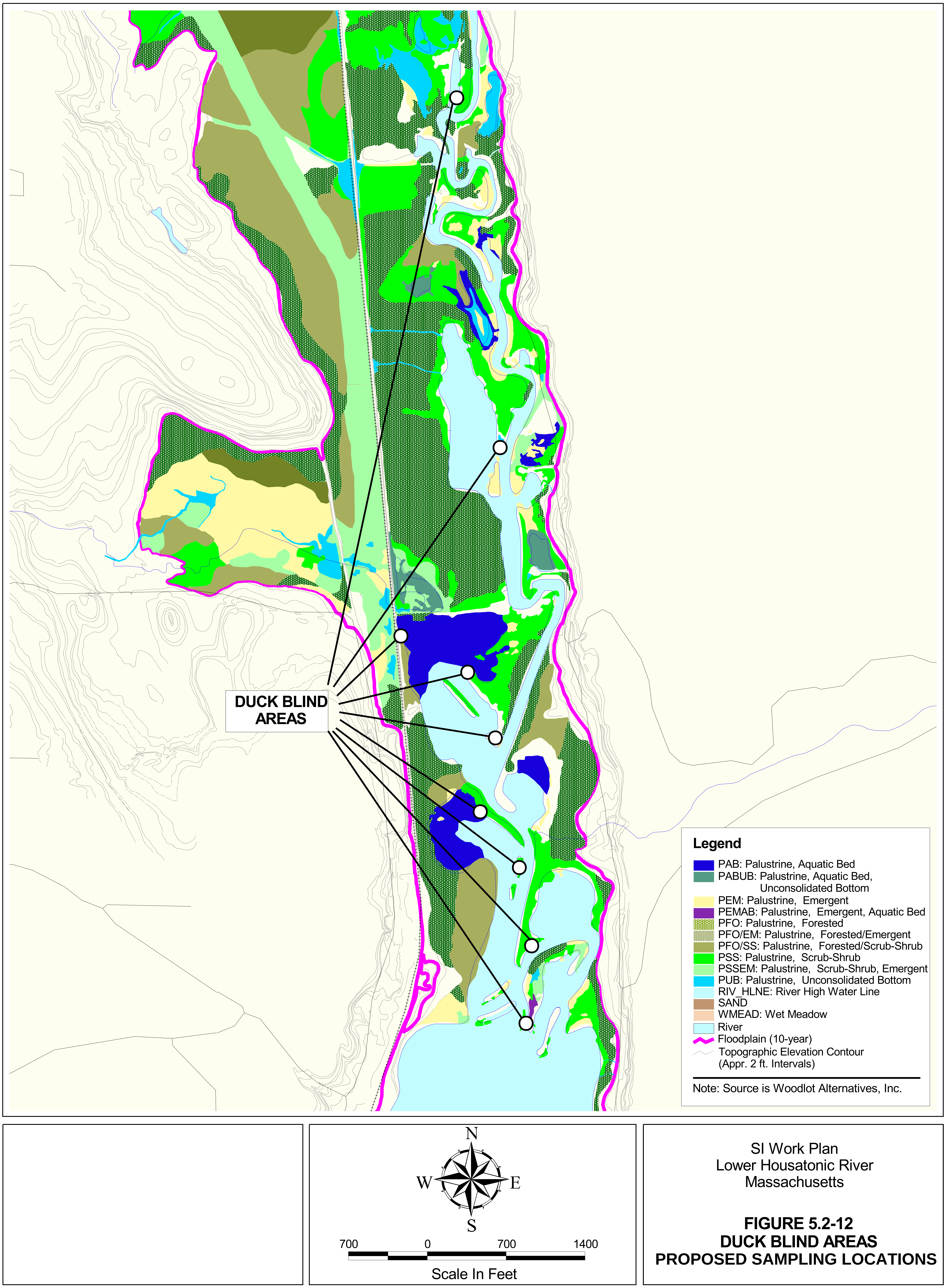
FIGURE 5.2-10
LENOX SPORTSMANS CLUB
PROPOSED SAMPLING LOCATIONS





SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-11
ACCESS AREAS
PROPOSED SAMPLING LOCATIONS



SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-12
DUCK BLIND AREAS
PROPOSED SAMPLING LOCATIONS

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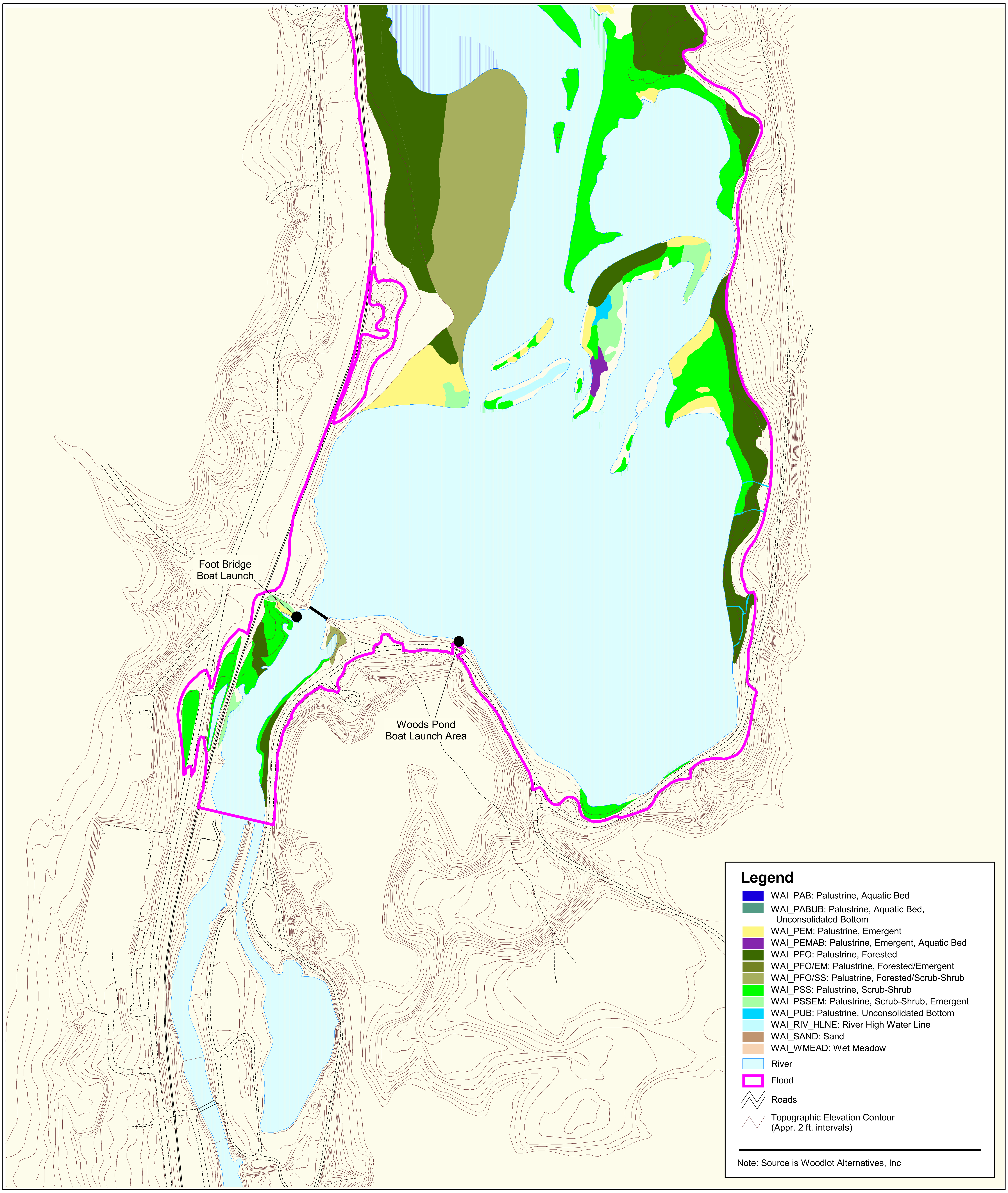


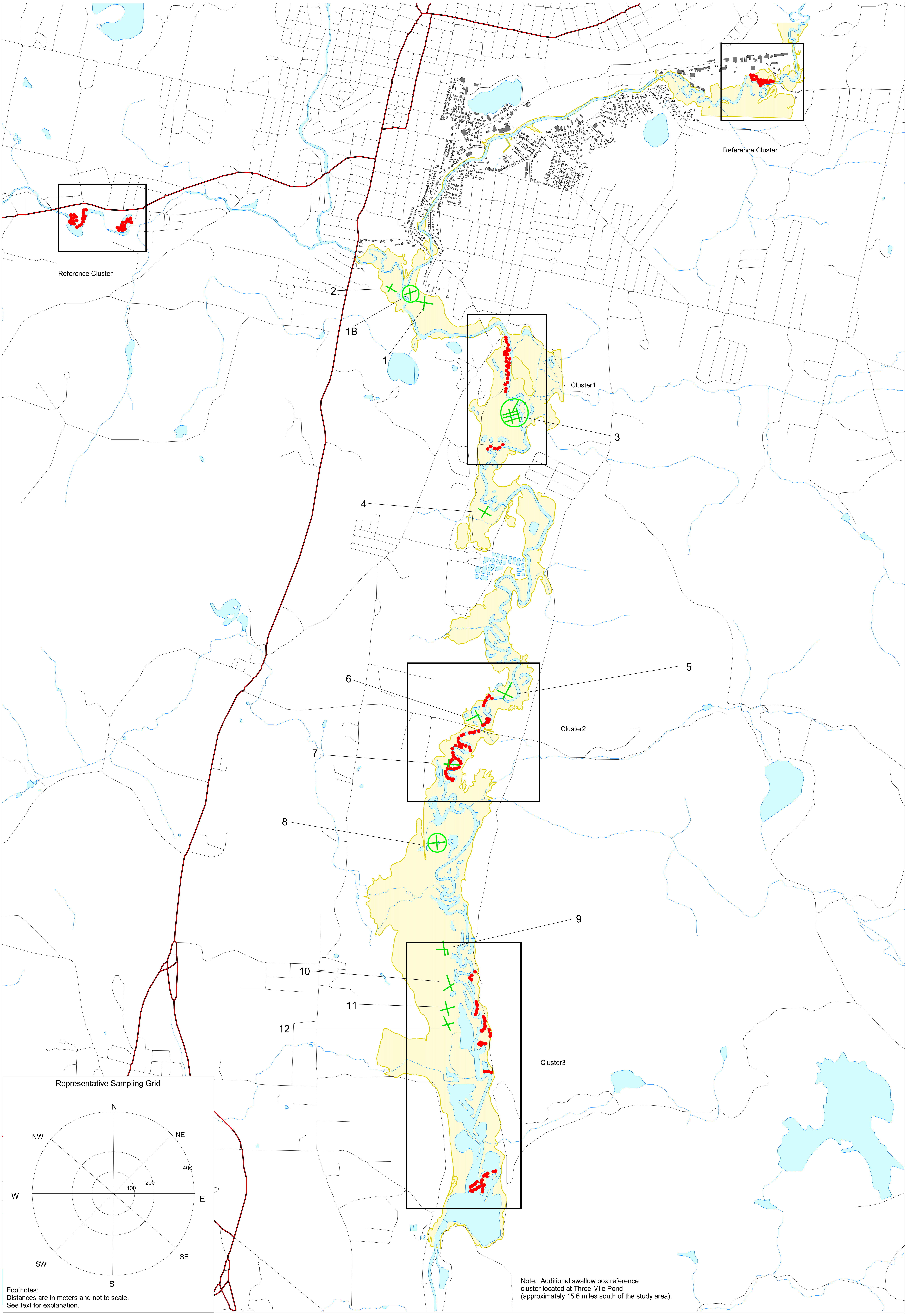
N W E S

300 0 300 600

Scale In Feet

Housatonic River Project
Pittsfield, Massachusetts

FIGURE 5.2-13
WOODS POND BOAT LAUNCH AREA
PROPOSED SAMPLING LOCATIONS



LEGEND:
- Swallow Box Locations
- 1B Trap Arrays
- 2 Soil Sample Locations/Proposed Trapping Areas
- Roads
- Hydrology
- Floodplain
- Buildings

N

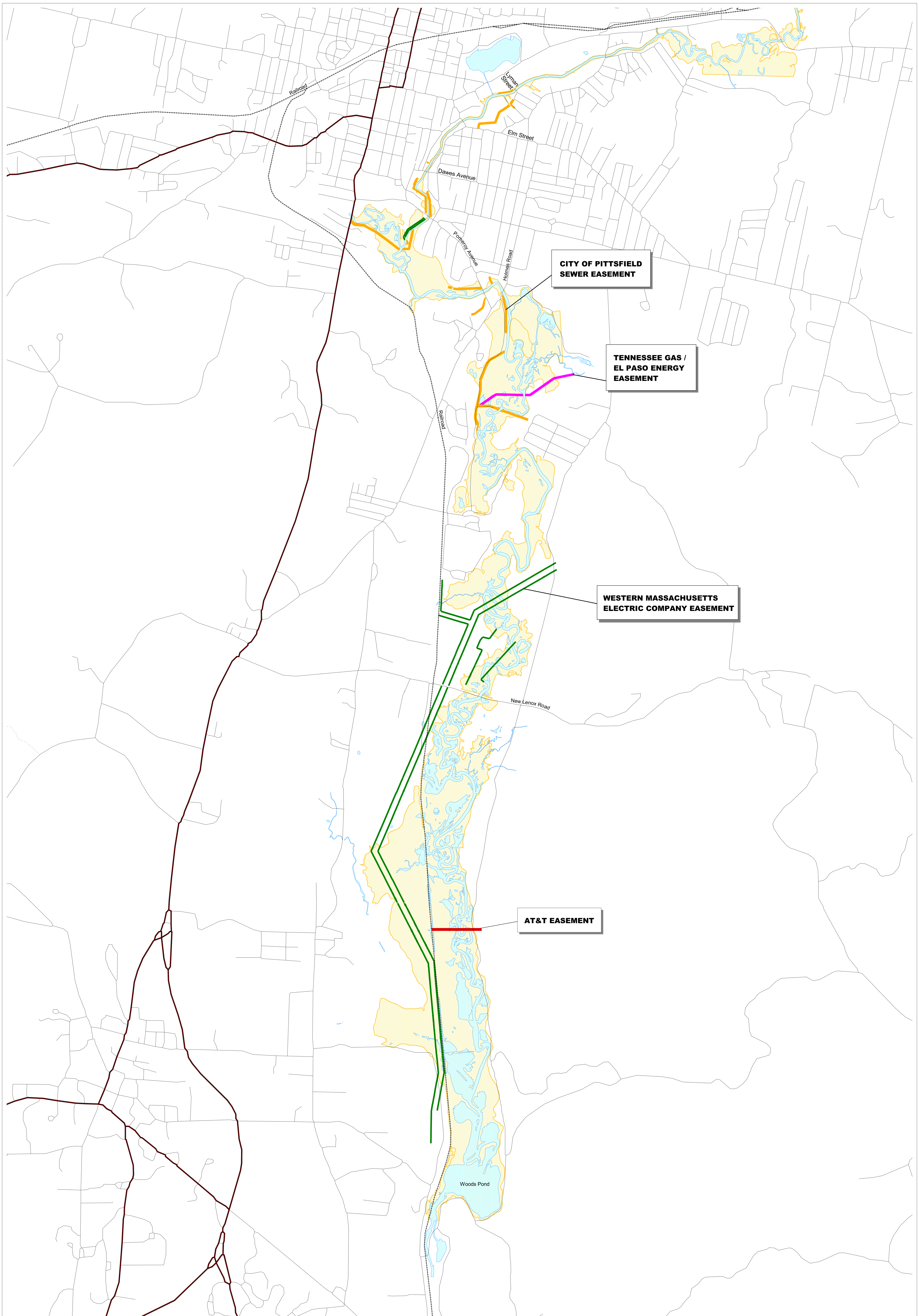
Scale in Feet

1500 0 1500 3000 4500

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-14
TREE SWALLOW BOX LOCATIONS, SMALL MAMMAL TRAP ARRAYS, AND SOIL SAMPLING LOCATIONS

| o:/gepitt/aprs/swi-workplan/swallow.apr | cluster100% | o:\gepitt\aprs\swi-workplan\in\swallow.eps | 3:35 PM, 2/18/2000 |



LEGEND:

- Electric Company Easement
- Gas Company Easement
- Sewer Company Easement
- Telephone Company Easement
- Roads
- Railroads
- Hydrology
- 10-year Floodplain

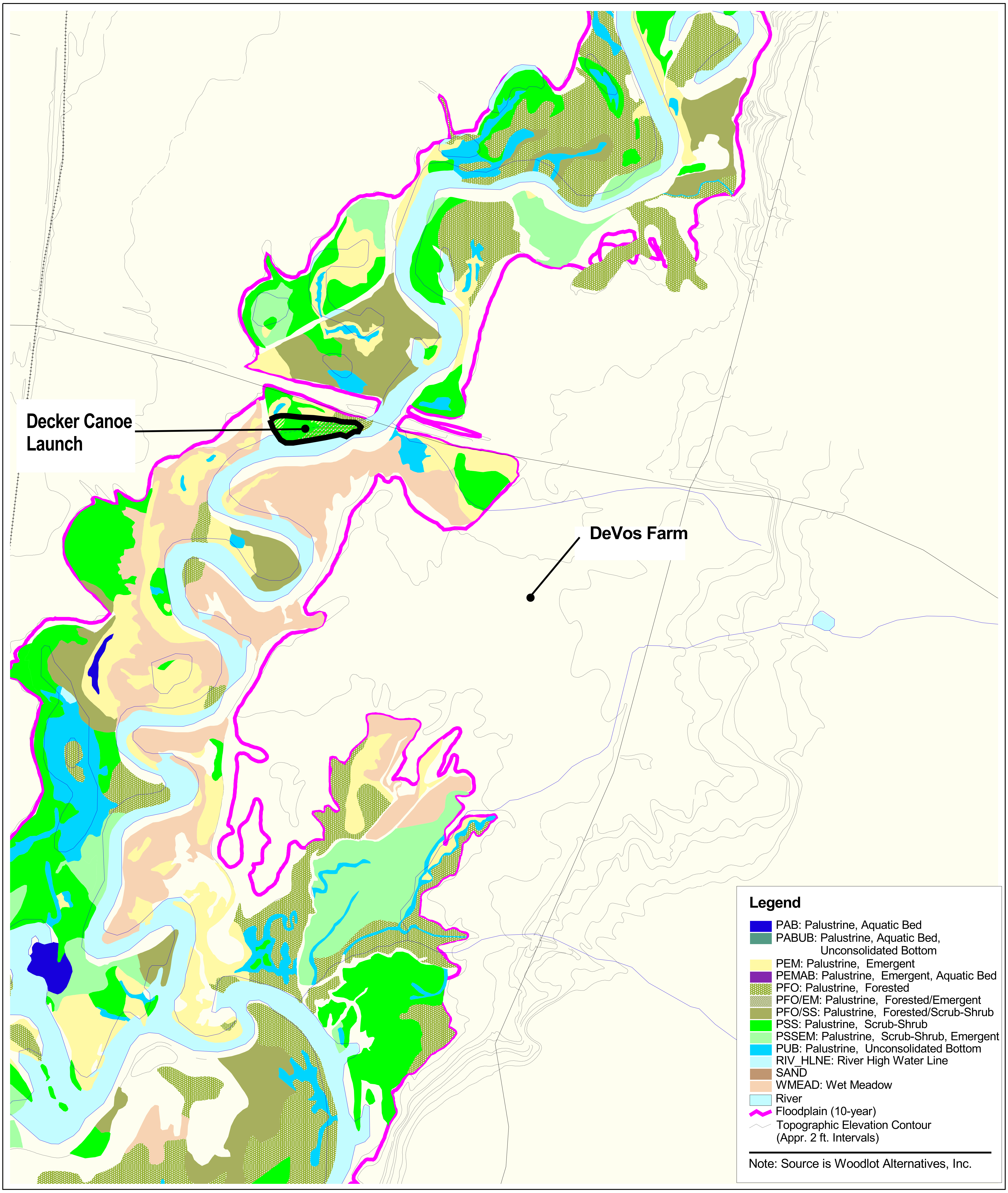
N

Scale in Feet

1500 0 1500 3000 4500

SI Work Plan
Lower Housatonic River
Massachusetts

FIGURE 5.2-15
PUBLIC UTILITY EASEMENT LOCATIONS



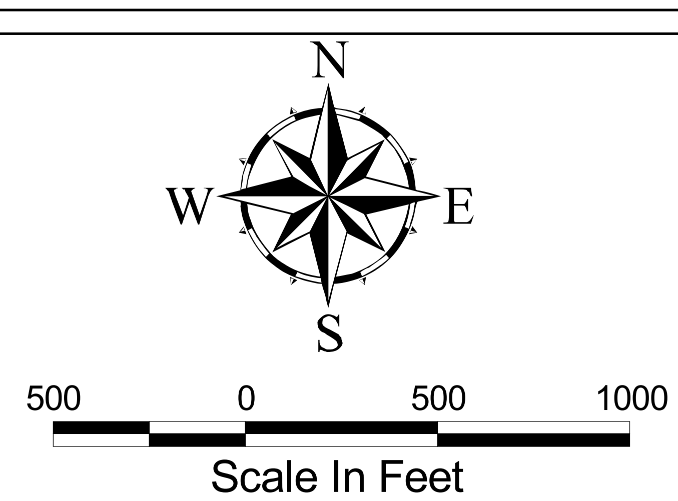


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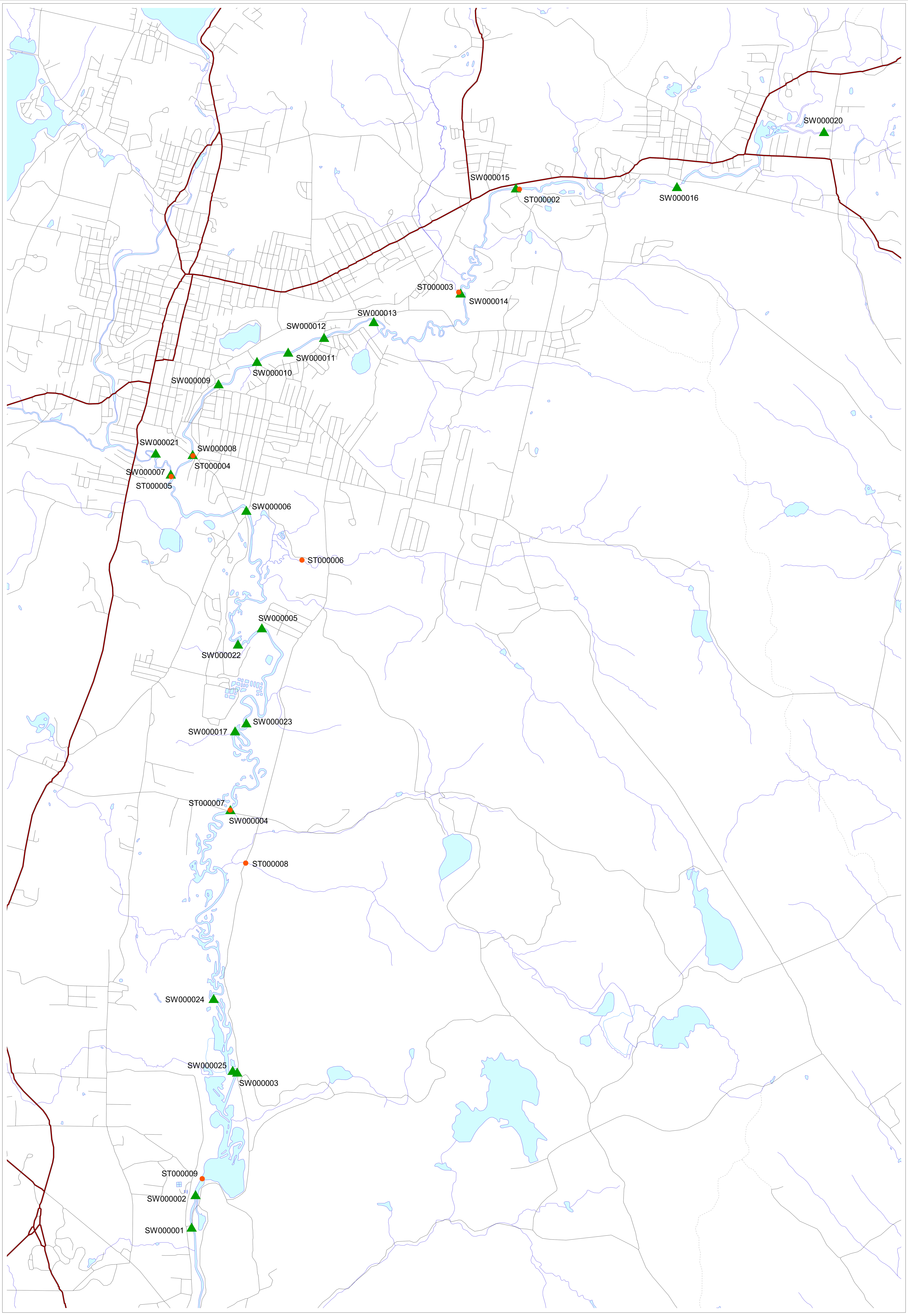
FIGURE 5.2 - 16
DEVOS FARM
PROPOSED SAMPLING LOCATIONS



LEGEND:

- Surface Water Sample Locations
- Storm Water Sample Locations
- Roads
- Hydrology

N

Scale in Feet

2000 0 2000 4000 6000

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FIGURE 5.3-1
PROPOSED SURFACE WATER AND STORM EVENT SAMPLING LOCATIONS

| o:\gepitt\aprs\water_loc.apr | layout - water sampling | o:\gepitt\epsfiles\portrait24x36\in\sw-locs.eps | 3:56 PM, 12/2/1999 |

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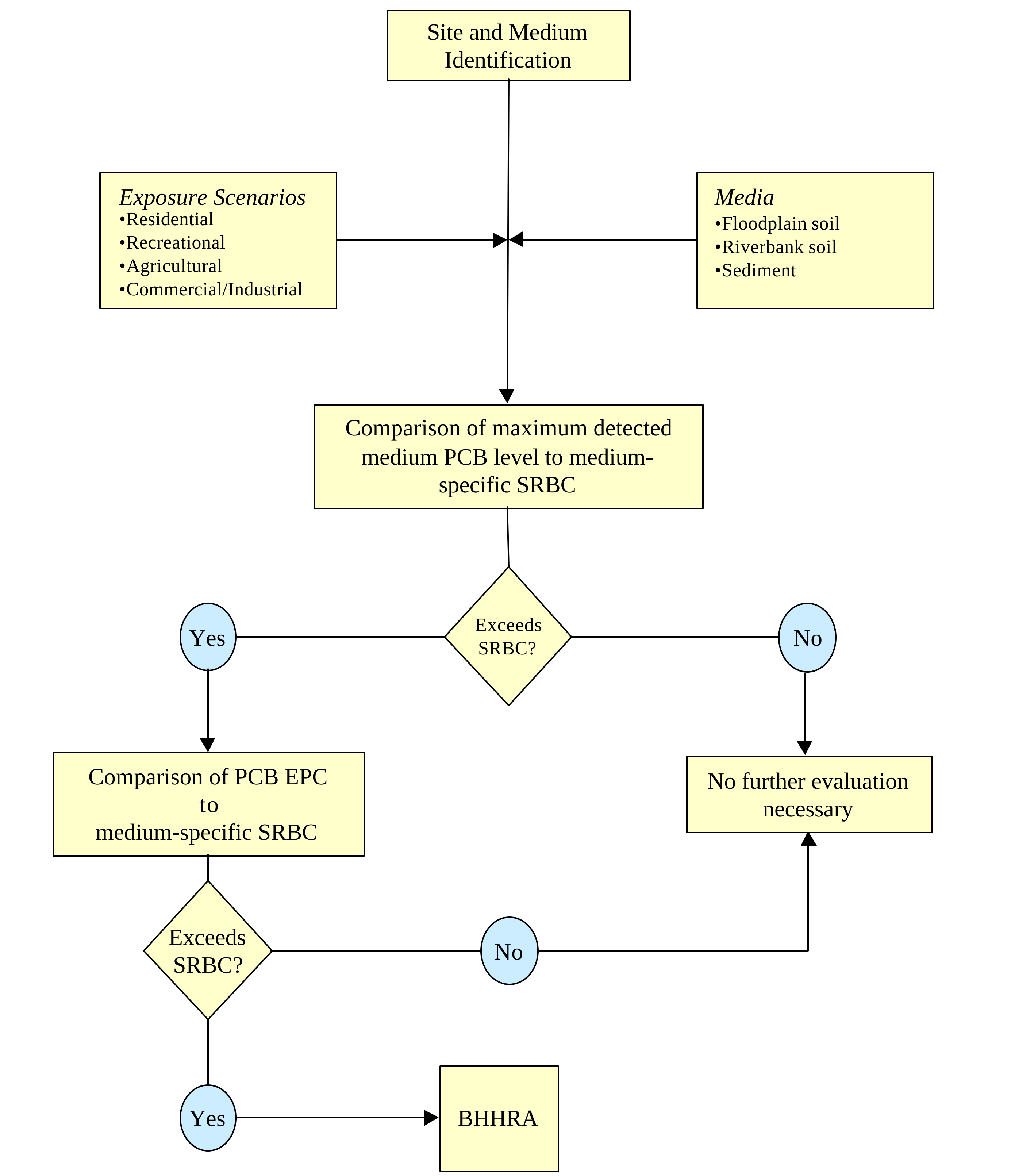
FIGURE 5.3-2
PROPOSED FLOODPLAIN AND CHANNEL GEOMETRY TRANSECT LOCATIONS BETWEEN THE CONFLUENCE AND WOODS POND

| o:\gepitt\aprs\swi-workplan\trans_util.apr | layout - transects | o:\gepitt\aprs\swi-workplan\in\transects.eps | 1:59 PM, 11/5/1999 |



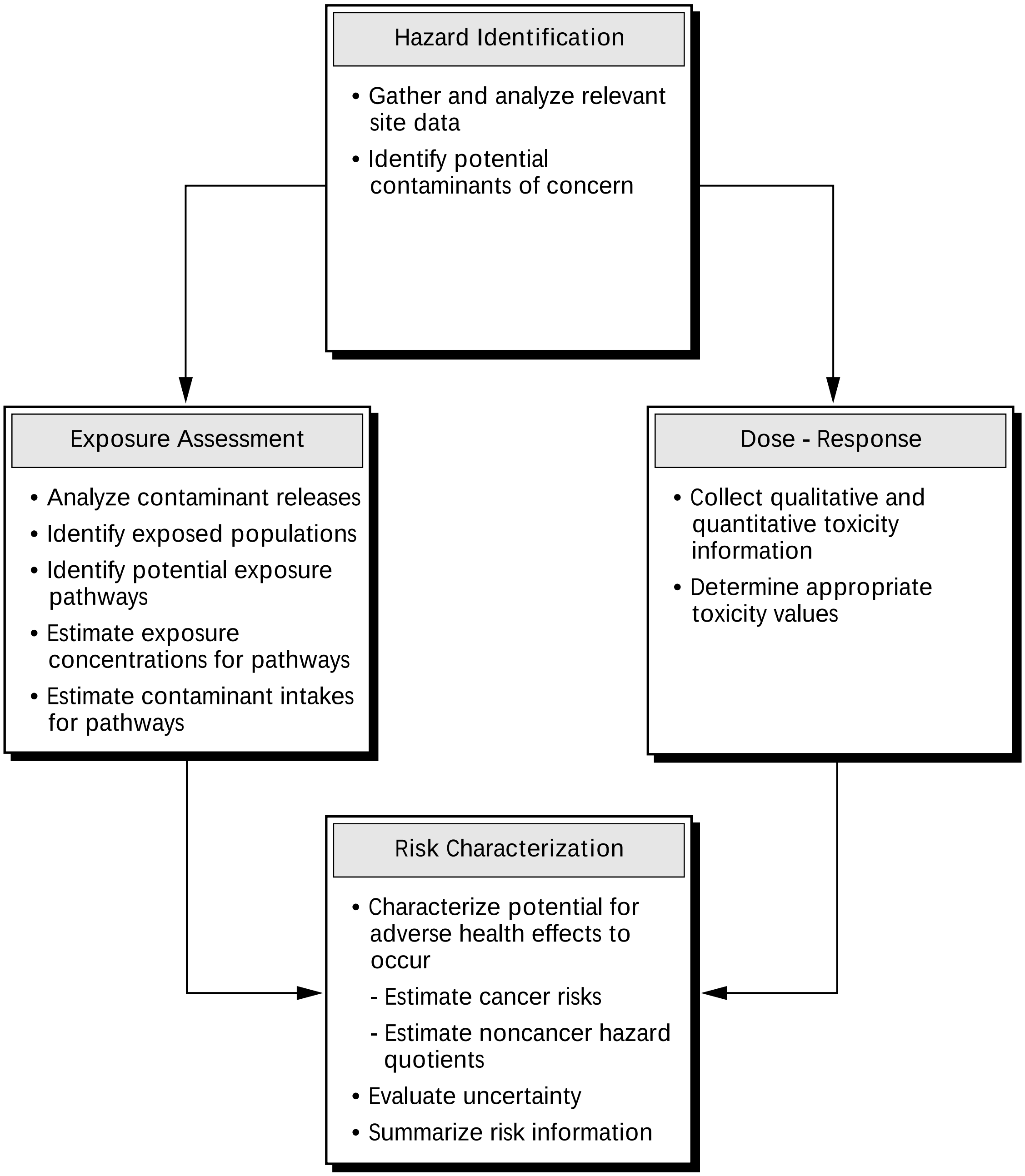
SRBC = Screening Risk-Based Concentration

BHHRA = Baseline Human Health Risk Assessment

EPC = Exposure Point Concentration

PCB = Total Polychlorinated Biphenyls

Figure 6.1-1
Phase 1 Site Screening Approach
Lower Housatonic River
Pittsfield, MA



00P-0214

FIGURE 6.1-2 BASELINE HUMAN HEALTH RISK ASSESSMENT PROCESS

Figure 6.2-1A
FLOODPLAIN SOIL
PCB SRBC = 2 mg/kg(1)

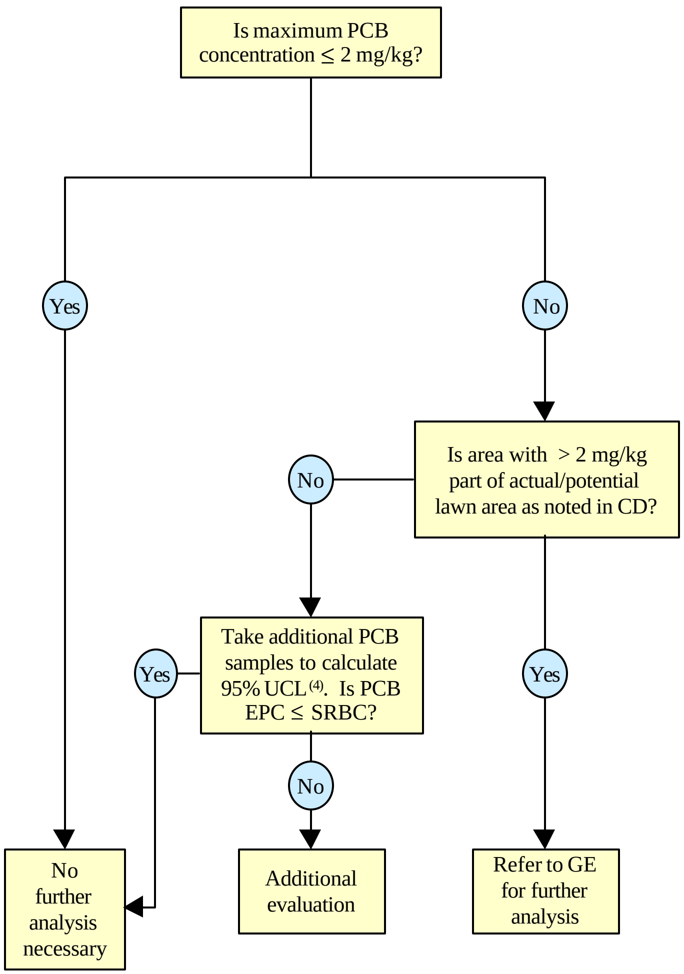
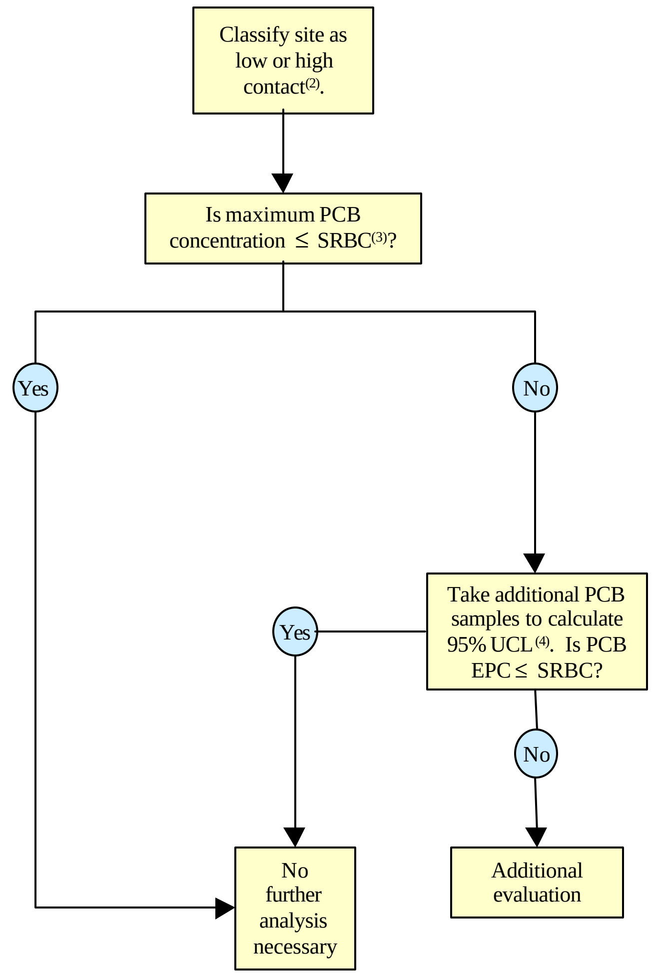


Figure 6.2-1B
RIVERBANK SOIL AND SEDIMENT
SRBC for Incidental Ingestion
and Dermal Contact



(1) Based on the Consent Decree (CD).

(2) Accessibility of riverbank soil and sediment will be determined to select low contact or high contact SRBC.

(3) SRBCs will be calculated for high and low contact exposure potentials.

(4) In cases where several residential properties are adjacent to each other, sample values may be combined to develop an EPC defined as the lower of either the 95% UCL of the mean or the maximum detected concentration.

Figure 6.2-1
Phase 1 Site Screening Approach
for Residential Exposure
Lower Housatonic River

Figure 6.2-2A
FLOODPLAIN SOIL
SRBC for Incidental Ingestion
and Dermal Contact

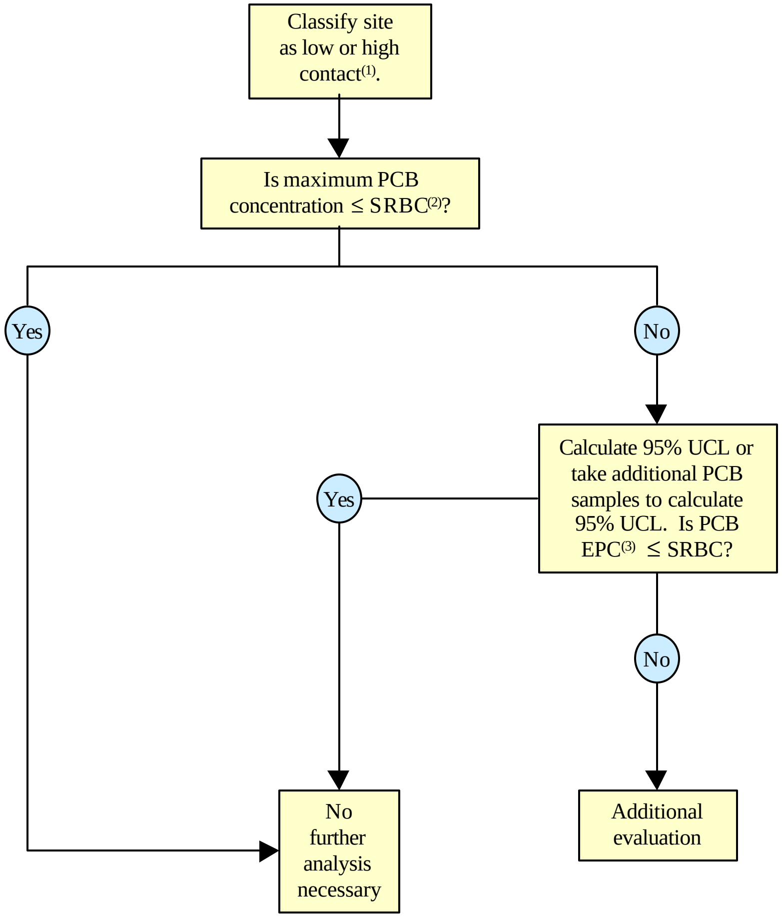
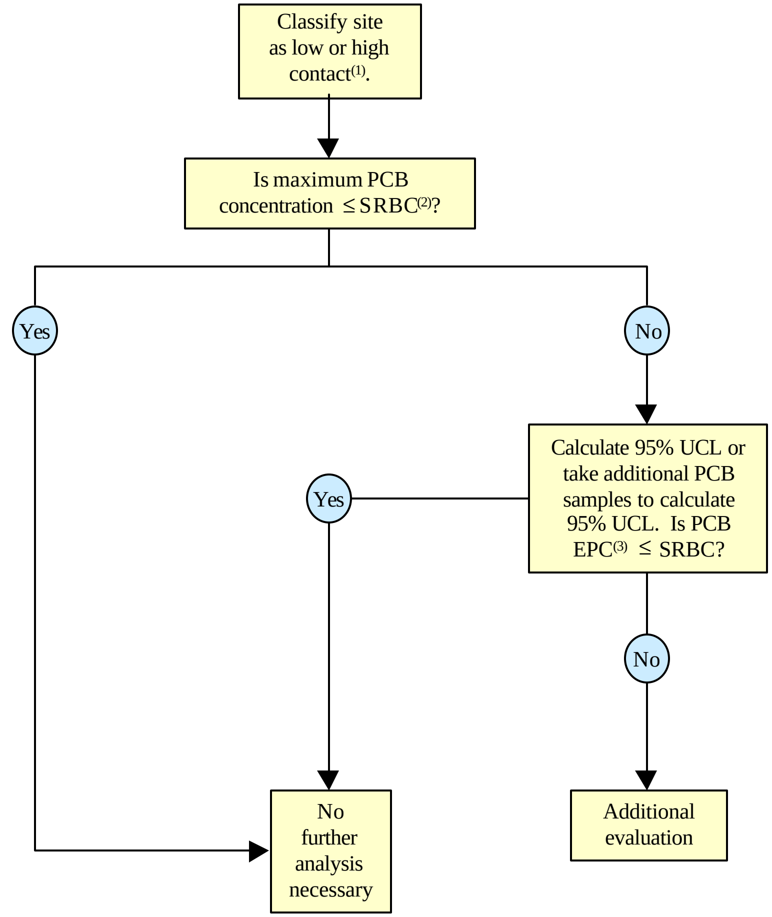


Figure 6.2-2B
RIVERBANK SOIL AND SEDIMENT
SRBC for Incidental Ingestion
and Dermal Contact



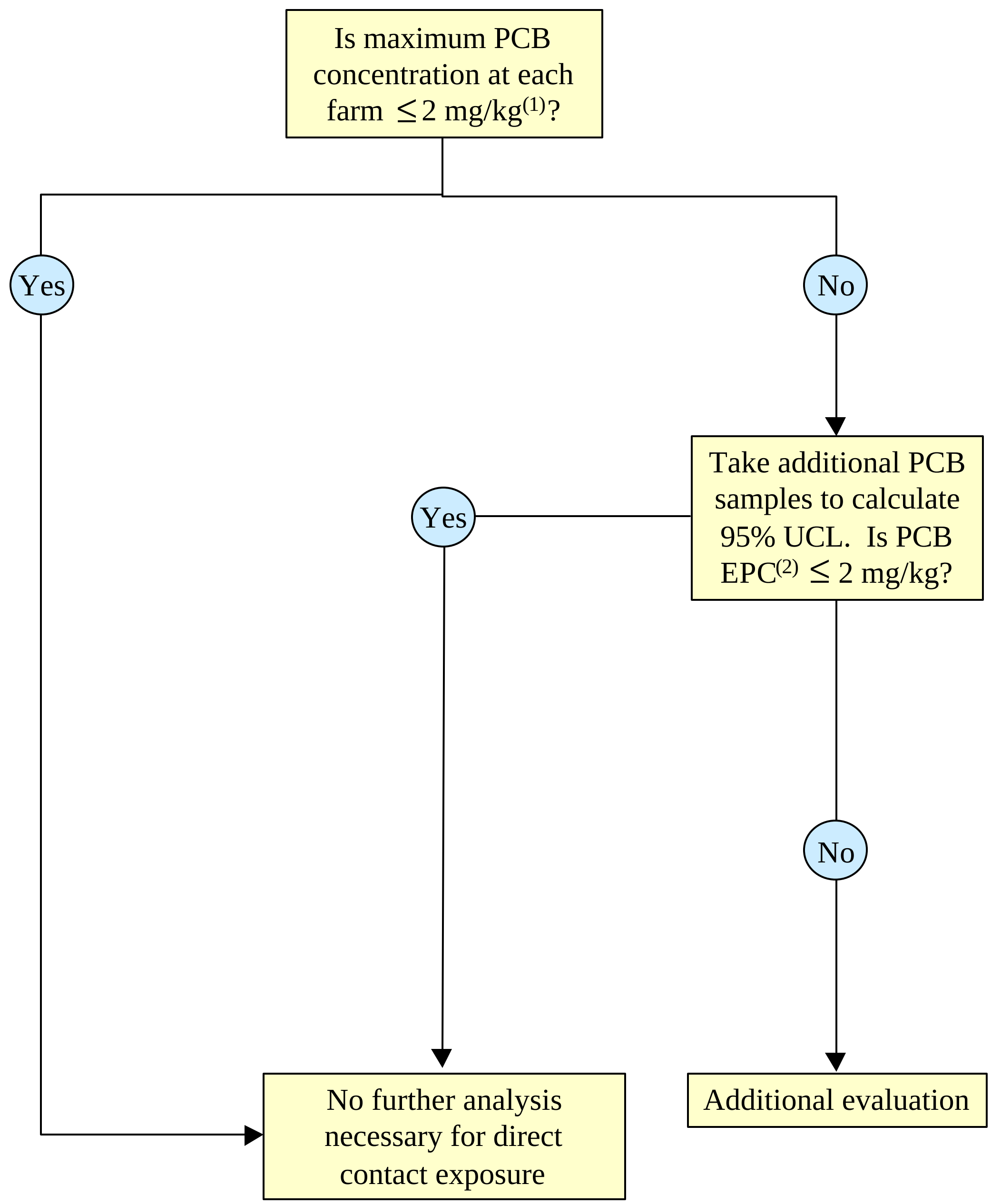
(1) Accessibility of riverbank soil and sediment will be determined to select low contact or high contact SRBC.

(2) SRBCs will be calculated for low and high contact exposure potentials.

(3) EPC = Exposure point concentration defined as the lower of either the 95% UCL of the mean or the maximum detected concentration.

Figure 6.2-2
Phase 1 Site Screening Approach
for Recreational Exposure
Lower Housatonic River

FLOODPLAIN SOIL
SRBC for Direct Soil Contact



(1) The 2 mg/kg value presented for residential floodplain soil in the Consent Decree will be used as the SRBC for agricultural floodplain soil.
(2) EPC = Exposure point concentration defined as the lower of either the 95% UCL of the mean or the maximum detected concentration.

Figure 6.2-3
Phase 1 Site Screening Approach for Agricultural Exposure Lower Housatonic River

Figure 6.2-4A
FLOODPLAIN AND RIVERBANK SOILS
(Utility Worker)
RBC for incidental ingestion
and dermal contact

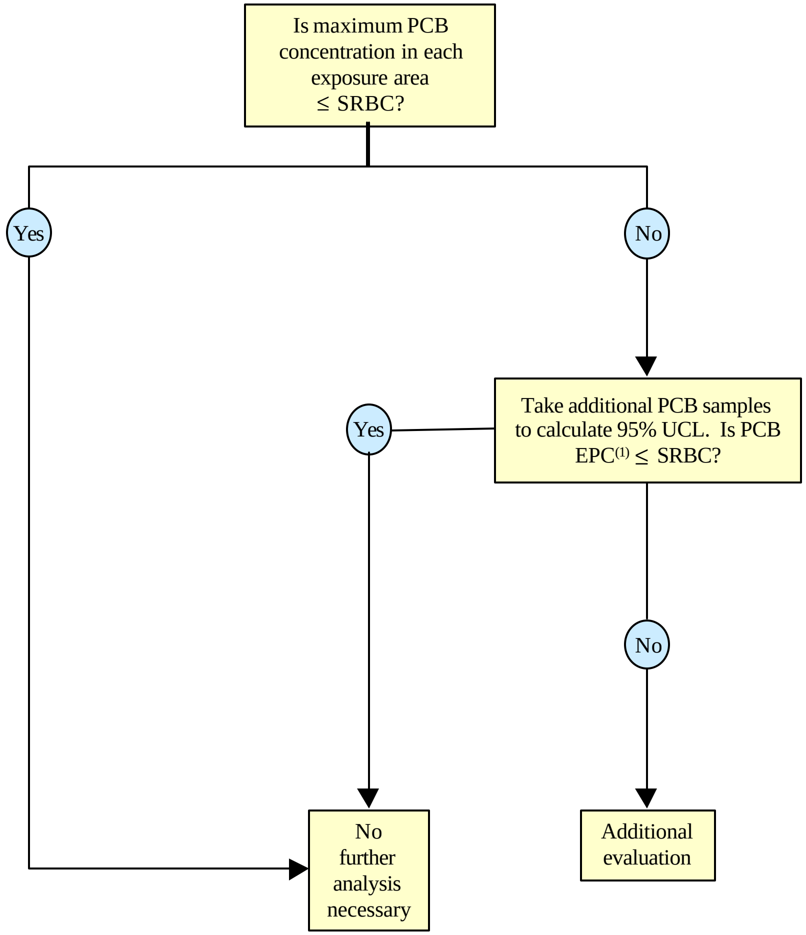
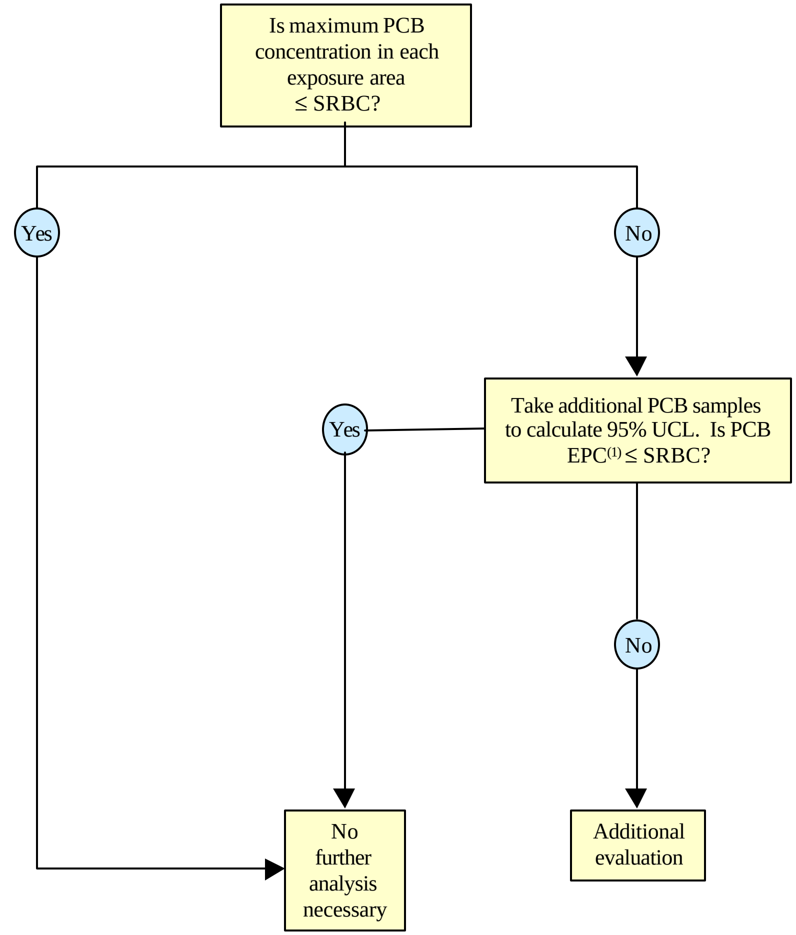
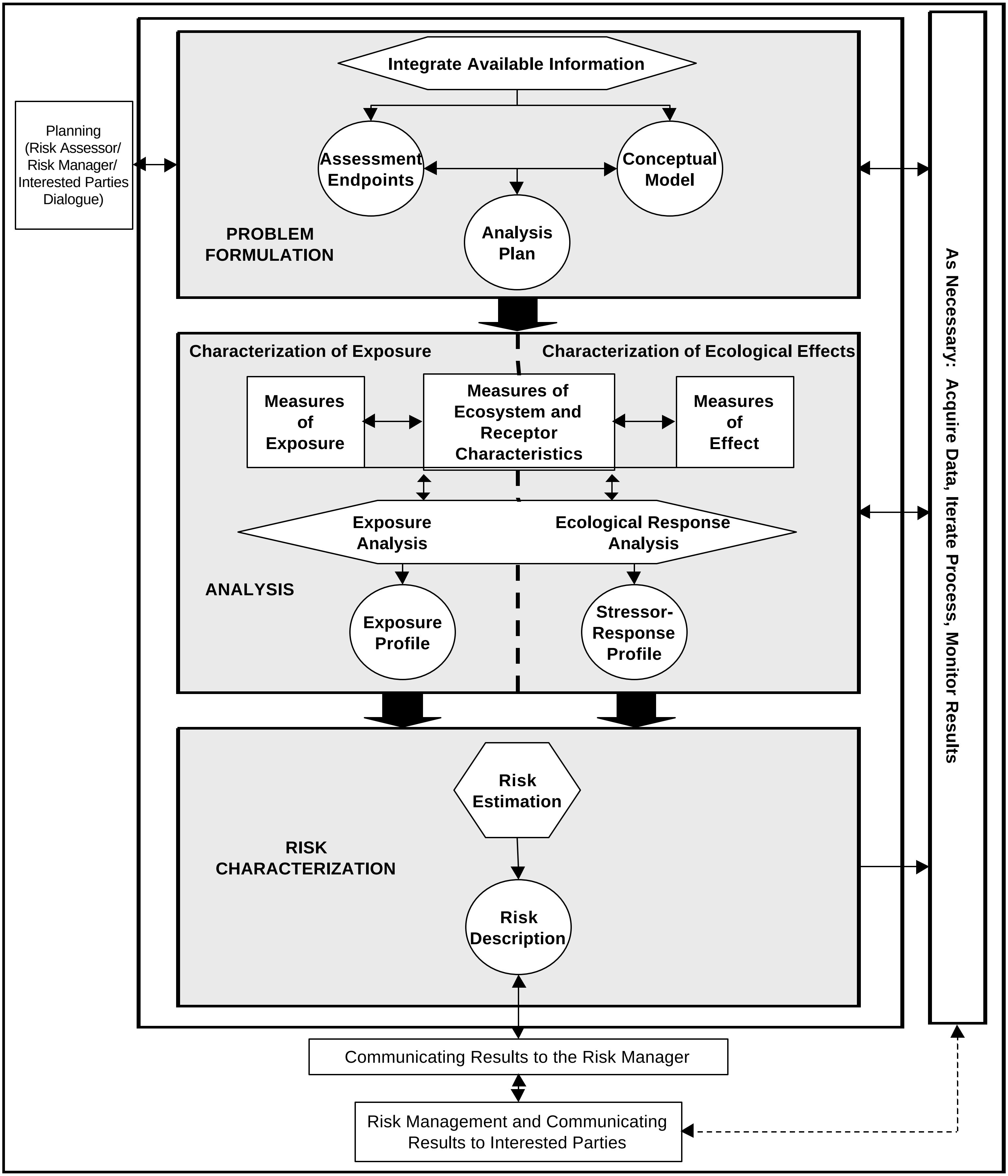


Figure 6.2-4B
FLOODPLAIN SOIL
(Groundskeeper)
RBC for incidental ingestion
and dermal contact



(1) EPC = Exposure point concentration defined as the lower of either the 95% UCL of the mean or the maximum detected concentration.

Figure 6.2-4
Phase 1 Site Screening Approach
for Commercial/Industrial Exposure
Lower Housatonic River



SOURCE: ADAPTED FROM U.S. EPA, 1998

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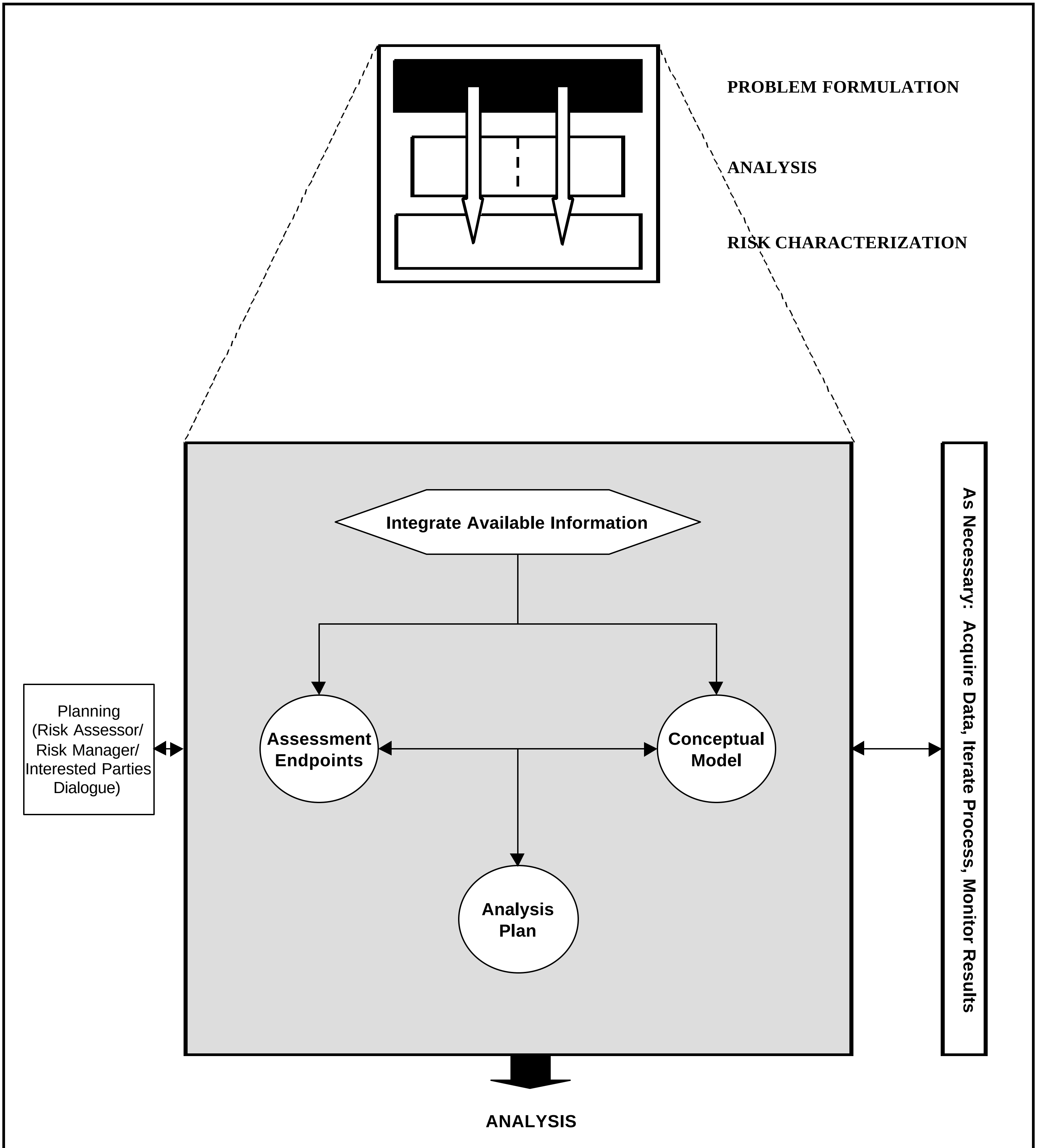
FIGURE 7-1
FRAMEWORK FOR ECOLOGICAL RISK ASSESSMENT



SOURCE: ADAPTED FROM U.S. EPA, 1998

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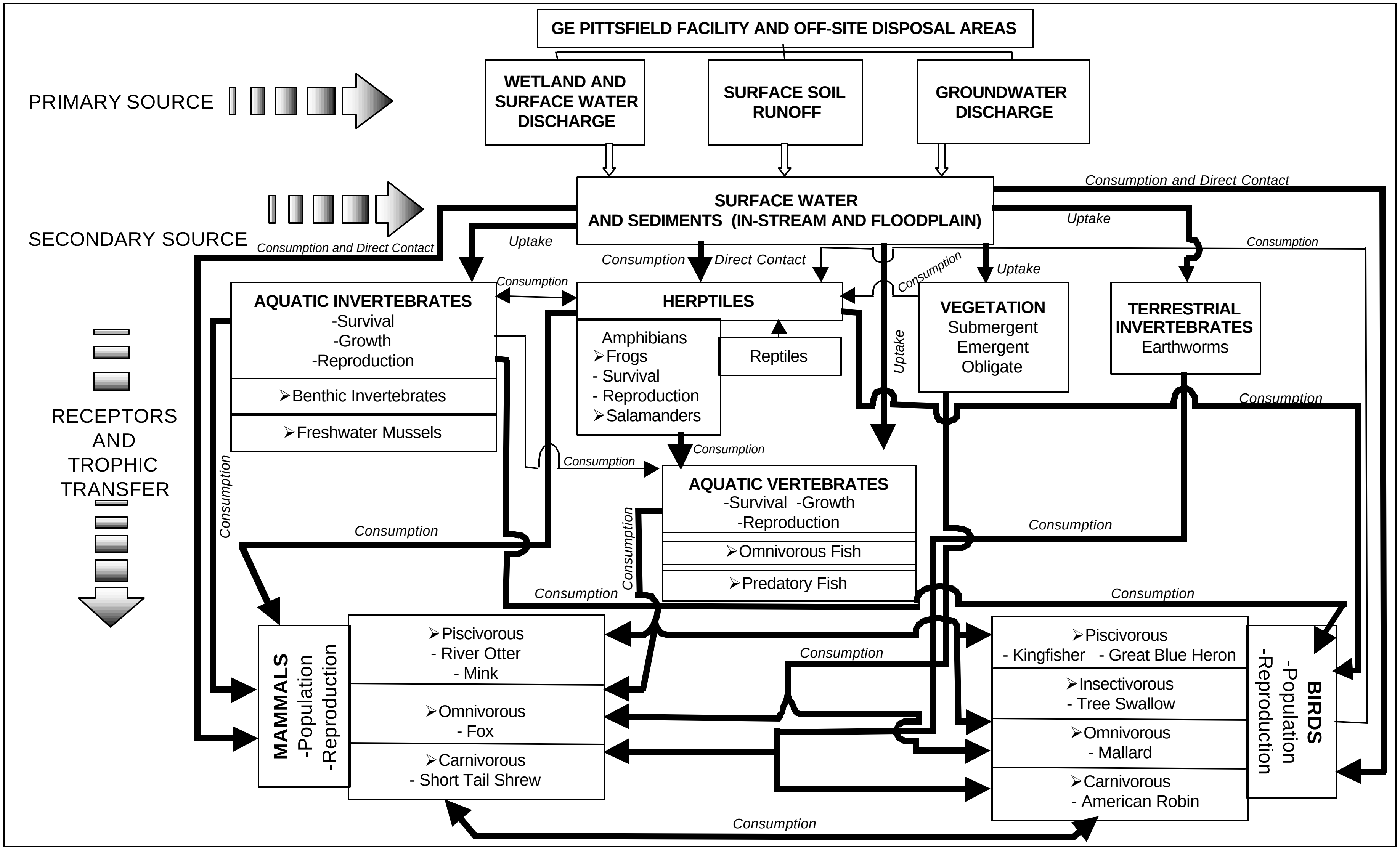
FIGURE 7-2
FRAMEWORK FOR PROBLEM FORMULATION
PHASE OF ECOLOGICAL RISK ASSESSMENT



LEGEND

Prime Areas of Consideration

➤ ➢Target Species

Pathway Evaluated

Pathway Not Evaluated

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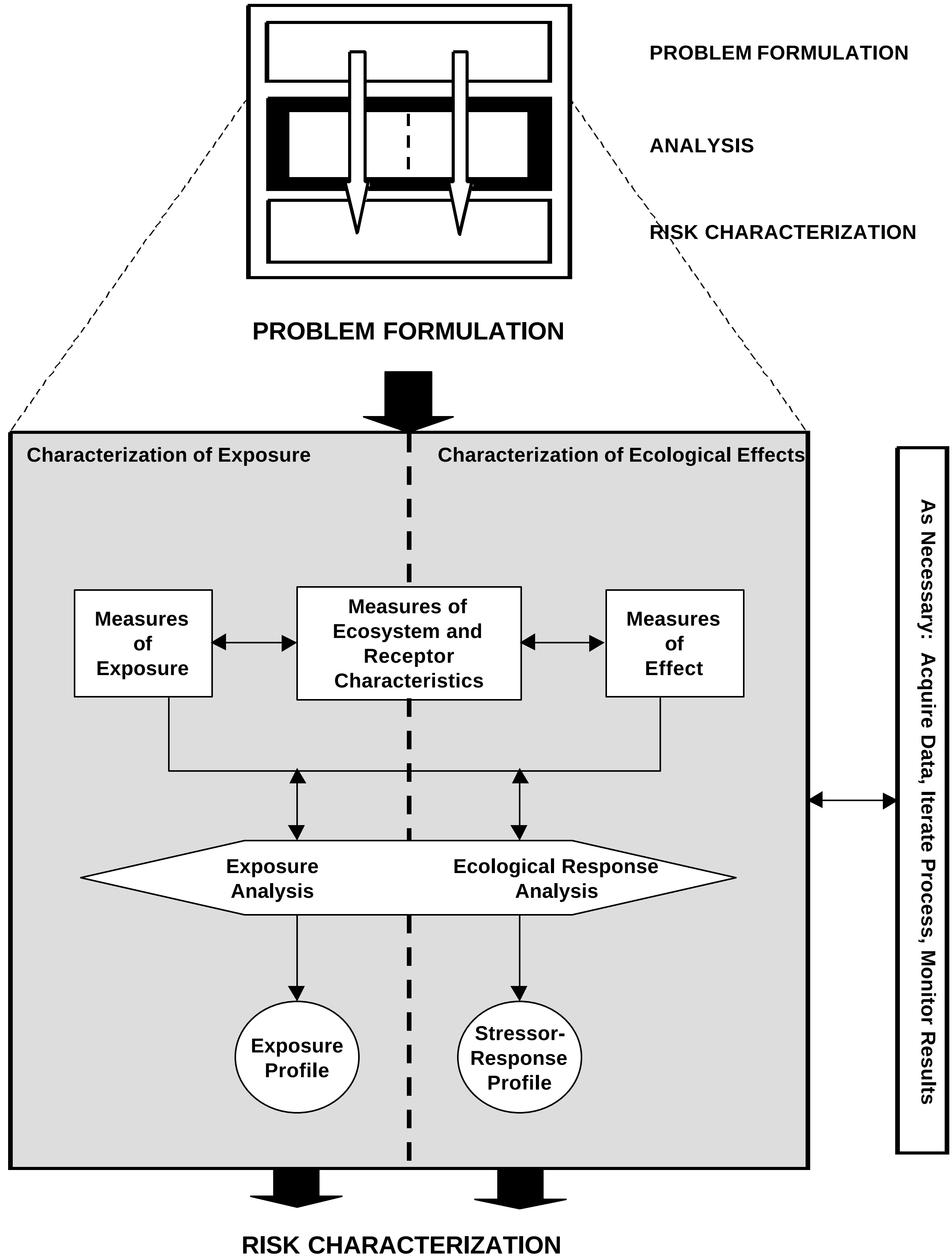
FIGURE 7-3
CONCEPTUAL DIAGRAM OF POTENTIAL TRANSPORT AND EXPOSURE PATHWAYS OF CONTAMINANTS OF CONCERN FROM THE SITE THROUGH AQUATIC AND TERRESTRIAL ECOSYSTEMS



SOURCE: ADAPTED FROM U.S. EPA, 1998

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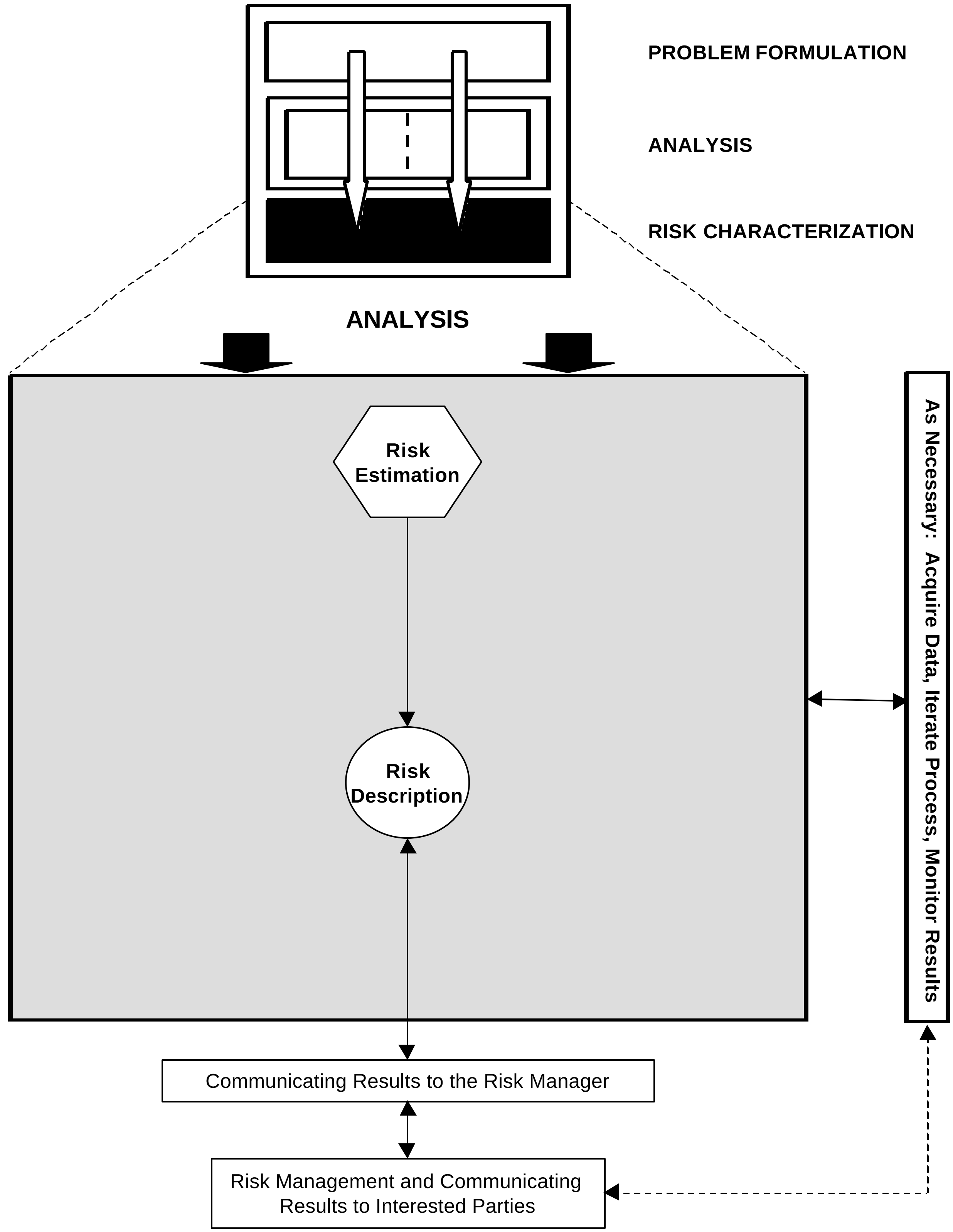
FIGURE 7-4
FRAMEWORK FOR ANALYSIS PHASE
PHASE OF ECOLOGICAL RISK ASSESSMENT



SOURCE: ADAPTED FROM U.S. EPA, 1998

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FIGURE 7-5
FRAMEWORK FOR RISK CHARACTERIZATION PHASE OF ECOLOGICAL RISK ASSESSMENT