U.S. Army Corps of Engineers

New England District
Concord, Massachusetts

U.S. Environmental Protection Agency

New England Region
Boston, Massachusetts

FINAL

MODELING FRAMEWORK DESIGN:

Modeling Study of PCB Contamination in the Housatonic River

DCN: GE-042104-ACDP

April 2004

Environmental Remediation Contract
GE/Housatonic River Project
Pittsfield, Massachusetts

Contract No. DACW33-00-D-0006

Task Order No. 0003

04P-0151-1

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ENVIRONMENTAL REMEDIATION CONTRACT
GENERAL ELECTRIC (GE)/HOUSATONIC RIVER PROJECT
PITTSFIELD, MASSACHUSETTS

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Prepared for

U.S. ARMY CORPS OF ENGINEERS
New England District
Concord, Massachusetts

and

U.S. ENVIRONMENTAL PROTECTION AGENCY
New England Region
Boston, Massachusetts

Prepared by

WESTON SOLUTIONS, INC.
West Chester, Pennsylvania

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LIST OF ACRONYMS

µg/g	microgram per gram
µg/g-ww	microgram per gram-wet weight
µg/L	microgram per liter
µm	micrometer (or micron)
ACO	Administrative Consent Order
ADCP	Acoustic Doppler Current Profiler
ARM	Agricultural Runoff Management
BAF	bioaccumulation factor
BD	bulk density
BMPs	best management practices
BOD	biochemical oxygen demand
BP	Before Present
BSAFs	biota-sediment accumulation factors
C-14	carbon-14
CAWQC	Chronic Ambient Water Quality Criterion
cfs	cubic feet per second
Cl/BP	chlorines per biphenyl
cm	centimeter
cm/s	centimeter per second
CMS	Corrective Measures Study
COCs	contaminants of concern
CP	capture probability
CR	resistance factor
CTDEP	Connecticut Department of Environmental Protection
CWA	Clean Water Act
DEHP	di-2-ethylhexyl phthalate
DEM	digital elevation model
DO	dissolved oxygen
DOC	dissolved organic carbon
DOJ	U.S. Department of Justice
DOM	dissolved organic matter
EDS	energy dispersive system
EE/CA	Engineering Evaluation/Cost Analysis
EFDC	Environmental Fluid Dynamics Code
EIA	"effective" imperviousness

LIST OF ACRONYMS
(Continued)

EOEA	Massachusetts Executive Office of Environmental Affairs
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
EqP	equilibrium partitioning theory
EqP-based	equilibrium partitioning-based
ERDC	Engineering Research and Development Center
FCM	Food Chain Model
FESWMS-2D	Finite Element Surface Water Modeling System
foc	fraction of organic carbon
fps	feet per second
Fr	Froude number
ft	feet
g/L	gram per liter
g/m^2	gram per square meter
g/m^3	gram per cubic meter
g/min	gram per minute
GE	General Electric Company
GIS	geographic information system
gpd/ft^2	gallons per day per square foot
GUI	Graphical User Interface
HEM3D	three-dimensional hydrodynamic-eutrophication model
HSA	hydrologic study area
HSCTM-2D	Hydrodynamics, Sediment and Contaminant Transport Model
HSPF	Hydrological Simulation Program-Fortran
HSWA	Hazardous and Solid Waste Amendments
IADN	Integrated Atmospheric Deposition Network
km	kilometer
L/kg	liter per kilogram
LA	load allocation
LDA	laser-Doppler anemometer
LR	linkage reach
m/m	meter per meter
m^3	cubic meter
MDEP	Massachusetts Department of Environmental Protection
MDPH	Massachusetts Department of Public Health

LIST OF ACRONYMS
(Continued)

MFD	Modeling Framework Design
mg/kg	milligram per kilogram
mg/L	milligram per liter
mi^2	square mile
mm	millimeter
MSE	mean squared error
msl	mean sea level
MT	metric ton
MT/yr	metric ton per year
NAWQA	National Ambient Water-Quality Assessment Program
NEA	Northeast Analytical Laboratories
NO_2	nitrite
NO_3	nitrate
NPL	National Priorities List
NPS	nonpoint source
NWS	National Weather Service
OC	organic carbon
Pa	pascal
PCA	principal components analysis
PCBs	polychlorinated biphenyls
PES	particle entrainment simulator
PET	potential evapotranspiration
POC	particulate organic carbon
POM	particulate organic matter
ppm	parts per million (mg/kg)
PSA	Primary Study Area
PSD	particle size distributions
QA	quality assurance
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
QEA	Quantitative Environmental Analysis
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RM	river mile
SEM	scanning electron microscope

LIST OF ACRONYMS
(Continued)

SNL	Sandia National Laboratories
SOP	Standard Operating Procedure
STORET	STORage and RETrieval
SWAT	Soil and Water Assessment Tool
TEF	toxic equivalency factor
TMDLs	total maximum daily loads
TOC	total organic carbon
tPCB	total PCB
TSCA	Toxic Substances Control Act
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VDCs	vertical definition cores
VSS	volatile suspended solids
WES	Waterways Experiment Station
WESTON	Weston Solutions, Inc.
WIFM-SAL	WES Implicit Flooding Model, constituent transport finite difference model
WMS	Watershed Model System
WQAM	Water Quality Assessment Methodology
WQC	water quality criteria
WWTP	Wastewater Treatment Plant
XRD	X-ray diffraction
yd^3	cubic yard
YOY	young of year

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EXECUTIVE SUMMARY

ES.1 PURPOSE AND OBJECTIVES OF THE MODELING FRAMEWORK DESIGN

Evaluation of the risks posed to human health and the environment from contaminated sediment often requires the application of coupled watershed/hydrodynamic/water quality models and contaminant fate and bioaccumulation models to address the full range of migration pathways of contaminants released to the environment. The use of an integrated modeling framework is needed to produce a scientifically defensible application of models to support regulatory decisionmaking.

The modeling study was developed to: (1) represent the full range of physical, chemical, and biological processes of concern for polychlorinated biphenyl (PCB) fate, transport, and bioaccumulation in the Housatonic River watershed; and (2) address each of the following site-specific study objectives:

- Quantify future spatial and temporal distribution of PCBs (both dissolved and particulate forms) within the water column and bed sediment.
- Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment.
- Quantify the historical and relevant contribution of various PCB sources to bioaccumulation in targeted species.
- Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of “clean” sediment (i.e., natural recovery).
- Estimate the time required for PCB concentrations in fish tissue to be reduced to concentrations that no longer pose either a human health or ecological risk based on various remediation and restoration scenarios, including allowing for natural recovery.
- 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.

ES.2 MODELING STUDY OVERVIEW

Historical releases of certain classes of organic and inorganic contaminants into waterbodies have left a legacy of aquatic sediment enriched with these contaminants. In some sediments these contaminants have accumulated to concentrations that may pose an unacceptable human health and ecological risk. Of particular concern is the historical release to waterbodies of compounds known as polychlorinated biphenyls (PCBs), given that they are toxic, persistent, and bioaccumulate in the food chain.

PCBs historically were released to the Housatonic River from the General Electric Company (GE) facility in Pittsfield, MA. Over a period of decades, these compounds have accumulated in the river's bed sediment and impoundments. High-flow events have transported PCB-laden sediment onto the adjacent floodplain. Data collected from 1980 to the present have documented the magnitude and extent of the PCB contamination of the sediment and floodplain soil adjacent to the Housatonic River downstream of the GE facility, into Connecticut. The extent of the PCB contamination falls within the 10-year floodplain of the Housatonic River.

In addition, PCBs in fish tissue have accumulated to concentrations that pose a risk to human health. A recent U.S. Geological Survey (USGS) report (Garabedian et al., 1998) notes that PCB concentrations in Housatonic River streambed sediment and fish tissue constitute some of the highest PCB concentrations of all of the National Water-Quality Assessment Program (NAWQA) study sites nationwide.

The State of Connecticut posted a fish consumption advisory for most of the Connecticut section of the river in 1977 as a result of the PCB contamination in the river sediments and fish tissue. In 1982, the Massachusetts Department of Public Health (MDPH) issued a consumption advisory for fish, frogs, and turtles for the Housatonic River. In addition, in 1999, MDPH issued a waterfowl consumption advisory from Pittsfield to Great Barrington due to PCB concentrations in wood ducks and mallards collected from the river by the U.S. Environmental Protection Agency (EPA) and Massachusetts Division of Fisheries and Wildlife.

The geographic focus of the modeling study is from the confluence to Woods Pond Dam because data indicate that this area contains the principal mass of PCBs (BBL and QEA, 2003).

ES.3 REGULATORY FRAMEWORK

In September 1998, after years of scientific investigations and regulatory actions, a comprehensive agreement was reached between GE and various governmental entities, including the U.S. Environmental Protection Agency (EPA), Massachusetts Department of Environmental Protection (MDEP), the U.S. Department of Justice (DOJ), the Connecticut Department of Environmental Protection (CTDEP), and the City of Pittsfield. The agreement provides for the investigation and cleanup of the Housatonic River and associated areas. The agreement has been documented in a Consent Decree between all parties that was entered in the U.S. District Court in October 2000.

Under the terms of the Consent Decree, EPA is conducting the following investigations:

- Human health risk assessment.
- Ecological risk assessment.
- Modeling study of hydrodynamics, sediment transport, and PCB fate and bioaccumulation in the Housatonic River below the confluence of the East and West Branches and the encompassing watershed.

The Consent Decree also includes specific language that requires the risk assessments and components of the modeling studies to be submitted for formal Peer Review to help guide the effort and ensure consistency with EPA policy and guidance. This report, the proposed Modeling Framework Design (MFD), is the first component of the modeling study that was submitted for Peer Review in April 2001.

ES.4 CONCEPTUAL MODEL OF THE HOUSATONIC RIVER

A conceptual model of the Primary Study Area (PSA) of the river was developed to summarize the significant physical, chemical, and biological processes that may affect the transport and fate of PCBs. The conceptual model combines an evaluation of the available data relevant to the study area with a determination of which processes are significant for inclusion in the modeling effort, which processes should be excluded, and which processes require further evaluation.

The Housatonic River in the PSA is a mature, highly meandering river system with four distinct hydraulic regimes that affect sediment and PCB transport and fate. PCBs have been detected across the entire study area out to the 10-year floodplain boundary, with the highest concentrations detected in river sediment, along the riverbanks, and in adjacent floodplains. Woods Pond Dam, which defines the downstream boundary of the PSA, is the first impoundment downstream from the GE facility. The dam has created a backwater effect, resulting in significant deposition of sediment and PCBs in the pond and backwater areas immediately upstream. Extensive sampling of a wide variety of biota indicates that most of the biological components of the system are also contaminated with PCBs.

Data collected since 1998 have indicated that the bulk of sediment transport, and presumably of PCBs through the system, occurs primarily as a result of storm events rather than base flow in the river. It appears that both suspended sediment loads and, to a lesser extent, bed load contribute to much of the sediment and PCB transport. The data further show that sequestering of PCBs is not occurring to any appreciable extent. Data from Woods Pond show that the highest PCB concentrations occur at or near the sediment surface. Evaluation of relative PCB concentrations in water and sediment indicates that partitioning is not in equilibrium over portions of the study area, possibly as a result of the occurrence of PCBs as a coating on quartz sand grains.

ES.5 MODELING FRAMEWORK

Modeling studies are based on four fundamental principles: (1) conservation of momentum, (2) conservation of mass and energy, (3) thermodynamics, and (4) ecological interactions and processes.

An environmental modeling framework for a contaminant such as PCBs is designed to represent the most important physical transport processes; pollutant loads; and physical, chemical, and biological processes representing the fate of the chemical of concern, while maintaining mass balance. This type of modeling study is designed to describe how releases of a chemical are transported and become distributed throughout the watershed in the river, sediment bed, floodplain, and aquatic animals and plants. The primary components of an environmental modeling framework are quantitative descriptions of: (1) inputs of the contaminant and other related constituents; (2) water motion from physical transport; and (3) kinetic transfers of the contaminant and other related constituents among the water column, sediment bed, floodplain, and biota.

To conduct a modeling study of the environmental impact of remedial scenarios in comparison to the baseline or “no action” alternative, the modeling framework must first be systematically tested (i.e., calibrated and validated) to ensure that the modeling framework is scientifically credible. During the model calibration process, values of some parameters and coefficients of the model, assigned from either site-specific data or the literature, are adjusted until the comparison of model results to data satisfies the established criteria. Model results are then validated by running the model over a longer duration using a second, independent set of data collected for a different time period. The “goodness of fit” of the model and data used for validation are evaluated using the criteria established for how well the model results agree with the data. Additional detail on model calibration and validation procedures and acceptance criteria are provided in the Modeling Study QAPP (WESTON, 2000).

In the calibration and validation of an environmental model, the fundamental test of any modeling study is to demonstrate that a “mass balance” has been achieved for each primary constituent being modeled. For this investigation, the primary constituents included in the assessment of mass balance are water, solids, and PCBs. The principle behind achieving a mass balance is to ensure that all inputs, outputs, and internal gains and losses have been properly accounted for by the descriptions of water motion and the kinetic pathways of solids and PCBs. Satisfaction of the mass balance principle requires an accurate representation of the relevant physical, chemical, biological, and geological processes within the model framework that will be used for this investigation.

The ability of any model to precisely answer questions and/or predict future conditions over a period of decades must be carefully considered. Consequently, in the final analysis, a “weight-of-evidence” approach will be taken, including all available information and tools in addition to the model output.

The modeling framework was specifically developed to address each objective of the Housatonic River PCB fate and transport modeling study described above and the requirements identified in the development of the conceptual model. A modeling framework is needed because no single model is capable of representing all the physical, chemical, and biological processes pertinent to this investigation over the wide range of spatial and temporal scales that exist at the site.

The basic modeling framework for this study proposes the use of the Hydrological Simulation Program-FORTRAN (HSPF) as the watershed component, Environmental Fluid Dynamics Code (EFDC) as the hydrodynamic and sediment transport component, and QEAFDCHN (Food Chain Model [FCM]) as the PCB fate and bioaccumulation component.

ES.6 HSPF–WATERSHED HYDROLOGY AND NON-POINT SOURCE LOADS MODEL COMPONENT

For the past 20 years, HSPF has been the state-of-the-art model available for developing watershed-based simulations of hydrology and water quality processes. HSPF has been widely accepted by experts in environmental modeling and has been used for hundreds of complex applications, including the development of a hydrologic model of the Housatonic River watershed for the State of Connecticut. HSPF has been selected by the EPA Office of Science and Technology as the watershed model component of the BASINS model framework.

The watershed model encompasses the largest spatial extent of the system in this modeling study. The physical domain of the watershed model includes 282 square miles of the drainage basin of the Housatonic River from the headwaters to Great Barrington, MA. The watershed model is designed to account for the hydrologic balance of the drainage basin between precipitation, infiltration, and streamflow runoff.

The principal use of HSPF is to establish certain external boundary conditions, primarily flow, for input to the hydrodynamic and sediment transport model (EFDC).

ES.7 EFDC–HYDRODYNAMICS AND SEDIMENT TRANSPORT MODEL COMPONENT

EFDC is a public domain model developed with funding from the Commonwealth of Virginia and EPA. EFDC is a three-dimensional, state-of-the-art computational physics model that incorporates submodels for hydrodynamics, sediment transport, contaminants, eutrophication, and water quality within a single source code. EFDC has been selected by the EPA Office of Science and Technology to provide the primary hydrodynamic, sediment transport, contaminant, and eutrophication model components for EPA.

The spatial area represented in the EFDC model includes the PSA of the Housatonic River extending 11 miles from the confluence of the East and West Branches of the river in Pittsfield to Woods Pond Dam. The physical domain includes the river channel, the sediment bed, the 10-year floodplain, Woods Pond, and the backwater areas of the Woods Pond impoundment.

The principal use of EFDC in the model framework is to provide exposure concentrations of total PCBs (tPCBs) and dissolved organic carbon and particulate organic carbon in the water column and the surficial (active layer) sediment bed as inputs to FCM. In the surficial bed, the simulated mass of tPCBs is normalized to the dry weight of solids, particulate organic carbon, and sediment bed surface area. The tPCB results provided by EFDC will also be used to provide concentrations of selected congeners for use by FCM based on site-specific relationships of tPCB concentrations and congeners. Because the spatial and time scales of the EFDC model are much more detailed than the coarse space and time scales used in FCM, the model results generated by EFDC will be integrated over a 24-hour time scale and summed over the multiple EFDC grid cells that correspond to each larger FCM reach.

ES.8 FCM–PCB FATE AND BIOACCUMULATION MODEL COMPONENT

The food chain model selected for application in the Housatonic River modeling study is QEAFDCHN Version 1.0 (FCM), a chemical bioaccumulation model that simulates the transfer of contaminants in aquatic food webs. Relevant previous applications include the calculation of PCB bioaccumulation in the Hudson River (QEA, 1999) and PCB bioaccumulation in the Lower Fox River and Green Bay (QEA, 2001).

FCM uses a bioenergetics-based approach to model uptake and elimination of PCBs in invertebrates and fish. The model represents several trophic levels including predatory fish, forage fish, bottom-feeding fish, and the invertebrates at the base of the food web that consume particulate material in the water column and sediment bed. Contaminant concentrations within biota are tracked and output in units of micrograms per gram wet weight (μg/g-ww). For the Housatonic River application, the model is being run using a daily time step.

FCM includes two submodels, an invertebrate uptake model and a fish uptake model. The invertebrate submodel is a steady-state model in which kinetic formulations are used to calculate the relationship between uptake and elimination processes. The fish uptake submodel also uses kinetic formulations to determine the rate of chemical uptake and elimination, but the total concentration of contaminant is solved using differential equations. The fish submodel also uses more complex equations to calculate food consumption due to bioenergetics and to calculate elimination processes within each species. Typically, invertebrate species are simulated using a single model compartment whereas fish species are simulated using an appropriate set of age classes.

1. INTRODUCTION

1.1 OVERVIEW

Historical releases of certain classes of organic and inorganic contaminants into waterbodies have left a legacy of aquatic sediment enriched with these contaminants. In some sediments, these contaminants have accumulated to concentrations that may pose unacceptable human health and ecological risks. Of particular concern is the historical release to waterbodies of compounds that are toxic, persistent, and bioaccumulate in the food chain, including polychlorinated biphenyls (PCBs).

PCBs historically were released to the Housatonic River (see Figure 1-1) from the General Electric Company (GE) facility in Pittsfield, MA. Over a period of decades, these compounds have accumulated in river sediment in Massachusetts and Connecticut. High-flow events have transported PCB-laden solids onto the adjacent floodplain. Data collected from 1982 to the present have documented the magnitude and extent of the PCB contamination of the sediment and floodplain soil adjacent to the Housatonic River downstream of the GE facility. The extent of the PCB contamination has been determined to fall within the 10-year floodplain of the Housatonic River (BBL and QEA, 2003).

In addition, PCBs in fish tissue have accumulated to concentrations that pose a risk to human health (EPA, 1998a; WESTON, 2003). A recent U.S. Geological Survey (USGS) report (Garabedian et al., 1998) noted that PCB concentrations in streambed sediment and fish tissue in the Housatonic River are some of the highest of all the National Water-Quality Assessment Program (NAWQA) study sites across the country. The State of Connecticut posted a fish consumption advisory for most of the Connecticut section of the river in 1977 as a result of the PCB contamination in the river sediments and fish tissue. In 1982, the Massachusetts Department of Public Health (MDPH) issued a consumption advisory for fish, frogs, and turtles for the Housatonic River. In addition, in 1999, MDPH issued a waterfowl consumption advisory from Pittsfield to Great Barrington due to PCB concentrations in wood ducks and mallards collected from the river by the U.S. Environmental Protection Agency (EPA) and Massachusetts Division of Fisheries and Wildlife.

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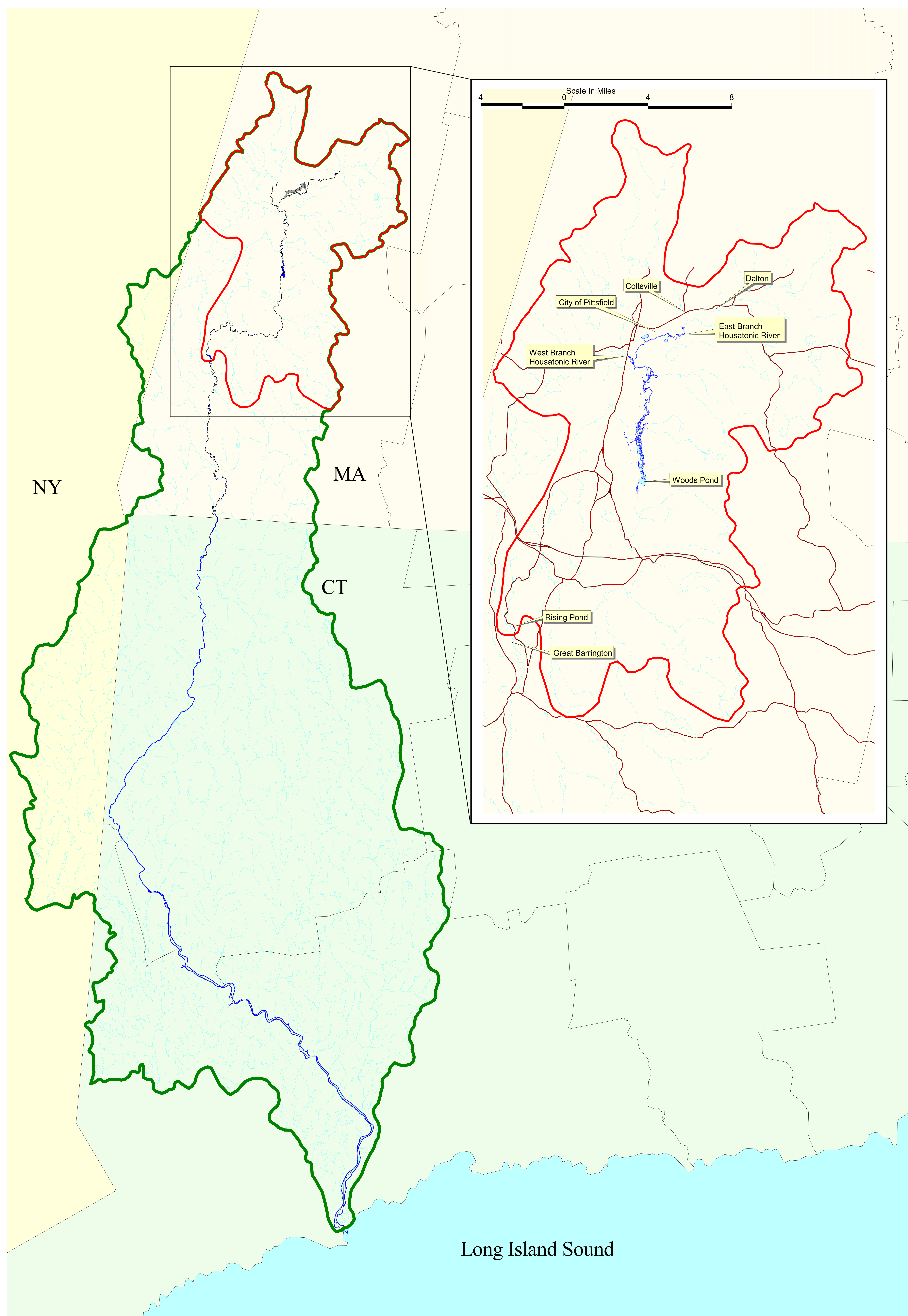
The Consent Decree also includes specific language that requires the risk assessments and components of the modeling studies to be submitted for formal Peer Review. This report, the proposed Modeling Framework Design (MFD), was the first component of the modeling study to be submitted for Peer Review. The Peer Review was conducted in April 2001, and EPA issued a Responsiveness Summary in June 2002. This final MFD reflects the input of the Peer Review panel.

1.2 PURPOSE AND OBJECTIVES OF THE HOUSATONIC RIVER MODELING STUDY

Evaluation of the risks posed to human health and the environment from contaminated sediment often requires the application of watershed/hydrodynamic/water quality models and contaminant fate and bioaccumulation models to address the full range of migration pathways of contaminants released to the environment, and potential exposures under future conditions. The use of a fully integrated modeling framework is needed to produce a scientifically defensible application of models to support regulatory decisionmaking.

The proposed modeling study design was developed to (1) represent the range of physical, chemical, and biological processes of concern for PCB fate, transport, and bioaccumulation in the Housatonic River watershed; and (2) address each of the following site-specific study objectives:



LEGEND:

- Surface Hydrology
- Housatonic Watershed Boundary
- Watershed Area Above Great Barrington

N

Scale in Miles

6 0 6 12

GE/Housatonic River Project
Pittsfield, Massachusetts

FIGURE 1-1
HOUSATONIC RIVER
WATERSHED

- Quantify future spatial and temporal distribution of PCBs (both dissolved and particulate forms) within the water column and bed sediment.
- Quantify the historical and relative contributions of various sources of PCBs on ambient water quality and bed sediment.
- Quantify the historical and relevant contribution of various PCB sources to bioaccumulation in targeted species.
- Estimate the time required for PCB-laden sediment to be effectively sequestered by the deposition of "clean" sediment (i.e., natural recovery).
- 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.
- 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.

1.3 BROADER MODELING STUDY OBJECTIVES

In addition to meeting the site-specific objectives, the modeling study was designed to achieve even more basic objectives inherent to the successful execution of any modeling effort. These broader objectives are discussed below.

1.3.1 Achieving Mass Balance

A fundamental test of any complex modeling study is to demonstrate that "mass balance" has been achieved for each of the primary constituents being modeled. For this investigation, the primary constituents being modeled are water, solids, and PCBs. The principle behind achieving a mass balance is to ensure that all inputs, outputs, and internal source/sink terms have been properly accounted for in the models, which requires an accurate representation of the relevant physical, chemical, biological, and geologic processes within the models.

1.3.1.1 Water Mass Balance

The modeling study must achieve an overall water mass balance that reproduces the historical distribution of observed flows within the Housatonic River. This is an important component of the analysis, given the role hydrodynamics play in the physical transport of solids and PCBs. To impose an appropriate external forcing function on the hydrodynamic model, a calibrated and validated hydrologic model must be developed. The hydrologic model accounts for tributary flows into the region covered by the hydrodynamic model as well as movement of water through the main river channel at the boundaries of the hydrodynamic model.

The hydrologic model establishes these external boundary conditions to the hydrodynamic model under both historical conditions and projected future conditions. The hydrodynamic model, in turn, uses the external boundary conditions to simulate the distribution of flows within the system and resulting internal forces acting on the sediment bed. To represent future conditions, an implicit assumption is made that historical conditions (e.g., spatial and temporal distribution of flow and solids) are representative of future conditions. A validated hydrologic model provides the technical basis for developing probability-based, future boundary conditions to the hydrodynamic model.

1.3.1.2 Solids Mass Balance

Because of the preferential adsorption of PCBs to solids, achieving mass balance of solids is important to the success of the model in accurately representing the conditions in the system. A change in the solids mass balance will ultimately affect the overall PCB mass balance. The purpose of the solids mass balance is to ensure that both short- and long-term transport of solids can be reproduced.

1.3.1.3 PCB Mass Balance

The PCB mass balance is the primary objective of this study. Numerous complex fate and transport processes influence the distribution of PCBs within the river and the floodplain. Definition of the PCB mass balance requires accurate source characterization and representation of the distribution of PCBs in the conceptual model for the site.

1.3.2 Ability to Provide an Estimation of Future Conditions

The primary objective that will be pursued after achieving acceptable mass balance in the models is to answer questions regarding the future spatial and temporal distribution of PCBs in the various media under baseline conditions and with different potential remedial scenarios.

The ability of any model to reasonably answer questions and/or predict future conditions that span a period of decades must be carefully considered. Consequently, in the final analysis a "weight-of-evidence" approach will be taken, including all available information and tools in addition to the model output.

1.3.3 Evaluation of Uncertainty

Any modeling study presumes that the fundamental questions to be answered with the assistance of models are known a priori. This is an appropriate assumption given that a scientifically valid modeling framework cannot be defined otherwise. Since the modeling framework provides the mathematical representation of the science underlying the study, it is necessary that the models applied within the framework are appropriate for the purpose of answering these questions. In other words, the models must incorporate algorithms that are credible representations of real-world processes.

Because natural systems inherently have complex, random, and nonlinear processes that cannot be accounted for in any model, any model formulation strives for a compromise between physical reality and practicality. This is particularly true of numerous physical, chemical, and biological processes occurring within this system. In many cases, no empirical or predictive methods exist that would allow a model to reproduce the consequences of these processes.

However, one cannot simply dismiss these processes as only introducing marginal or second-order error terms into the solids and PCB mass balance equations because no empirical relationships exist to predict their distribution and occurrence. Therefore, as stated above, model output will be augmented using a "weight-of-evidence" approach with other nondeterministic methods to reduce the degree of uncertainty associated with these processes. In addition, effort has been made to identify other areas of uncertainty such as changes in channel dimensions, entrainment of slumped bank sediment, partitioning behavior of PCBs, population fluctuations, and seasonal macrophyte die-back.