UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION II
JACOB K. JAVITS FEDERAL BUILDING
NEW YORK, NEW YORK 10278

JUN 18 1992

To All Interested Parties:

The U.S. Environmental Protection Agency (EPA) released a Review Copy of the Phase 2 Work Plan for the Hudson River PCBs site Reassessment RI/FS on June 5, 1992. The work plan describes the work that EPA is planning to conduct during this phase of the study. Within the review copy, there are several items that may be misleading or confusing to reviewers of the document and therefore, EPA has prepared this errata sheet.

Please note the following changes to the Review Copy of the Phase 2 Work Plan:

1. p. 2-1, last paragraph - EPA is not planning to do any groundwater or air monitoring during the Phase 2 work effort. Please delete the reference to such work.

2. p. 3-6, first full paragraph - EPA does not expect to conduct any total water column analysis using 1-liter samples by NYSDEC methods, as had been proposed in the Phase 2A Sampling Plan. Instead, the techniques to be used for suspended matter and dissolved phase PCB congener-specific analyses will provide EPA with total water column information.

3. p. 4-3, 4.2.2 - EPA does not intend to conduct groundwater sampling for congener-specific data at the Hudson Falls GE plant as part of the Phase 2 work effort.

4. p. 6-1, first paragraph - EPA does not intend to collect air monitoring data as part of the Phase 2 work effort.

5. p. 8-4, 8.4.2 - At this time, EPA does not intend to conduct any bench or laboratory scale treatability studies during the Reassessment process.

6. p. A-9, third bullet - As stated above, EPA does not plan to analyze a subset of water column samples by NYSDEC methods using 1-liter samples. This reference should be deleted.

7. p. A-18, Table A.1.1 - As stated above, EPA is not planning to conduct total water column analysis using 1-liter samples as analyzed by NYSDEC methods. The references to such sampling on this table should be deleted.

Please note these corrections while reviewing and commenting on the Phase 2 Work Plan. EPA still requests that all comments on the work plan be submitted by July 10, 1992.

If you have any questions specific to these revisions, please feel free to contact me at (212) 264-7508.

Sincerely yours,

Douglas J. Tomchuk

Douglas J. Tomchuk, Project Manager
Hudson River PCBs Site Reassessment

PHASE 2 WORK PLAN AND SAMPLING PLAN - REVIEW COPY

HUDSON RIVER PCB REASSESSMENT RI/FS

EPA WORK ASSIGNMENT NO. 013-2N84

JUNE 1992

Region II

ALTERNATIVE REMEDIAL CONTRACTING STRATEGY (ARCS)
FOR
HAZARDOUS WASTE REMEDIAL SERVICES

EPA Contract No. 68-S9-2001

TAMS Consultants, Inc.

and

Gradient Corporation

PHASE 2 WORK PLAN AND SAMPLING PLAN - REVIEW COPY

HUDSON RIVER PCB REASSESSMENT RI/FS

EPA WORK ASSIGNMENT NO. 013-2N84

JUNE 1992

Region II

ALTERNATIVE REMEDIAL CONTRACTING STRATEGY (ARCS)
FOR
HAZARDOUS WASTE REMEDIAL SERVICES

EPA Contract No. 68-S9-2001

TAMS Consultants, Inc.

and

Gradient Corporation

312079

PAGE INTENTIONALLY LEFT BLANK

PHASE 2 WORK PLAN

AND SAMPLING PLAN - REVIEW COPY

HUDSON RIVER PCB REASSESSMENT RI/FS

PHASE 2 WORK PLAN CONTENTS

REVIEW COPY
PHASE 2 WORK PLAN CONTENTS
(continued)

PHASE 2 WORK PLAN CONTENTS
(continued)

PHASE 2 WORK PLAN CONTENTS
(continued)

REVIEW COPY
PHASE 2 WORK PLAN CONTENTS
(continued)

Phase 2 Work Plan Figures and Tables

REVIEW COPY
Phase 2 Work Plan Figures and Tables
(continued)

APPENDIX
PHASE 2 SAMPLING PLAN CONTENTS

Sampling Plan Table, Plates and Figures

PHASE 2 WORK PLAN
HUDSON RIVER PCB REASSESSMENT RI/FS

1. INTRODUCTION

1.1 Background

This document describes the work to be performed in Phase 2 of the Hudson River PCB Reassessment Remedial Investigation/Feasibility Study (RI/FS). The Hudson River PCB Superfund site extends from Hudson Falls in Warren County, New York to the Battery in New York City. USEPA's previous Feasibility Study (FS), the 1984 No Action Record of Decision for contaminated river sediments and reasons for this Reassessment are described in the Introduction to the Phase 1 Report for this Reassessment. As was the case in the 1984 FS and ROD, the scope of potential remedial activities for this Reassessment is limited to the PCB-contaminated Hudson River sediments between Hudson Falls and Federal Dam at Troy.

In January 1991 USEPA issued a Phase 1 Work Plan describing the activities to be performed in that phase. In August 1991, USEPA issued a Phase 1 Report, entitled Interim Characterization and Evaluation, which described the results of Phase 1 studies. The findings presented in the Phase 1 Report are based on analysis of approximately 30,000 records of sediments, water, fish and other data, compiled from numerous sources. The purpose of the Phase 1 analysis was to:

- provide an interim evaluation, based on existing information concerning current levels of PCBs in various media of concern in the river, and changes in these levels;
- provide a preliminary or interim assessment of risks to human health and the environment posed by PCBs in the river; and
- provide the basis for assessing the needs for further sampling and analysis in Phase 2.

In September 1991, USEPA issued a Phase 2A Sampling Plan. The Phase 2A work began in December 1991 and is continuing. The complete Phase 2A effort is described in this document, as it is part of the Phase 2 work.

It is USEPA's continuing goal since this Reassessment commenced to solicit information and provide feedback to the public through a Community Interaction Program (CIP). CIP participants and committees have provided written and verbal comments on the Phase 1 Work Plan and Phase 1 Report, and the Science and Technical Committee discussed the Phase 2A Sampling Plan. These comments are appreciated; they were reviewed and considered and in several cases were instrumental in developing this Phase 2 Work Plan.

1.2 Objective and Scope

The overall objective of Phase 2 is to complete the site characterization for the Reassessment RI/FS. This will be accomplished by obtaining information relating to the nature and extent of the PCB contamination in the river sediments as described below in Section 2, identifying sources of PCBs to the sediments and other media also to the extent described later in this Work Plan, and developing an understanding of the fate and transport of PCBs in the river system. This information will be utilized to prepare the baseline human health risk assessment and the baseline ecological risk assessment. The results of Phase 2 activities will also be used in Phase 3 to define and evaluate remedial alternatives. The Phase 2 effort will culminate in a Phase 2 Report, similar in format to that of the Phase 1 Report.

This document contains two Phase 2 plans: the Phase 2 **Work Plan** and the Phase 2 **Sampling Plan**. The Phase 2 **Work Plan** follows this Introduction as Sections 2 through 8. It describes field investigations and scientific/engineering analyses that will be conducted during Phase 2. The Sampling Plan, contained in Appendix A, describes with more specificity than the Work Plan itself, sampling techniques, locations, and number of samples proposed for Phase 2 field investigations.

The Phase 2 Sampling Plan (Appendix A) distinguishes between field studies for Phase 2A and those for Phase 2B whereas the Work Plan does not distinguish between phases. The description of Phase 2A in Appendix A incorporates modifications to the Phase 2A Sampling Plan. The description of Phase 2B sampling includes field and laboratory studies that will commence following approval of this document and related documents, *e.g.*, Health and Safety Plan, Sampling and Analysis Plan and Quality Assurance Project Plan.

The Reassessment requires knowledge of the source areas of PCBs and the future impact of PCBs in the Hudson River system under conditions of No Action and various remedial alternatives. In the Phase 1 Report it was determined that human health risks from Hudson River PCBs are caused primarily by the consumption of contaminated fish. Therefore, two of the major questions that the Reassessment will address are: what is the reduction in PCB levels which is necessary to decrease fish tissue concentrations to levels that meet human health criteria and; the ancillary question of which source areas, if any, may require remediation in order to achieve that reduction. The effort in Phase 2 will focus on obtaining the information necessary to answer these questions among others. EPA will utilize this information in Phase 3 to select the most appropriate remedial alternative based upon this information, in light of the requirements of CERCLA and the National Contingency Plan (NCP).

PAGE INTENTIONALLY LEFT BLANK

2. OVERVIEW OF DATA COLLECTION PROGRAM FOR PHASE 2

This section presents an overview of Phase 2 data collection tasks and a summary of these activities by geographic study areas. This section is intended for those readers interested in an overview of proposed Phase 2 efforts. Additional discussion of these tasks occurs in Section 3 and in Appendix A.

The Hudson River PCB Superfund site extends from Hudson Falls, NY at River Mile (RM) 197 to the Battery at RM 0. Because of the site's size, three study areas have been defined, as well as one additional study area immediately north of the site. The four study areas, shown in Figures 2.1 and 2.2, are:

- <u>Study Area A</u> - The Hudson River above Fenimore Bridge in Hudson Falls, NY (RM 197) to upstream (RM 209) of Glens Falls, NY;
- <u>Study Area B</u> - The Hudson River from Fenimore Bridge in Hudson Falls, NY to the Federal Dam at Troy (RM 153);
- <u>Study Area C</u> - The northern, freshwater portion of the tidal Hudson River, extending from the Federal Dam (RM 153) to RM 55, the average northernmost extent of salt water; and
- <u>Study Area D</u> - The brackish portion of the tidal Hudson River, extending from the average northernmost extent of salt water (RM 55) to the Battery (RM 0).

The Phase 2 data collection program includes many specialized tasks involving PCB-congener analyses, geophysical surveys, water and sediment sampling, groundwater and air sampling and ecological studies. Four main data tasks comprise most of the Phase 2 data collection activities. These tasks are briefly described first in Section 2.1. Section 2.2 presents the specific data collection tasks proposed for each study area.

2.1 Summary of the Four Main Data Collection Tasks

2.1.1 Congener-Specific Analysis of PCBs

Analyses of PCBs have been reported historically on an Aroclor basis (Aroclors are commercial mixtures of PCBs.) This analytical approach has become questionable, because Aroclor mixtures released to the environment do not remain there unaltered. To estimate the effects of processes that alter Aroclor mixtures, *i.e.*, absorption, volatilization, oxidation and biodegradation, it will be necessary to perform congener-specific PCB analyses for all media sampled in Phase 2. The term congener refers to the 209 individual compounds classified as PCBs. Congener-specific analysis can be used to differentiate newly released Aroclor mixtures from older, altered mixtures. It is expected that a maximum of 70 to 80 congeners will be classified in this study, because of calibration standard limitations.

2.1.2 Water-Column Sampling

Water-column sampling, to be performed in Study Areas A and B, entails collection of samples to identify sources of PCB loads in the water column. One sampling approach will involve the collection of water-column samples at 10 locations in Study Areas A and B. The other sampling approach will involve the collection of flow-averaged water-column sample composites. Flow-averaged samples will be collected at a limited number of stations in the Upper Hudson to examine the mean PCB loading generated across several important reaches of the river. All samples will be separated into suspended matter and dissolved phase fractions for analysis. Other pertinent parameters will be measured as well. Samples will also be collected to study PCB suspended matter-dissolved phase equilibrium. Archival extracts of water-column samples taken during the period 1977 to 1986 from the Lamont-Doherty Geological Observatory and Renssalaer Polytechnic Institute will be reanalyzed to examine historic water-column PCB levels on the same basis as the current samples.

2.1.3 High and Low Resolution Sediment Coring

High resolution sediment coring involves the collection of sediment cores from depositional zones in all four study areas. These cores are divided into thin layers for subsequent PCB congener-specific, radionuclide and other analyses. Because sediments are first transported by the water-column as suspended matter, analyses of the radionuclide-dated sediments at depositional locations can be used to examine historic, water-column PCB transport on suspended matter. By using data from water-column monitoring and from the literature, the total water column loading can be examined over time as well. The sediments also record the congener mixture on the suspended matter. These data can be used to examine and fingerprint current and historic PCB sources to the river and their relative importance. Reanalysis of archived high resolution sediment core extracts will be compared with current sediment samples to examine *in situ* degradation.

Low resolution sediment coring involves the collection of sediment cores in order to determine PCB concentrations in sediment. These cores will be divided into thick sections for subsequent PCB congener-specific analysis, radionuclide dating, and other analyses. Low resolution sediment coring will be used to examine a limited number of previously defined hot spots in the Upper Hudson as well as to classify various sedimentological zones defined on the basis of the geophysical surveys. The samples will assist in defining the depth of PCB-bearing sediments in Study Area B.

2.1.4 Geophysical Surveying and Confirmatory Sampling

Geophysical surveys will be made of the river bottom in portions of the Upper Hudson (Study Area B). These surveys will be made using sonar techniques to map river bathymetry, sediment morphology, sediment texture, and fine grained sediment thicknesses. The sonar results will be calibrated or confirmed by sediment sampling in the survey areas. Based on the survey results maps of river depth and sediment characteristics will be created. These maps will be used in the selection of low resolution coring sites, the estimation of sediment PCB inventories, the scourability assessment and the Feasibility Study.

2.2 Data Collection Program By Study Area

2.2.1 Study Area A: Fenimore Bridge to Upstream (RM 209) of Glens Falls

Study Area A is defined as the reach of the Hudson River from RM 209 (Sherman Island Dam) downstream to Fenimore Bridge at Hudson Falls, NY (see Figure 2.1). The purpose of delineating a study area above Fenimore Bridge is to identify baseline contaminant inputs to downstream Study Area B. As indicated in the Phase 1 Report, some release of PCBs may have occurred above Fenimore Bridge; therefore, it cannot be assumed that river water flowing from Study Area A is free of contaminants.

The sampling program for Study Area A has been designed to determine current PCB loads entering Study Area B from Study Area A by sampling the water column upstream of Fenimore Bridge and analyzing the samples for PCBs on a congener-specific basis. Both the water-column transects and the flow-averaged water sampling will be performed. Historic water column loads of PCBs from Study Area A to Study Area B will be estimated using data obtained from high resolution sediment core samples also taken within this study area. Figures 2.3 and 2.4 show the water column monitoring and high resolution sediment coring locations, respectively.

In addition to examining the total water column load, the congener composition of PCB load in Study Area A will be determined. These data will be compared with downstream congener mixtures to evaluate the importance of PCB sources from Study Area A in downriver areas. Suspended matter/dissolved phase partitioning data obtained from the water column sampling effort will be used in the interpretation of the high resolution sediment core samples. The literature investigation will continue in Phase 2 to provide additional data on known historic and current PCB sources, discharges and levels in Study Area A. These data will aid in the interpretation of the Study Area A sample data with the goal of estimating current and future sources of PCBs from Study Area A to Study Area B.

2.2.2 Study Area B: Federal Dam to Fenimore Bridge

Study Area B is defined as the 40 miles of the Upper Hudson beginning at Fenimore Bridge and terminating at the Federal Dam in Troy. There are two major Hudson tributaries in this reach, the Mohawk and the Hoosic. Although these tributaries are not considered part of the Hudson River site, they may be sources of contaminants to the Hudson River.

The principal objective of additional data collection in Study Area B is to assess the current sources and loads to the area and to evaluate their impact within the area as well as on the Lower Hudson (Study Areas C and D). This investigation considers sources and loads under current conditions, as well as those potentially produced during high flow events. A significant finding from Phase 1 is that a large portion of the water column PCB load in Study Area B appears to enter the river upstream of Rogers Island. Therefore, the data collection program will focus on parts of the river upstream of Rogers Island, as well as zones of known contamination, such as the Thompson Island Pool.

2.2.2.1 Main Data Collection Tasks

The investigation of Study Area B will include all tasks described in Section 2.1. The water-column sampling efforts will be conducted to examine conditions under high flow and low flow conditions. (Stations for Study Area B are shown in Figure 2.3.) The results of the water-column sampling combined with the flow monitoring data obtained by the US Geological Survey (USGS) will permit the calculation of PCB water column loads for Study Area B. Estimation of PCB loads passing each sampling location will be used to identify the river segments contributing most significantly to those loads. Thus, the water-column studies will provide an independent confirmation of the relative contribution of the Upper Hudson's sediments to water-column PCB loads. Congener-specific data will provide assistance in determining potential contaminant sources, since these data will be compared to the congener profile of potential sources. For example, it can be expected that, in Study Area B, only sediment-related sources will have experienced *in situ* degradation and, therefore, these sources will yield a water column congener mixture dominated by less chlorinated PCB congeners.

The water-column studies will also address questions related to temporal variability in PCB loads and factors that influence PCB transport. Both river flows and PCB loads exhibit strong seasonal variability. It has been postulated that PCB transport dominantly occurs during the spring high flow season when the river's suspended load is high. As flow rates decrease from spring into summer, both suspended matter and total PCB load diminish. Data obtained from analysis of suspended and dissolved sample fractions are expected to permit the examination of temporal variability in water-column PCB load. These data will consequently provide additional insight into the source of water-borne PCBs and the mechanisms influencing contaminant transport. It is important to note that under nearly all current conditions found in the Hudson, the water column concentrations of PCBs are not limited by the solubility of the congeners but rather by PCB input and loss rates and by adsorption onto suspended sediments.

High resolution sediment cores will be obtained at a number of Study Area B depositional locations using hand coring techniques (see Figure 2.4). Sediment chronology at each coring location will be established using radio-nuclide dating techniques, as described in Section 3.

Because sediment deposited at a specific location is assumed to reflect the composition of suspended matter transported past that point, interpretation of data from the high resolution cores permits identification of different contaminant sources in current sediment PCB mixtures. Thus, the high resolution program will lend support to results of the water-column studies previously described.

In addition to enabling a determination of current, water-column PCB congener concentrations and contributing sources, the high resolution coring program will facilitate evaluation of historic PCB levels, loads and sources. These data will be compared to the historic Upper Hudson River, water-column database to obtain a refined estimate of historic, suspended phase PCB loads passing the coring locations. Using PCB partition data from the Phase 2 data collection program and the literature, an estimate will also be made of historic total water-column PCB load. Because *in situ* PCB degradation may have affected high resolution samples, particular care will be exercised in comparing the data.

A number of archived sediment cores and sediment core extracts collected by previous investigators will be reanalyzed and compared to data from high resolution samples taken during this Phase 2 investigation from the same locations. Figure 2.5 shows the sampling locations of existing and archived high resolution cores. Archived and Phase 2 sediment sample pairs will be used to determine *in situ* degradation rates for PCBs by comparing sediment layers from the same time horizon in the paired samples. For example, the layer corresponding to 1963 from the archived core will be compared with the 1963 layer from the Phase 2 core. The change in congener composition and concentration divided by the time between core collection events is expected to yield an estimate of the degradation rate.

Geophysical measurements, along with confirmatory sampling, will provide information on river sediment textures, sediment thickness, and river topography, so that a plan view of river bottom conditions can be generated. Plate A.1 shows the proposed geophysical survey areas. When coupled with other sediment sampling, the geophysical program will provide sufficient data to estimate sediment distribution patterns throughout the most contaminated reaches of Study Area B.

Taken together, the sediment's physical and contamination distribution patterns derived from geophysical measurements and the sampling programs detailed in this plan constitute much of the basic information needed in Phase 2. These data are needed to assess potential PCB sediment sources to the water column, sediment mobility during storm events, operational difficulties likely to be associated with sediment removal, and requirements for establishing a long-term monitoring program.

Low resolution sediment coring will be used to examine PCB contamination in a limited number of locations and will allow updating of estimates of the spatial distribution of PCBs to be developed by kriging techniques (see Section 2.2.2.2). The low resolution coring program will not be performed on the scale of NYSDEC'S 1984 effort, but will, instead, be directed at maximizing the information that can be extracted from the geophysical surveys, the high resolution coring study and the kriging analysis. Figure 2.6 shows the anticipated locations for low resolution coring.

Some river reaches within Study Area B will be examined intensively in order to compare historic and current contaminant levels. Both PCB concentrations and congener distributions will be examined to determine changes in the sediment inventory over time. In other instances, samples will also be located so as to examine PCB levels in zones displaying particular geophysical patterns as determined from the geophysical investigation. In this manner, it may be possible to characterize sediment PCB levels extensively without having to sample intensively. Low resolution coring may also be applied to the Bakers Falls Pool and the submerged Remnant Deposit 1, because these locations may represent sources of PCBs to the water-column.

The ultimate use of the low resolution data will be to generate estimates of PCB sediment mass for major zones of contamination. This information will be used in conjunction with kriging results (see Section 2.2.2.2 below), the scourability assessment (Section 5), and other site data to designate PCB contaminated areas potentially subject to scour. Data collected and made available by GE will be included in the evaluation. If appropriate, the GE data will also be used to estimate which PCB-contaminated sediments represent likely sources of water-column PCBs under average flow conditions.

2.2.2.2 Kriging of Sediment Data from Thompson Island Pool

In addition to the main data collection tasks described above, sediment contaminant distribution and mass will be evaluated using geostatistical techniques. The 1984 NYSDEC database for the Thompson Island Pool provides the only basis for a relatively comprehensive assessment of PCB mass distribution in Study Area B at a particular point in time. Kriging methods, which attempt to find the minimum variance (most accurate), unbiased estimate of spatially correlated data, will be applied to the 1984 data set with the refinements noted here.

Although previous attempts to apply geostatistical analysis to the analytical data obtained in the 1984 sediment survey have met with only limited success,[1] available data appear not to have been utilized fully. Most samples collected in 1984 were first screened by a mass spectrometer; typically, those testing high for PCBs were sent for laboratory gas chromatographic (GC) analysis. Thus, the laboratory analyses represent only a fraction of the total data collected. The Phase 2 analysis will use the screening data as well as the GC results in the geostatistical analysis. Prior to submission of this Phase 2 Work Plan, a theoretical approach was developed by TAMS/Gradient to incorporate both data sets in the analysis. Preliminary tests of the method on PCB data for the southern part of the Thompson Island Pool revealed that the method has substantial potential to improve the accuracy of estimation. Also, a shift in the analysis coordinate system from northing-easting coordinates to a grid aligned with the direction of river flow is expected to improve further the spatial correlation analysis.

Interpretation of estimates of sediment PCB contamination derived from kriging will depend upon how successfully the low resolution cores reproduce the results of the 1984 sediment levels. To the extent that the levels agree, the estimates derived from kriging will be assumed to be good estimates of

[1]Brown, M.P., M.B. Werner, C.R. Carnsone and M. Klein. 1988. "Distribution and PCBs in the Thompson Island Pool and the Hudson River: Final Report of the Hudson River PCB Reclamation Demonstration Project Sediment Survey." Division of Water, NYSDEC, Albany, NY.

current conditions in locations where low resolution coring is not performed. To the extent that they do not, then the estimates will not provide a direct indication of current sediment levels and additional low resolution coring may be required.

2.2.2.3 Other Data Collection Tasks

Two other data collection tasks are planned for Study Area B: sampling to assess scourability for contaminant transport modeling (Section 5) and sampling related to the ecological risk assessment (Section 7). These tasks are described in the referenced sections of this Work Plan and in the Phase 2 Sampling Plan (Appendix A).

2.2.3 Study Area C: RM 55 to Federal Dam

Study Area C represents the northern, freshwater portion of the Hudson River estuary. The downstream boundary at River Mile 55 was selected, because it is considered to be the average upstream limit of the salt front.

The main objective of the Phase 2 investigation in Study Area C is to evaluate the relative importance of loading from Study Area B to the overall PCB load in Study Area C. An estimate of Upper Hudson PCB loading to the estuary was provided in the Phase 1 Report. Additional data as previously discussed will be generated during Phase 2 to update that estimate. Available historic data poorly accounts for the contribution of the Mohawk River to overall PCB releases to the estuary; during Phase 2, both water-column samples and a high resolution core will be obtained within the Mohawk. Data obtained from these samples will be used to estimate current and historic PCB loads contributed by the Mohawk to the Upper Hudson and, in turn, to the estuary.

High resolution coring is the only sampling task scheduled for Study Area C. High resolution cores to be obtained at several locations within Study Area C will be analyzed for congener-specific PCBs and a range of other parameters, which are necessary to evaluate adequately contaminant fate and transport. Figure 2.7 shows the high resolution coring locations for Study Area C. As in Study Areas A and B, the high resolution cores will be used to estimate historic PCB loads passing a particular sampling location. An assessment of possible sources of the sediment-borne PCBs will be derived from the congener-specific profiles of cores collected throughout the length of Study Area C. Since these cores will be radiometrically dated, a comparison of congener profiles in sediments is expected to provide insight as to whether one upriver source is responsible for the contaminant load or whether multiple sources have contributed to the load.

Archived sediment core sections are also available for historic coring locations in Area C (see Figure 2.8). These samples will be paired with their Phase 2 equivalents to assess *in situ* degradation in Study Area C.

In addition to Phase 2 sampling, an intensive review of PCB discharge records will be conducted to determine the likelihood of other significant releases to Study Area C. Data research will include discharge permit files (SPDES permits), NYSDEC and NYSDOH records of uncontrolled PCB releases, landfill leachate records, STORET system water quality data base (for tributary-related contamination), and other information which may be available in local agency files. Once an estimate has been made of the relative importance of current Study Area B-derived loads on the total Study Area C PCB burden, it will be possible to assess the relative impact of remedial alternatives for Study Area B on Study Area C.

2.2.4 Study Area D: Battery to RM 55

The Hudson River reach covered by Study Area D is the southern part of the estuary. It is defined as a separate study area, because its brackish water distinguishes it from the typically freshwater part of the estuary. Separating study areas of the estuary at River Mile 55 is also considered appropriate, because: 1) contaminant discharges from industries in the New York City Metropolitan Area are not expected to migrate upstream of the salt front;

and 2) the ecosystem and sediment geochemical characteristics upstream of the salt front are different from those below the salt front.

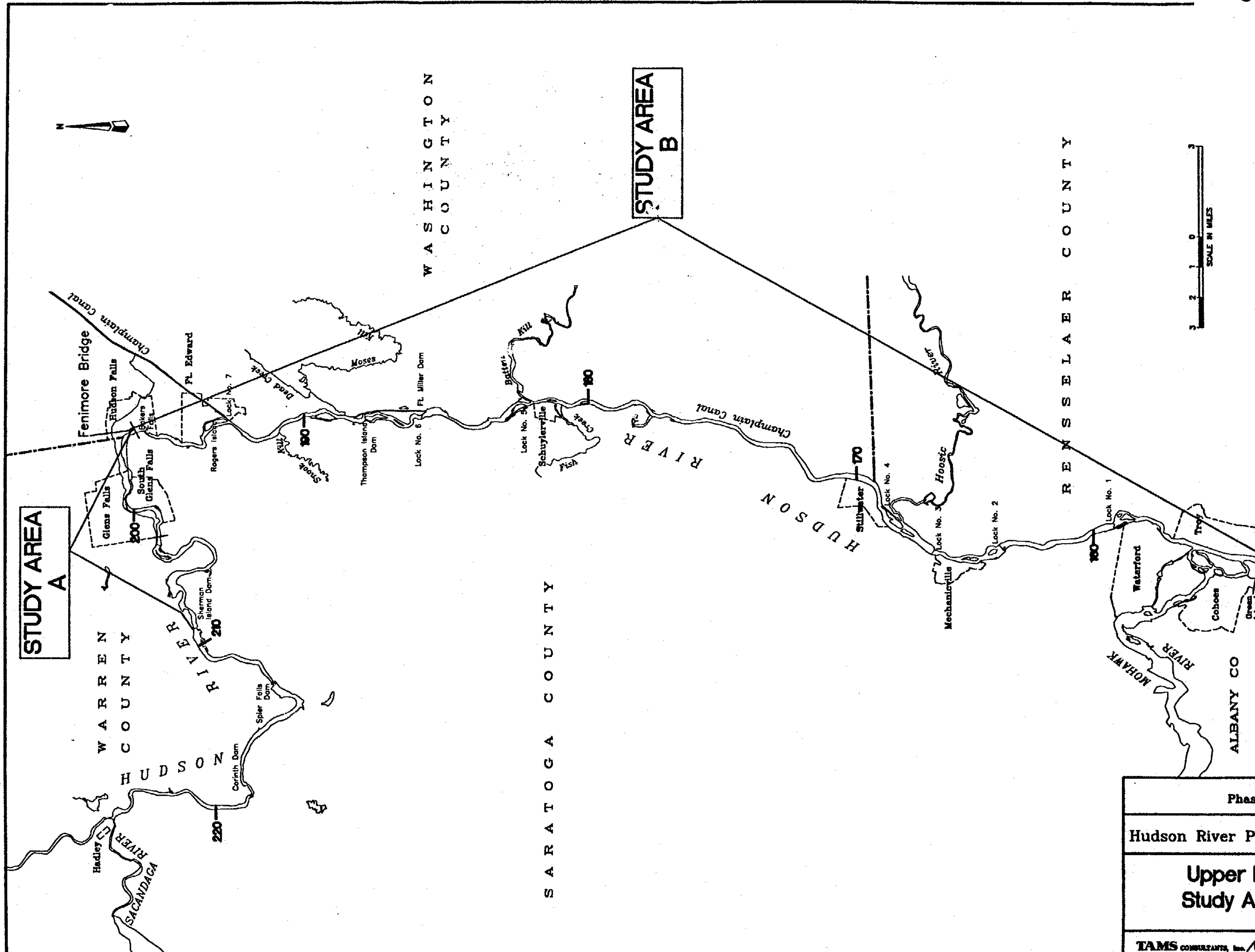
The focus of investigations in Study Area D will be to establish the significance of current PCB releases from the Upper Hudson (Study Area B) to the total contaminant burden found within Study Area D by determining the relative importance of various PCB inputs from the sediment records and other available release data to the estuary. Once an estimate of the relative burden contributed by various sources has been established, an assessment of the significance of remedial actions in Study Area B on Study Area D can be made.

A number of sediment cores will be collected within Study Area D for purposes of high resolution analysis (see Figure 2.7). These cores will be analyzed in the same manner as high resolution samples collected elsewhere in the Hudson and the resulting data will be evaluated similarly. Using the suspended load estimates derived from the high resolution core samples and literature data, total water column PCB concentrations will be computed for current and historic conditions. Since high resolution samples are to be analyzed for PCBs on a congener-specific basis, the historic PCB congener profile will also provide significant additional insight about sources of the contaminant load. Figure 2.8 shows the historic high resolution core locations for Study Area D.

The high resolution core program for Study Area D must be considered in the context of the total effort described in this plan. Data derived from sediment cores collected in all four study areas will be needed to evaluate PCB sources and loads within Study Area D. For example, trends in congener patterns observed in Study Area C samples should continue into samples collected in Study Area D. Therefore, shifts in congener patterns, for example, from an Aroclor 1242 pattern to one representative of a more heavily chlorinated Aroclor, are expected to be observable when all the high resolution core data are compared. The presence of a discernible congener pattern change from north to south may imply different sources.

A number of analysts have generated estimates of current PCB discharges to New York Harbor. The Phase 1 Report identified several such efforts and provided a tabulation of various PCB sources and their magnitudes. In addition, an independent estimate was generated, during Phase 1, of PCB loads currently released to the Hudson estuary (Study Area C) from the river above Federal Dam (Study Area B). During Phase 2, a projection of long-term PCB loading to the estuary will be formulated, using information derived from the water column study and the high resolution coring program described earlier in this plan. The sediment sampling and analysis effort to be conducted within the estuary will provide additional data upon which to base an estimate of the relative importance of various sources of PCBs.

PAGE INTENTIONALLY LEFT BLANK



Legend

180 River Mile

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

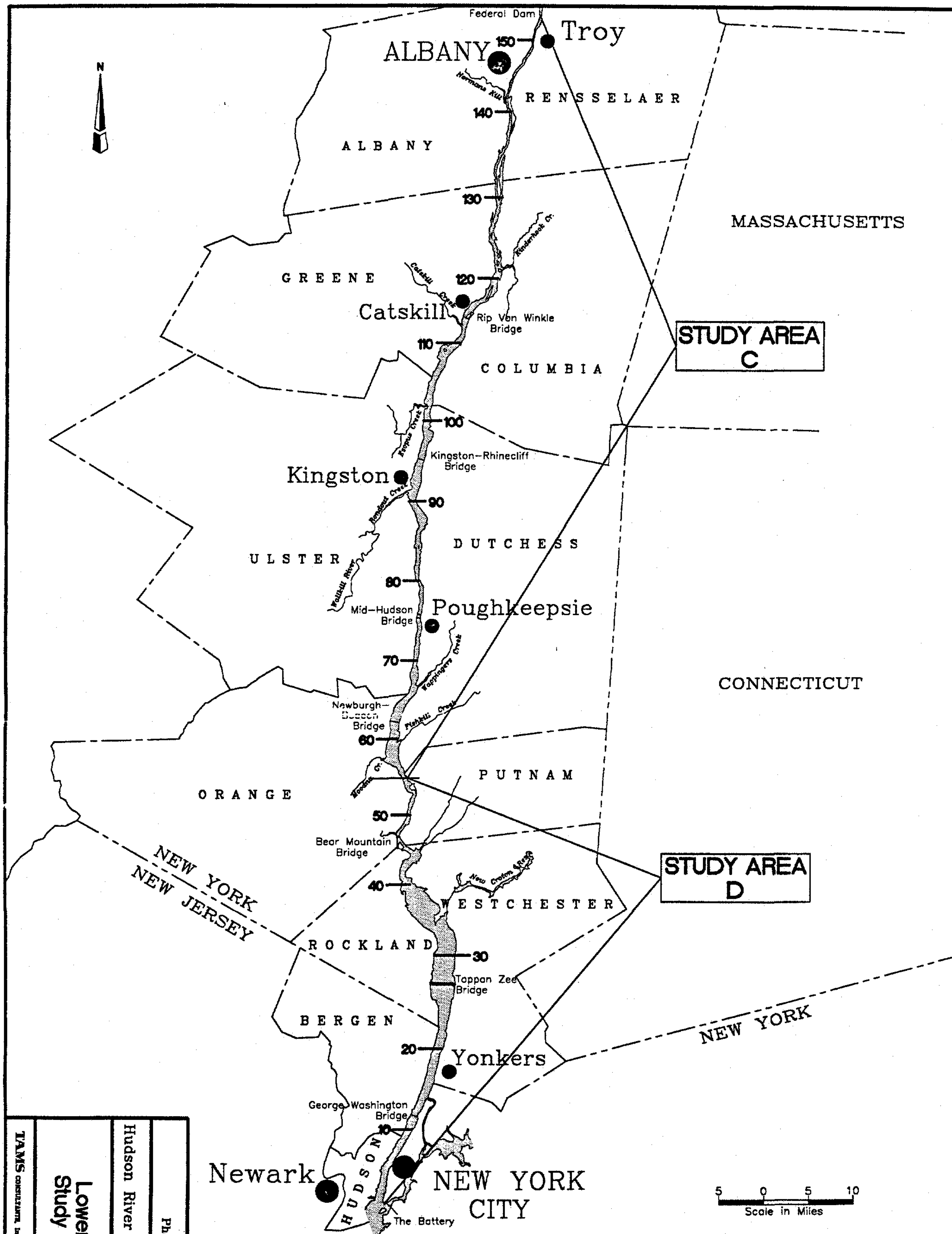
Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Upper Hudson River Study Areas A and B

TAMS Consultants, Inc./Gradient Corporation

Figure 2.1



Legend

100 River Mile

Note:

1. Study Area C: Federal Dam to River Mile 55
2. Study Area D: River Mile 55 to The Battery

Phase 2 Work Plan

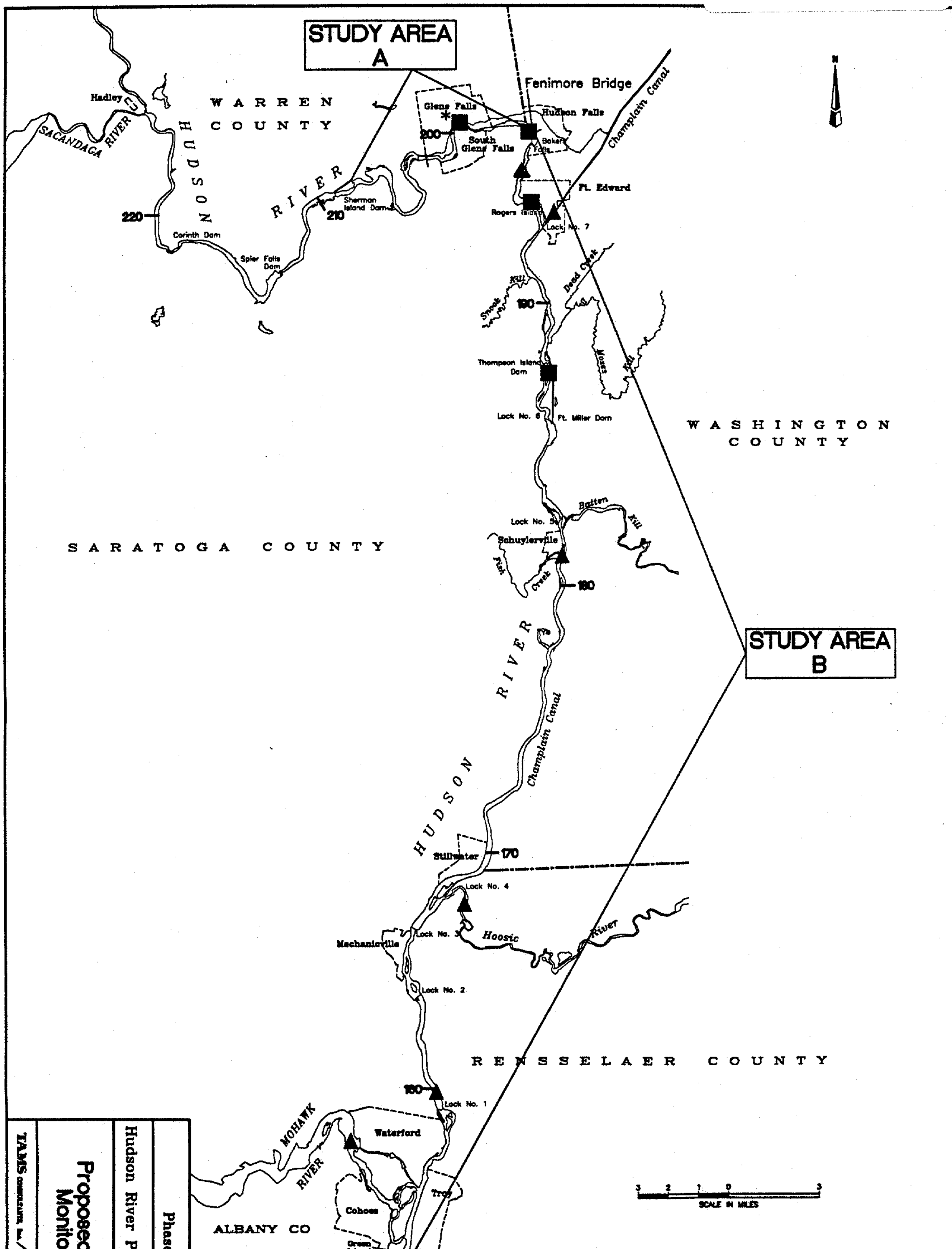
Hudson River PCB Reassessment RI/FS

Lower Hudson River Study Areas C and D

TAMS Consultants, Inc./Gradient Corporation

Figure 2.2

312109



Legend

190	River Mile
▲	Proposed Water Column Transect Sampling Station
■	Proposed Combined Water Column Transect and Flow – Averaged Water Column Sampling Stations
*	A suitable location closer to the downstream limit of Study Area A will be used if available

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

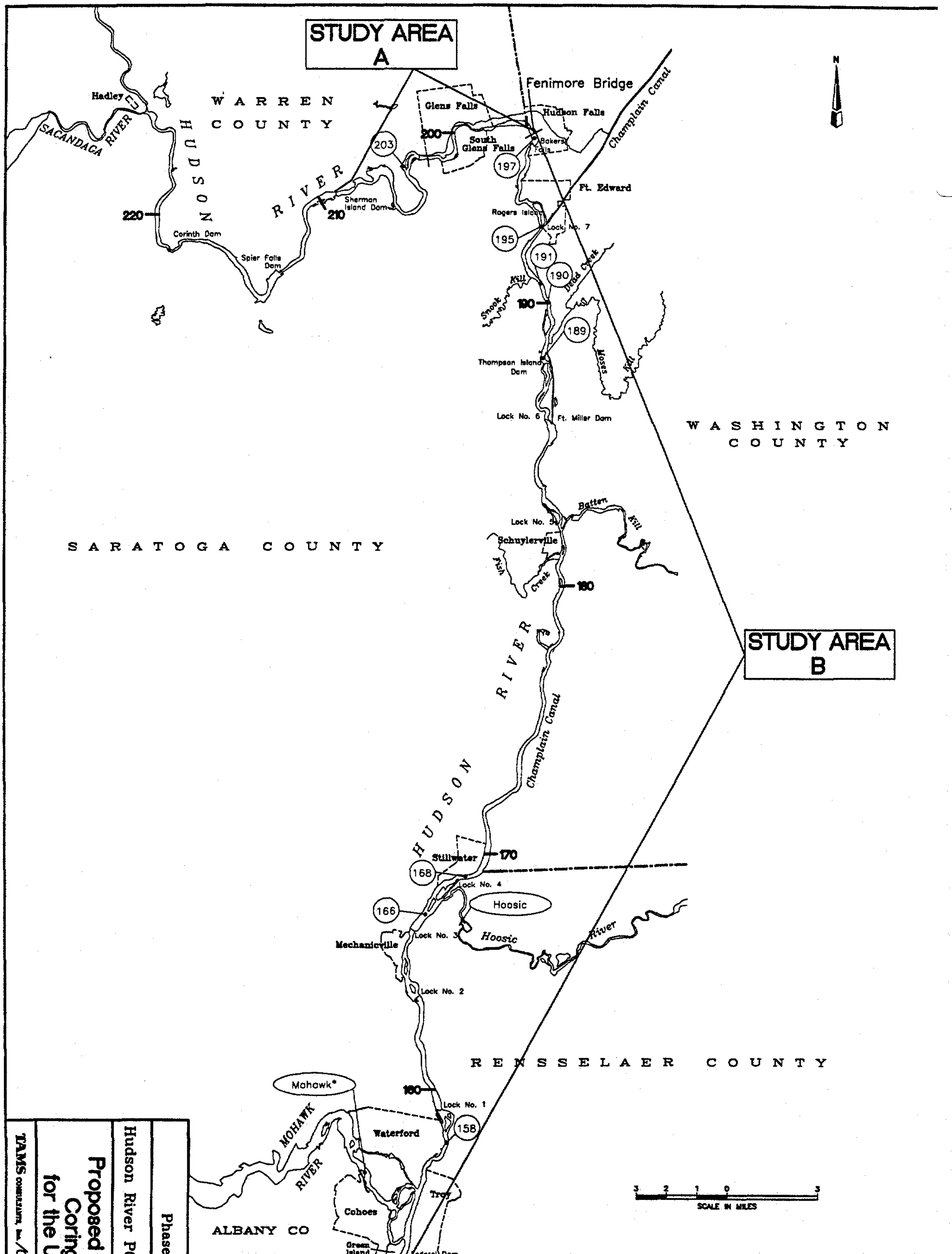
Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Proposed Water Column Monitoring Stations

TAMS Consultants, Inc./Gradient Corporation

Figure 2.3



Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Proposed High Resolution Coring Locations for the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation

Figure 2.4

Legend

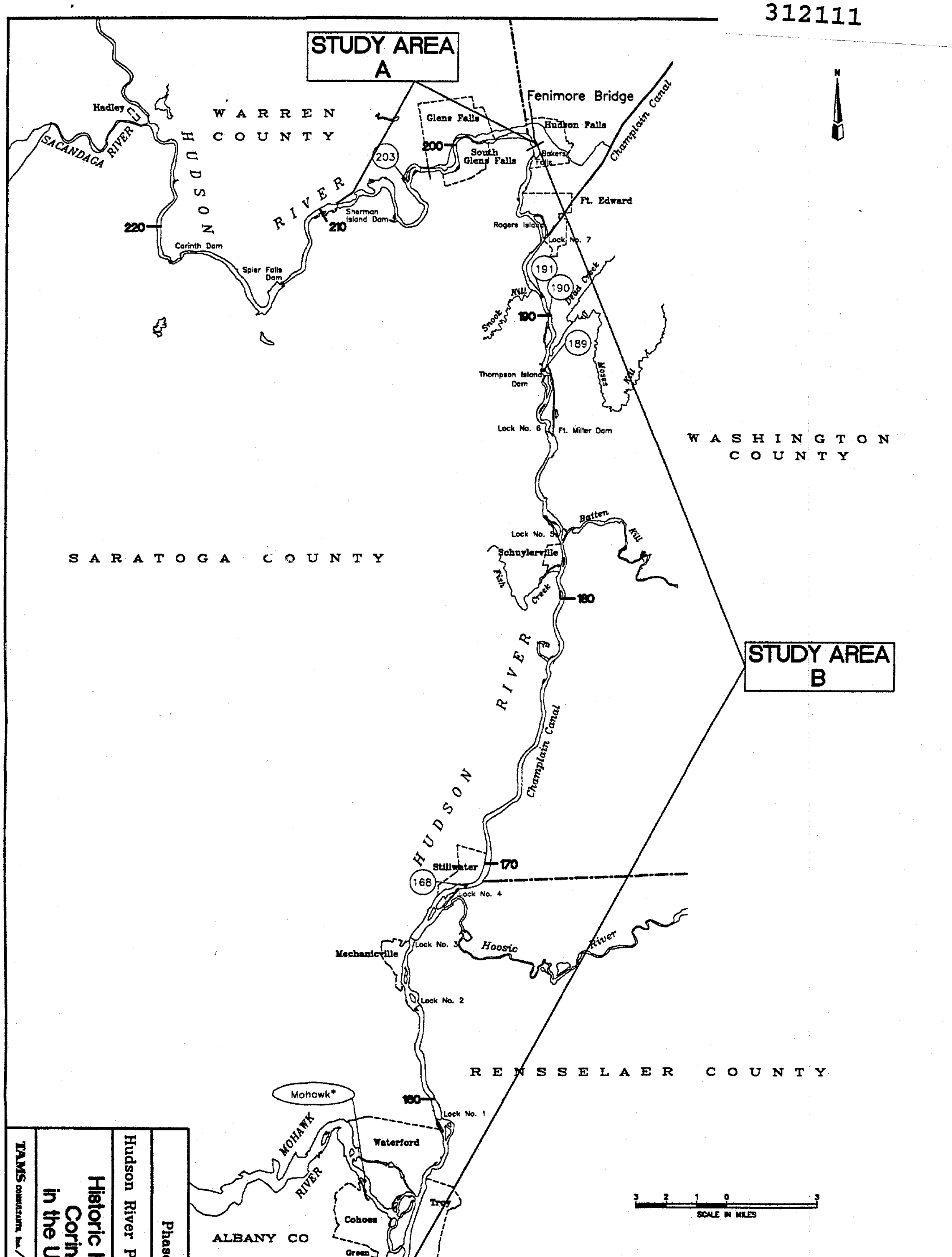
188 — Location of Proposed Core

180 — River Mile

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

* Note: Mohawk has two proposed core locations near this point.



Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Historic High Resolution Coring Locations in the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation

Figure 2.5

Legend

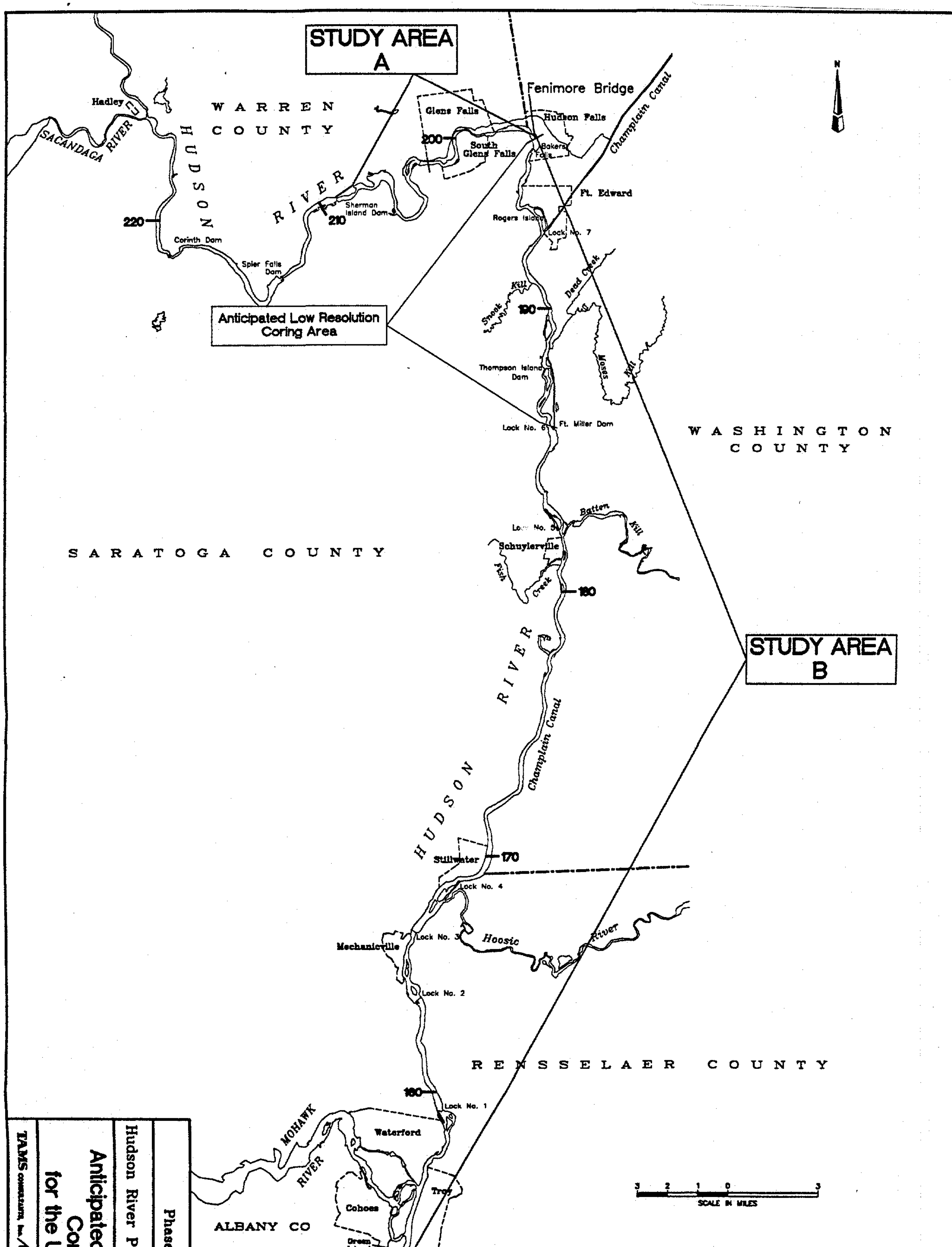
(188) Location of Historic Sediment Core

180 River Mile

* Mohawk has two historic core locations near this point.

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam



Legend

180 River Mile

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

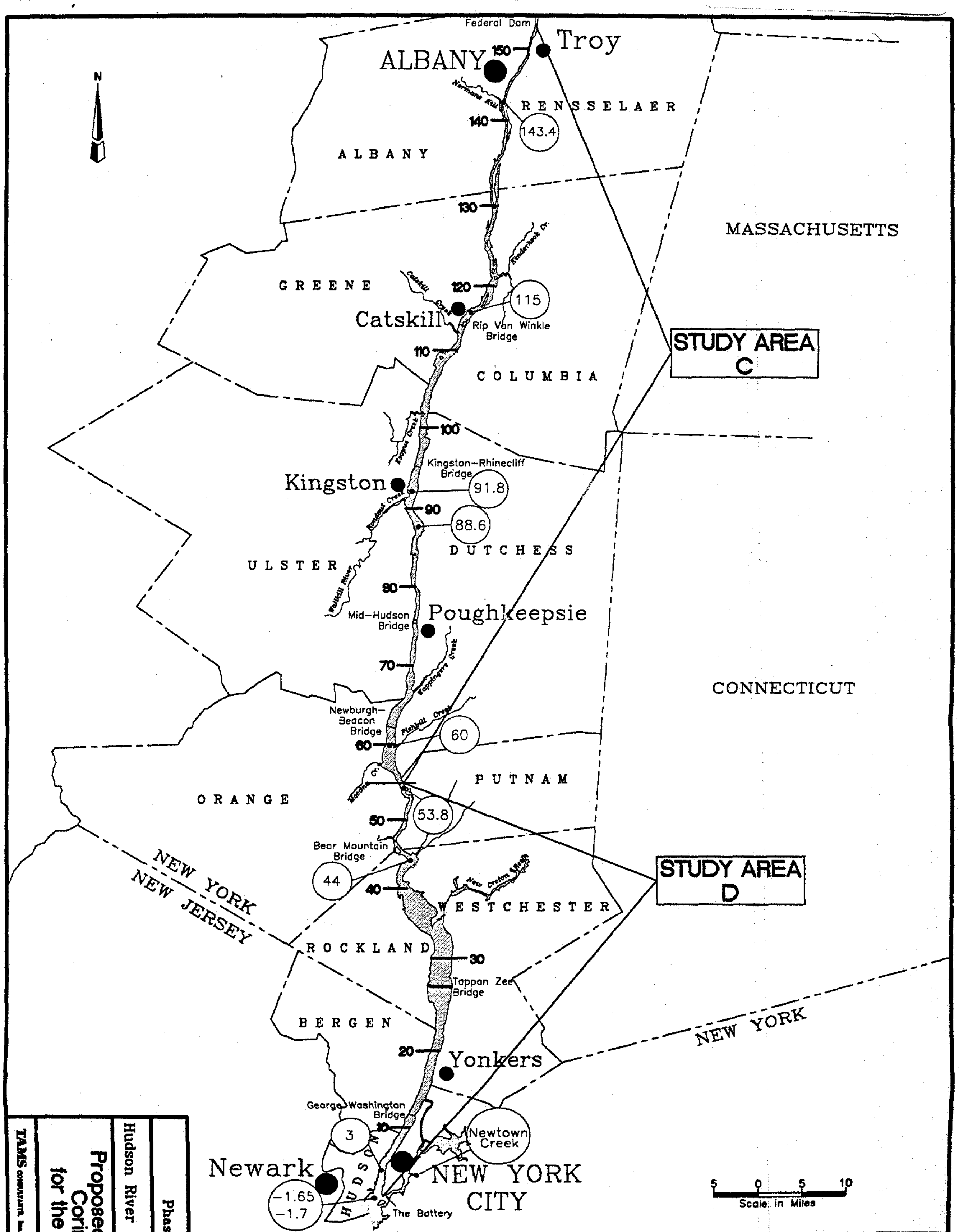
Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Anticipated Low Resolution Coring Area for the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation

Figure 2.6



Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Proposed High Resolution Coring Locations for the Lower Hudson

TAMS Consultants, Inc. / Gradient Corporation

Figure 2.7

Legend

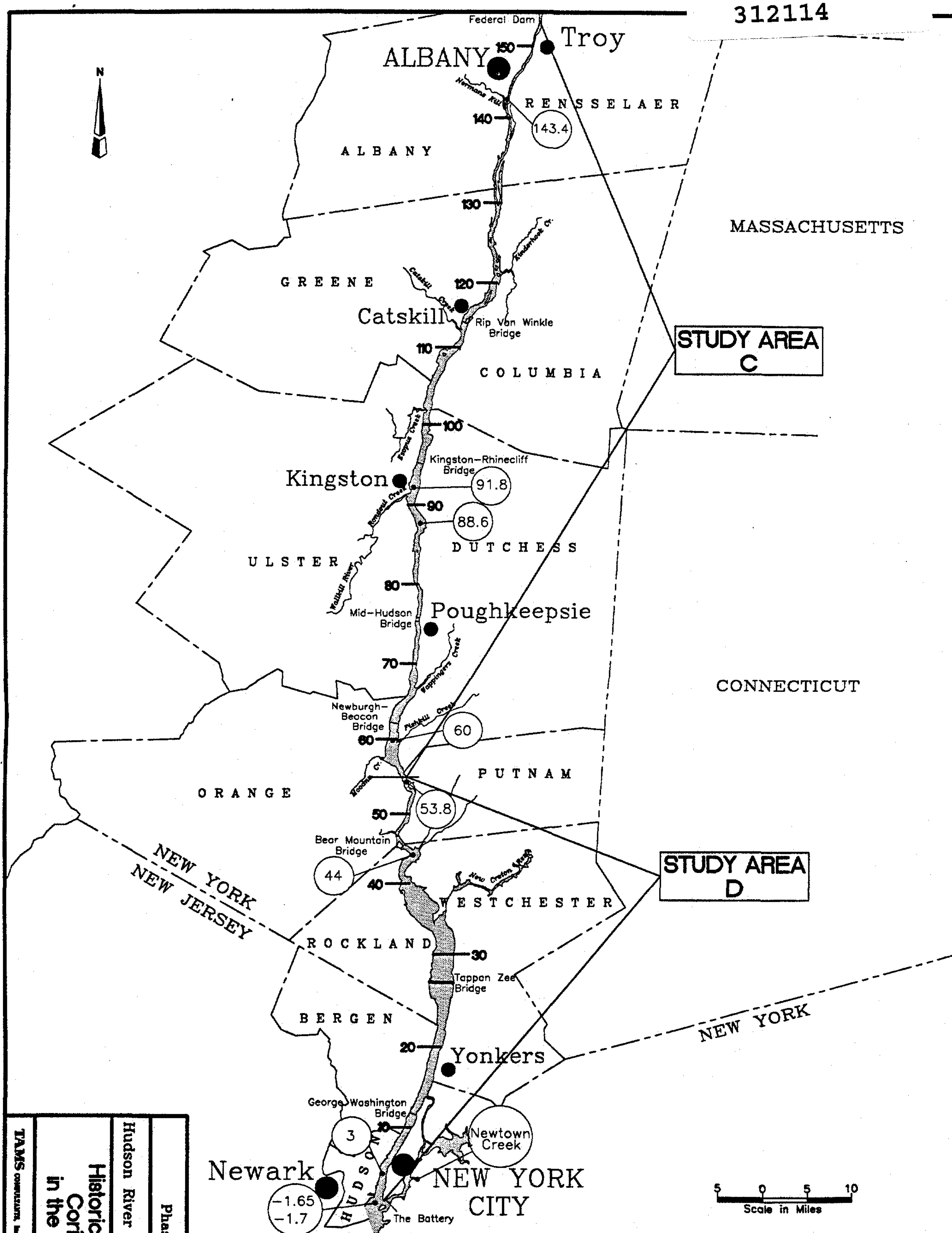
(60) Location of Proposed Core

100 River Mile

Note:

1. Study Area C: Federal Dam to River Mile 55
2. Study Area D: River Mile 55 to The Battery

312114



Legend

(60) Location of Historic Sediment Core

100 River Mile

Note:

1. Study Area C: Federal Dam to River Mile 55
2. Study Area D: River Mile 55 to The Battery

Phase 2 Work Plan

Hudson River PCB Reassessment RI/FS

Historic High Resolution Coring Locations in the Lower Hudson

TAMS Consultants, Inc./Gradient Corporation

Figure 2.8

3. MAIN DATA COLLECTION TASKS

This section presents a detailed discussion of the main data collection tasks, *i.e.*, congener analyses, water-column sampling, sediment sampling and geophysical surveys, in order to explain how the data derived from these tasks will be specifically utilized for analyses in Phase 2. (Section 2 provides an overview of these tasks for the general reader and summarizes data collection activities by study area.)

3.1 Congener-Specific Analysis of PCBs

As noted in the Phase 1 Report and elsewhere, the nature of PCB compounds is relatively complex. There are ten homolog groups, varying from one to ten in the number of chlorine atoms attached to the biphenyl molecule. Within each homolog group there exists a range of isomers, which vary based on the positioning of the chlorine atoms around the molecule. The number of isomers per homolog group varies from one for decachlorobiphenyl to forty-six for pentachlorobiphenyl. Collectively, the isomers are called congeners and refer to the 209 individual compounds classified as polychlorinated biphenyls.

The importance of this distinction in PCB classes arises from the means by which PCBs were produced and eventually released to the environment. PCBs were produced for industrial use as commercial mixtures called Aroclors, which typically contained several homolog groups, each containing many congeners. Analyses of PCBs in the environment have been reported historically on an Aroclor basis. This analytical approach became questionable, when it became generally known that Aroclor mixtures released to the environment did not remain there unaltered. Instead the mixtures undergo various processes, such as adsorption, volatilization, oxidation and degradation, which alter the present Aroclor mixture.

In order to assess the impact of these processes, which vary in degree throughout the Hudson, PCB analyses will be necessary, first on a congener-specific basis. For example, in some cases the variation in congeners within a single homolog group may be used to define a specific geochemical process. Congener-specific analysis can also be used to differentiate newly released Aroclor mixtures from relatively older, altered congener mixtures.

Congener-specific analyses are proposed for all PCB analyses in Phase 2, because of their ability to differentiate fresh Aroclor mixtures from each other, to separate altered from unaltered mixtures and to differentiate the net effects of the various geochemical and biodegradation processes. Figure 3.1 illustrates the differences among several standard Aroclor mixtures on a homolog basis. Even with these limited 10 basic divisions, differences among the mixtures are clear. When congener analyses are applied to environmental samples, these distinct Aroclor signatures plus the alterations as a result of various processes become evident.

In this study, congener-specific analysis is defined to include the separation of the sample PCB mixtures by gas chromatography into a maximum of about 120 peaks (two to three congeners are occasionally represented by a one peak). Nevertheless, the level of separation to be achieved is sufficient for the necessary resolution of data.

3.2 Water-Column Sampling and Analysis

As part of the investigation in Phase 2, a set of water-column samples will be collected from the Upper Hudson (Study Areas A and B). These samples will be analyzed for a number of parameters and used to examine both current PCB loads and geochemical processes affecting those loads.

The data collection program for the water-column consists of four separate subtasks:

- Water Column Transects Sampling;
- Water Column PCB Equilibratium Study;
- Flow-Averaged Water Column Sampling; and
- Analysis of Historic Water Column Samples.

These subtasks are described in Sections 3.2.1, 3.2.2, 3.2.3, and 3.2.4.

3.2.1 Transect Sampling

This subtask is designed to collect a series of analytical snapshots of water column parameters, as a parcel of water travels through the Upper Hudson (Study Areas A and B). The transect is defined as a longitudinal series of water-column sampling stations in the direction of flow between Glens Falls and Federal Dam. As a parcel of water travels through these areas, its PCB load may change. The purpose of the sampling program is to designate where the PCB load is derived and, once in the water column, how this load is altered or transferred to the Lower Hudson (Study Areas C and D).

To accomplish the purpose of this subtask, a series of sampling stations will be established to collect samples for the following parameters:

- Dissolved phase PCB congener concentrations;
- Suspended matter PCB congener concentrations;
- Total suspended solids (total suspended matter);
- Total organic carbon on suspended solids;
- Dissolved organic carbon (DOC);
- Chlorophyll-a;
- Total water-column PCBs;
- General water quality parameters, *e.g.*, pH, temperature, conductivity, dissolved oxygen.

The individual sampling events will be performed so as to follow in a general fashion the same parcel of water as it travels through the Upper Hudson. In this manner, changes in the parameters between two successive stations can be measured. Ignoring for the moment geochemical processes, increases in the water-column PCB concentration across a pair of monitoring stations would be interpreted as the result of an additional PCB load originating in the intervening river section. Decreases in concentration would be interpreted as the result of dilution by tributary additions or by loss from the water column. Comparison of the differences in congener mixtures at the two stations would yield information on the nature of the source or the geochemical processes in the intervening river section.

The use of congener-specific data, using preliminary data collected by General Electric in 1991, is shown in Figure 3.2, which illustrates changes in the water-column homolog mixture between two monitoring points in the Upper Hudson on two separate dates. The monitoring points represented are the Route 197 Bridge at Fort Edward and the Thompson Island Dam, *i.e.*, the input point and the output point of the Thompson Island Pool, respectively. The mixture of PCBs in the water-column shifts, as a result of passage through the pool, toward lighter homologs, *e.g.* the effect is more pronounced in May than in April 1991. On the same dates, water-column concentrations increased from Fort Edward to the Thompson Island Dam from 16 to 43 ng/L (April 5) and from 12 to 75 ng/L (May 3). A preliminary interpretation of these data suggests that a significant portion of the PCB load on these days was derived from the Thompson Island Pool and that the source from the Pool had a significant proportion of mono- and dichlorobiphenyls, unlike any of the known historic releases to the area. The mixture found at Fort Edward appears to be similar to that of Aroclor 1242, as shown in Figure 3.3. It could also be a blend of Aroclor 1242 (80 percent) and Aroclor 1254 (20 percent) also shown in Figure 3.3.

The use of congener-specific data can also show the variation of local source loadings with time. Figure 3.4, based on GE data, shows variability in the congener mixture over time at the Thompson Island Dam, specifically gradual increase in importance of the mono- and dichlorobiphenyls in the load leaving the pool. The occurrence of *in situ* biodegradation in the PCBs of the Thompson Island Pool would mean that the change in homolog mixture results from diffusion of the altered, partially dechlorinated PCBs out of the sediments and into the water column.

Through collection of information on dissolved and suspended matter, it will be possible to distinguish better among PCB sources. For example, if the Thompson Island Pool source of mono- and dichlorobiphenyls is a diffusive one, *i.e.* PCBs enter the water column in dissolved form, then the distribution of these congener concentrations would shift to the dissolved phase relative to the dissolved-suspended phase equilibrium. Conversely, if these PCBs enter the pool via scour or resuspension of sediments, then the distribution between dissolved and suspended matter phases would shift to suspended matter relative to equilibrium. No data are currently available to permit this type of analysis.

The collection of transect samples will permit identification of those regions of the river where PCB sources exist and provide information as to the type or nature of the source. Transect samples also effectively fingerprint the source by identifying the congener pattern derived from the source, which can then be traced in downstream reaches.

The measurement of total suspended solids is, however, needed to determine total PCB flux past any monitoring point. This measurement will be computed as follows:

$$Flux = Q \times \left[PCB_{Diss} + TSS \times PCB_{SS} \times \frac{1\ kg}{10^6\ mg} \right]$$

where:

Flux	=	PCB Flux in ng/s
Q	=	Water flow in L/s
PCB_{Diss}	=	Dissolved phase total PCB concentration in ng/L
TSS	=	Total suspended solids in mg/L
PCB_{SS}	=	Suspended solids total PCB concentration in ng/kg

Measurements of total organic carbon on suspended solids, dissolved organic carbon and chlorophyll-a are needed to interpret dissolved-suspended phase PCB partitioning, because each of these parameters affects equilibrium partitioning of PCBs in the water column. One or more of these parameters is expected to correlate with variations in measured dissolved-suspended phase PCB distributions. Specifically, increases of total organic carbon on suspended matter or chlorophyll-a permit a greater fraction of the water-column PCB load to be carried by suspended matter, since these properties would correlate with the fraction of PCBs adsorbed to particulate matter. Conversely, increases in dissolved organic carbon permit a greater fraction of PCBs to exist in the dissolved phase, since the presence of additional dissolved organic carbon would hold additional PCBs in solution bound to Dissolved Organic Carbon (DOC). (Herein, the term dissolved phase refers to both dissolved PCBs and PCBs bound to DOC.)

Total water-column PCB analysis will be done in accordance with NYSDEC analytical procedures to provide a tie between the other PCB analyses and standard NYSDEC results.

The remaining parameters (pH, temperature, conductivity and dissolved oxygen) are standard water quality parameters. These parameters will be monitored in the field across water sample locations and within a single sampling cross-section.

3.2.2 PCB Equilibrium Study

This subtask will involve the collection of duplicate water column transect samples, which will be held for approximately four days prior to filtration and analysis. The purpose of this subtask is to determine the effective equilibrium distribution of PCB congeners between dissolved and suspended matter phases. The basic premise is that PCB equilibration between these phases is not instantaneous in the water column. The samples for this study will be held sufficiently long to permit the system to reach an effective equilibrium. By comparing these results to samples that are filtered shortly after collection, it will be possible to evaluate the ambient congener distribution relative to the equilibrium distribution. The definition of equilibrium for this system is not necessarily a true thermodynamic one. It is the point at which little change takes place in the dissolved and suspended matter PCB-congener concentrations, *i.e.* a steady-state end point. In general, this end point appears to be fairly well-defined, based on the relatively consistent observed partition coefficients reported in the literature.

The differences in the PCB-congener distributions at various points relative to equilibrium will be used to define the type of PCB source to the river and aid in the actual identification. For example, if a sample yields a congener distribution that shows dissolved phase dominance relative to equilibrium, the conclusion would be that the PCB source in the upriver reach was predominantly a dissolved phase input. Such sources would include PCB diffusion from the sediments or a groundwater input. The measured distribution could not be obtained by sediment scour or a suspended matter input.

Evidence for this lack of equilibrium can be seen in the data collected on Upper Hudson water column suspended matter in 1983 by Bopp *et al.* (1985).[1] Their data were derived from eleven sample pairs consisting of a large volume water sample. One of the pairs was filtered using a glass fiber filter (GFF) several days after collection; the other of the pairs was a large volume filter (LVF) sample, which was collected *in situ* by placing a filtering apparatus directly into the river. The results of one such pair of samples taken at Mechanicville, NY are shown in Figure 3.5, showing the packed column peak data for the samples. Packed column peak analysis separates the congeners into approximately 22 peaks and typically yields several congeners for each peak. In general, the resolution between congeners decreases with increasing peak number. In Figure 3.5, the main peaks represent tri- and tetrachlorobiphenyls, which are the main components of Aroclor 1242. A clear difference in congener distribution occurs between the *in situ* sample (LVF) and the sample held for several days (GFF). This difference in congener pattern was also accompanied by an increase in the total PCB concentration for the peaks shown in the suspended matter on the GFF sample (6.6 mg/kg) relative to the LVF sample (1.25 mg/kg). These results plus those of the other sample pairs suggest that PCB inputs upstream of Mechanicville (located between Waterford and Stillwater) in 1983 contained a significant dissolved phase source and that given sufficient time, the dissolved PCB would sorb to the suspended matter.

---

[1] Bopp, R.F., H.J. Simpson, and B.L. Deck. 1985. "Release of Polychlorinated Biphenyls from Contaminated Hudson River Sediments." Final Report NYS C00708 to NYSDEC, Albany, NY. Lamont Doherty Geological Observatory of Columbia University, Palisades, NY.

Bopp *et al.* (1985) note that part of the difference between the samples may stem from differences in the filters used. The large change in the total PCB concentration and the congener pattern, however, would suggest that a real change occurred during sample storage.

Samples for this PCB Equilibrium Study will be collected at 10 transect sampling locations, during both a high flow condition and a low flow condition. These samples should provide equilibrium partition coefficients for the range of conditions expected in Study Areas A and B.

Dissolved organic carbon will also be measured to evaluate whether measured changes in the PCB distribution are related to changes in this parameter.

3.2.3 Flow-averaged Sampling

Unlike water-column transects, which are designed to obtain snapshots, this subtask is designed to determine relatively long-term averages of water-column conditions. The need for this type of sampling stems from the inherent variability found in water-column samples. Figure 3.6 presents preliminary GE monitoring data from Study Area B for the period April 1 to June 24, 1991. Data were collected three times per week at each sampling station. The measured variability shown by the vertical lines in Figure 3.6 is substantial. This variability can be attributed to variations in suspended matter load, flow and sediment scour, etc.

Flow-averaged sampling avoids those variations by compositing samples. (The water-column transect study will be subject to these variables, but effects will be minimized by monitoring appropriate parameters, separating dissolved from suspended matter PCBs, and by sampling the same parcel of water through Study Areas A and B.)

Figure 3.6 also shows the means in water-column PCB concentrations in Study Area B using spring 1991 data. The sampling to achieve these results were substantial, *i.e.*, 28 points per station for a total of 168 measurements. The flow-averaged sampling program is intended to obtain a similar analysis without an extensive analytical program. For the time period shown in Figure 3.6, the flow-averaged sampling would have produced three samples for analysis per station instead of twenty eight.

The flow-averaged water-column sampling program entails the collection of water column samples on a regular basis, essentially every other day. The volume of water collected on a given day is proportional to the flow measured that day by the USGS hydrologic monitoring stations in the Upper Hudson, using a scale developed prior to the onset of samplings. After the required number of samples are collected and the period of sampling is over, these samples are combined to yield one large sample for PCB analysis. The concentration in the combined sample is then a flow-weighted average of the water column concentrations.

A single combined sample will be generated for monitoring stations at Glens Falls, Fenimore Bridge at Bakers Falls, Route 197 Bridge at Fort Edward and Thompson Island Dam, for a minimum of three separate sampling periods. These samples will permit the construction of a plot similar to that shown in Figure 3.6. The set of sampling stations is limited to four, based on the trend in water-column loading developed in the Phase 1 Report and supported by the data from General Electric, which indicate that PCB loading originates in the reaches between these four monitoring stations.

The following analyses will be performed on the flow-averaged water column samples:

- Dissolved phase PCB congeners;
- Suspended matter phase PCB congeners;
- Dissolved organic carbon;
- Total suspended matter; and
- Standard water quality parameters - pH, temperature, conductivity, dissolved oxygen.

The dissolved and suspended matter phase PCB congener analyses are required to describe the flow-averaged total PCB concentration. The information will not be equivalent to the water column transect sampling, since the flow-averaged samples will be held for as many as several weeks before filtration, allowing the PCB distribution to equilibrate and losing the information on potential source type. Thus, the two sampling methods complement each other. The water column transect sampling gives instantaneous congener-related conditions, which can be used to locate contaminant sources and examine the effects of biogeochemical processes while generating an instantaneous PCB loading. The flow-averaged samples describe the mean total PCB loading, but potentially the congener distribution needed to identify specific sources and biogeochemical processes is altered.

The dissolved organic carbon and total suspended solids analyses will also be performed on a flow-weighted basis. These parameters are needed for the same reasons as for the water column transects.

The standard water quality parameters, pH, temperature, conductivity and dissolved oxygen, will be recorded at the time of sample collection. These data will be used qualitatively in support of the other parameters.

3.2.4 Analysis of Historic Samples

Scientists of the Lamont-Doherty Geological Observatory, between 1977 and 1986, have collected water-column samples for PCB analysis. These samples were separated into dissolved and suspended matter fractions, analyzed using packed column gas chromatography and archived. These samples are available for reanalysis on a congener-specific basis for the Phase 2 investigation and will provide information on the types of PCB congener mixtures historically carried by the Hudson River. The data will be compared with current congener mixtures to establish how the mixture has changed over time.

These archived sample analysis data complement other data sources available to the Reassessment, including the USGS monitoring records and the high resolution sediment coring effort. The large USGS data set is limited in both its detection limit and its resolution of PCB congeners. This data set provides many limited resolution snapshots of the water column PCB concentration. The high resolution sediment core data provides information on PCB congener concentrations of historic suspended matter, with a two to three-year level of resolution. Historic water column samples have the PCB congener resolution of the high resolution cores and the instantaneous nature of the USGS data and will be a useful tool in examining historic trends and extrapolating future trends.

The analysis of historic samples will provide the historic, dissolved phase PCB congener concentrations, a data set not available from any other source. These data will be used to assess the accuracy of using literature partition coefficient data to predict total water column PCB concentrations, based on suspended matter or high resolution sediment core PCB concentrations.

The analysis of the archived water column extracts will be essentially the same as the analysis of all other PCB samples for the Phase 2 investigation.

3.3 Sediment Coring and Analysis

The sediment investigations represent a major portion of the Phase 2 investigation, because of the considerable mass of PCBs contained in the sediments and the unique ability of sediments to record historic riverine conditions. The sediment investigations consist of four subtasks:

- High resolution sediment coring;
- Low resolution sediment coring;
- Analysis of archived sediment extracts; and
- Confirmatory sediment sampling.

These subtasks are described in Sections 3.3.1, 3.3.2, 3.3.3 and 3.3.4.

3.3.1 High Resolution Coring

The goal of this sampling subtask is to collect and analyze sediment cores from locations in all four study areas. These cores will be obtained from river areas known or believed to accumulate sediments at a rapid rate, typically 1 cm/yr or more. Because these areas rapidly accumulate sediments on a more or less continuous basis, they effectively preserve each year's sediment deposits. Since the river itself is responsible for continuously delivering the sediments to these locations as it transports sediments downstream and out to the Atlantic Ocean, the sediment deposits at each location represent an average of the water column suspended matter properties. By separating the deposits in annual or biannual layers, it is possible to examine the historic trend in water column suspended matter properties.

The term *high resolution* sediment coring refers to the method by which sediment cores are collected and separated. After collection, a sediment core is gently extruded from the coring tube and sliced into thin layers of 2 to 4 cm in thickness. These layers, which approximate annual or biannual deposit thickness, permit the analysis of one to two years of sediment accumulation per slice. This technique produces a highly resolved sediment deposition chronology.

Although the process of slicing a sediment core into thin layers is not sufficient to establish the history of sediment deposition at a given location, natural and anthropogenic time markers are incorporated into the suspended matter before it is deposited at a given location. These time markers are the radionuclides Beryllium-7 (Be-7), Cesium-137 (Cs-37) and Cobalt-60 (Co-60). Use of these radionuclides as time markers is based on their known rate of input to the Hudson Basin.

Geochemical application of these radionuclides is diverse and well-documented. They are utilized in lakes, rivers, oceans and estuaries as time markers or clocks for establishing sediment deposition rates. The power of the techniques arises, in part, from the simplicity of measurement. Radionuclides in sediments are analyzed by simply drying the sediment and placing it in a gamma spectrometer where the gamma radiation given off by the radionuclide can be measured and recorded. The sample is left in the counter for a period of hours to days in order to accumulate sufficient counting statistics. Once counted, the sample can then be used for other chemical analyses as needed. The sensitivity of the measurement is quite high. Typical detection limits are 200 picocurie per kilogram (pCi/kg) for Be-7 to 25 pCi/kg for Cs-137. (A picocurie is a measure of radioactivity. One picocurie represents about 2 disintegrations per minute.)

Radionuclides in the sediments are used in two ways, as a clock in the case of Be-7 and as an event marker in the case of Cs-137. Be-7 is a naturally occurring radionuclide produced in the upper atmosphere by cosmic radiation. Its rate of fallout is fairly constant with time. The fallout rate at Albany has been measured at 0.018 pCi/cm^2 day (Olsen, *et al.* 1984).[2] Because its input is relatively constant with time, Be-7 is suitable for use as a sediment clock. For Be-7 the clock is started at the time of sediment deposition. Because Be-7 exhibits an exponential decay with a half life of 53.3 days, it will only be detectable in sediments for six months to a year, and virtually all of the Be-7 will be decayed after one year. Thus, the Be-7 clock is limited to the uppermost sediment layers, typically 2 to 4 cm in depth.

Cs-137, on the other hand, is an anthropogenic radionuclide, produced in atomic weapons testing and nuclear power reactors. Most of its release to the environment has resulted historically from atmospheric weapons testing. The historic input of Cs-137 to the New York area has been summarized by Bopp *et al.*

---

[2]Olsen, C.R., I.L. Larson, R.H. Brewster, N.H. Cutshall, R.F. Bopp and H.J. Simpson. 1984. "A Geochemical Assessment of Sedimentation and Contaminant Distribution in the Hudson-Raritan Estuary." NOAA Technical Report NOS OMS 2, U.S. Dept. of Commerce.

(1982).[3] Figure 3.7 shows the history of atmospheric fallout and nuclear reactor releases to the Hudson Valley. The three main event markers are: 1) appearance of Cs-137 in 1954, as a consequence of the onset of atmospheric atomic weapons testing; 2) a Cs-137 maximum in 1963 corresponding to an extensive amount of atmospheric weapons testing just prior to the implementation of the atmospheric test ban treaty; and 3) the 1971 Cs-137 release directly to the Lower Hudson by the Indian Point nuclear power facility. The Cs-137 peak in 1971 can be distinguished from the 1963 peak by the presence of Co-60 in the sediments associated with 1971. Co-60 was released along with Cs-137 by the Indian Point facility. The impact of the reactor release of Cs-137 to the Lower Hudson is limited to the brackish portion of the estuary (Study Area D). Thus, for Study Areas A, B and C, there are three time constraints or horizons: Be-7 in surface sediments, Cs-137 maximum in 1963 and Cs-137 appearance in 1954; Study Area D has one more, corresponding to the 1971 reactor release.

Because of its geochemistry, the Cs-137 record in the sediments is not as simple as the history shown in Figure 3.7. Cesium is a particle reactive element, which quickly binds to soil and sediment. As a result, a large inventory in soil was generated as a result of pre-1966 atmospheric fallout. Although the maximum atmospheric input to the Hudson watershed occurred in 1963 and has since tapered off greatly, soils in the watershed continue to release Cs-137 to the Hudson River via soil erosion and dissolution. This release is such that any post-1954 sediment deposited in the Hudson contains Cs-137. The net result yields a Cs-137 maximum in 1963 to 1964 sediments, which gradually decreases to the present.

Figure 3.8 illustrates the Cs-137 record in a Lamont-Doherty core collected in 1986 at RM 88.6 near Kingston in Study Area C. The profile closely fits the known Cs-137 input function, yielding an annual deposition rate of 1.5 to 1.8 cm/yr. Be-7 was detected only in the top sediment layer (0-2 cm) with a deposition rate of less than 2 cm/yr, consistent with the Cs-137 deposition rate.

---

[3]Bopp, R.F., H.J. Simpson, C.R. Olsen, R.M. Trier and N. Kostyk. 1982. Chlorinated hydrocarbons and radionuclide chronologies in sediments in the Hudson River and estuary. *Environmental Science and Technology*, 16: 666-672.

This type of core chronology can be readily converted to a year of deposition relationship. The total PCB concentration for the core layers is plotted in Figure 3.8. The conversion is shown in Figure 3.9. The approximate uncertainty in the sediments' ages are shown by the vertical line on the total PCB curve. Like all of the interpretable high resolution cores collected by Lamont-Doherty in the Lower Hudson, this core shows a PCB maximum in the early 1970s.

The application of radionuclide analysis to sediment cores permits an estimation of the year of deposition for individual sediment layers. Knowing the approximate year of deposition and assuming that the sediments deposited that year directly reflected water-column conditions, it is then possible to estimate historic water-column trends.

Taken alone, the sediment record can be used to evaluate qualitatively long-term transport trends. Because data on water-column flow and suspended matter levels are available for the Hudson in some coring locations, it is possible to quantitate in these instances historic PCB transport at these locations. Literature data and data from the Phase 2 water-column studies will be used to predict the total water column PCB concentrations based on the sediment record. In addition to recording the total PCB transport, sediments also record the PCB congener mixture on the suspended matter. Thus, dated sediment samples can be used to determine the historic mean congener mixtures. To the extent that a specific congener mixture or fingerprint can be tied to a source or source area, the sediment record can then be used to monitor the importance of the source over time.

Most of the previous high resolution sediment core work was done in the 1970s and early 1980s. The core collection sites for the Phase 2 high resolution sediment core program were selected with the intention of updating data for these previous core locations and examining the most recent sediment and, therefore water-column trends. By coring at these previously studied locations, it is also possible to examine the fate of PCBs within the sediments, as discussed below.

Additional parameters to be analyzed as part of the high resolution core program are designed to augment the interpretation of the radionuclide and PCB data. Grain size distribution analysis will reveal any changes in the depositional environment at the coring location. Total carbon and total inorganic carbon analyses will be used to examine total organic carbon content variations through a core. The total inorganic carbon analysis is expected to represent a small correction to the total carbon analysis, so that only a limited number of total inorganic carbon analyses will be required. The total nitrogen and total organic nitrogen analyses are used in a similar way, except that organic nitrogen is measured directly. The differences between total nitrogen and total organic nitrogen measurements are expected to be small, therefore only a limited number of total organic nitrogen analyses will be performed as a check. The need for the total organic carbon and total organic nitrogen data is two-fold. First, sediment PCB concentration is expected to correlate with total organic carbon levels. Second, the organic carbon to nitrogen ratio is an excellent indicator of wood cellulose. Wood waste materials constitute much of the original deposits found behind the Fort Edward Dam. When the dam was removed, these woody materials were deposited with the sediments downstream of Fort Edward for many miles. Wood cellulose is characterized by very high C/N ratios relative to typical soil or sediment organic material. Thus, the C/N ratio will be a good indicator of materials deposited following removal of the dam.

The last parameter to be measured for the high resolution sediment coring program is reduction-oxidation potential (redox). Reducing sediments have been shown to correlate with anaerobic biodegradation in Study Area B by scientists at NYSDOH. The redox measurements should assist in the interpretation of PCB congener distributions in the sediments, since reducing conditions presumably should correlate with zones of obvious PCB degradation.

3.3.2 Analysis of Archived Sediment Extracts

This subtask is an extension of the high resolution sediment coring program. The goal is to reanalyze archived sediment core extracts for comparison with Phase 2 sediment core results. Because it is possible to date the sediment layers from a core, it is also possible to compare sediment layers of the same time horizon among cores. This subtask will involve the comparison of Phase 2 high resolution sediment core layers with their dated counterparts in archived sediment cores. The archived core layers require reanalysis, because they were originally analyzed by packed column gas chromatography. The Phase 2 sediment cores, like all Phase 2 analyses will be analyzed for PCBs on a congener-specific basis. Thus, the reanalysis of the archived cores will permit direct comparison of the two data sets. For example, the core layer corresponding to 1973 in a Phase 2 core collected in 1992 could be directly compared with the core layer corresponding to 1973 collected in a core from the same general location in 1977. This comparison would permit the study of *in situ* degradation rates over the intervening period, in this case 15 years. Thus, by selecting several layer pairs corresponding to various time intervals, it will be possible to examine the effects of *in situ* processes on potential PCB degradation at the coring location. The rate of degradation is an important parameter in estimating future river conditions, since *in situ* degradation affects the PCB inventory available for interactions with other site media. Thus, in areas where *in situ* degradation is substantial, future PCB levels and inventories may be reduced. Conversely, in areas where little degradation occurs, PCB sediment concentrations are likely to remain relatively constant.

In situ degradation is already known to occur in the sediments of the Upper Hudson although estimates of the rate of degradation are limited. In the Lower Hudson, evidence suggests, by comparison, that *in situ* degradation is slow or absent. By comparing archived and Phase 2 sediment core pairs for Study Areas A, B, C and D, it will be possible to estimate *in situ* degradation rates within each area.

The selection of archived sediment core layers for reanalysis will be based on the strength of dating constraints for the layer. The sediment layers most tightly constrained are those corresponding to the 1954 appearance of Cs-137, the Cs-137 maximum, the 1971 Cs-137/Co-60 maximum (Study Area D only), the early 1970s PCB maximum and the date of collection of the archived core.

3.3.3 Low Resolution Coring

The analytical program for low resolution coring is similar to that for high resolution coring. The difference between the two programs arises from the selection of coring sites and the subdivision of cores. The high resolution coring effort requires that particularly close attention be given to the selection of coring sites on the basis of the sediment deposition rate. The low resolution coring does not. While high resolution coring attempts to study water column trends, low resolution coring is intended to obtain estimates of sediment PCB mass. Thus, the high resolution cores are separated by long distance (typically 10 miles or more), while the low resolution coring locations will be limited to Study Area B, mostly in the region between the Fenimore Bridge and the Thompson Island Dam.

The term *low resolution coring* arises from the subdivision of these cores. In general, low resolution cores will be separated into 5 inch layers (13 cm) as compared to the 2 to 4 cm thick layers used in high resolution core separation. The relatively thick nature of the core sections in low resolution coring will permit only the approximate determination of the total depth of recent PCBs and Cs-137 bearing sediment. The purpose of this analysis is to determine the volume of contaminated sediment in a given area.

The selection of areas to be studied by low resolution coring will be based on the geophysical survey results and the results of the analysis of historical sediment PCB studies by NYSDEC (see discussion of kriging in Section 2). In some instances, the areas for study will be previously determined hot spots, which are deemed important enough to be re-examined by sampling. In other cases, the coring locations will be based on the geophysical surveys alone in order to classify the type of sediment contamination associated with a given sedimentological zone. In both cases, the interpretation of the coring data will be closely tied to the geophysical survey results. The final selection of low resolution coring sites will be based on the geophysical survey, which will not be completed until spring 1992.

3.3.4 Confirmatory Sediment Sampling

This subtask is intended to provide confirmatory data on the texture of sediments located throughout the geophysical survey area. Sediment textures depicted by the geophysical survey instruments represent relative changes in sediment topography, reflectivity and density. The confirmatory sediment samples provide an absolute measure of these sediment properties, which in effect are used to calibrate the geophysical survey data. The confirmatory sediment samples will be analyzed for only two parameters, grain-size distribution and a measure of organic carbon. In addition, some sediment cores will be X-rayed to examine sediment density variations. These variations should correspond with those seen by the geophysical surveying equipment. These parameters are sufficient to describe the sediments for geophysical survey purposes. The sediment parameters will also be used in the interpretation of other data collected in Phase 2 and will be particularly useful in the assessment of scourability presented in Section 5.

3.4 Geophysical Surveying

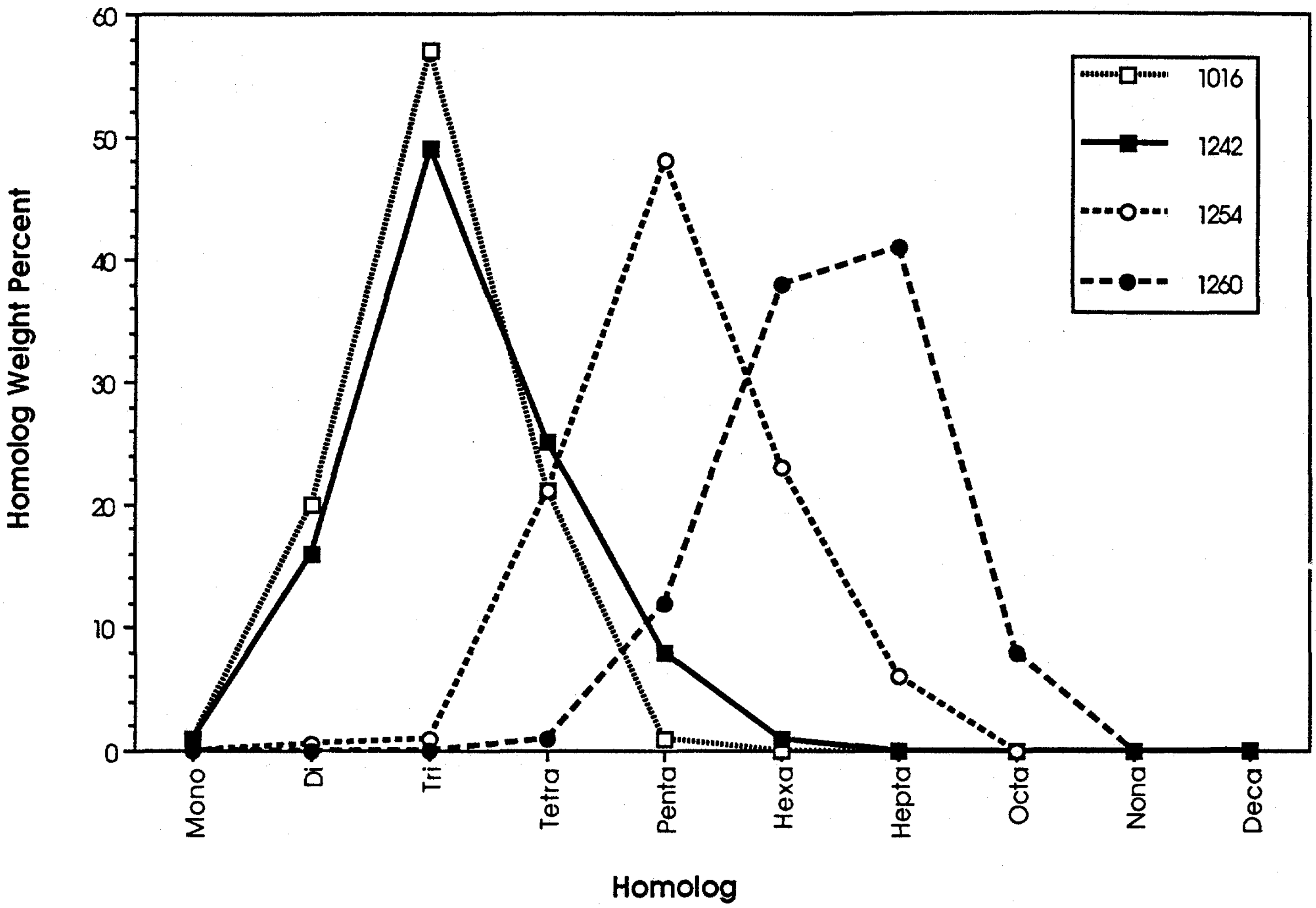
The goal of the geophysical surveying data collection task is to produce a set of maps detailing bathymetry, sediment morphology, sediment texture, and fine grained sediment thicknesses at specific locations within Study Area B only. These maps will be produced from the analysis of sonar data, which will be collected as a part of the geophysical surveys. The sonar results will be calibrated against the confirmatory sample results discussed above.

The basic principal of the geophysical surveying techniques is the use of sound as a replacement for light in generating a picture-like mosaic of the river bottom. The surveying equipment generates sonic signals, which pass through the water and are reflected by the bottom materials. The equipment uses several frequencies to scan the bottom of the river. As the equipment is pulled through the water by a survey vessel, various transponders scan the river bottom by generating and recording sonic signals. The survey vessel follows previously defined survey lines to ensure complete coverage of the river bottom.

Three transponder systems, a depth transponder, a subbottom profiler and a side scan sonar system, are used. The depth transponder determines river depth or bathymetry. The subbottom profiler is capable of penetrating fine grained sediments on the river bottom to determine their thickness. The depth of fine grain sediments is the difference between the river depth measured by the depth transponder and the depth of the reflection horizon measured by the subbottom profiler. The side scan sonar is the most sophisticated of the three transponder systems. This system uses two frequencies of sound to scan the river bottom. Each of the two frequencies generates its own reflectivity pattern for the river bottom. Unlike the other two measurement systems, the side scan sonar is able to measure in two dimensions, creating a picture-like image of the river bottom as the transponder is pulled through the water. The term side scan sonar comes from the ability of this measurement system to look to the side as well as straight down. This ability to look to the side is achieved by a sophisticated data processing scheme that handles the returning sonic signals. The swath of the river bottom covered by the side scan sonar is dependent upon the resolution required. For the Phase 2 survey work, the swath will be fairly small, about 75 meters (255 ft) wide in order to resolve the bottom features to a resolution of about 15 cm (6 in). At this resolution, bottom features such as boulders, logs, and bedrock outcrops are readily discerned. More importantly, areas of gravel, sand, and fine grained material can be discerned as well. The side scan sonar record will form the main data set for maps of the river's sediment morphology and texture.

The geophysical data are compiled, reviewed and linked to ship positioning data collected simultaneously with the geophysical data. Bathymetry will be used to generate maps of river bottom depth. The side scan sonar tracks are merged together to create mosaic pictures of the river bottom. These mosaics are then used to produce maps of sediment morphology by interpreting the reflectivity patterns in conjunction with the confirmatory sample results discussed in Section 3.3.4. The sub-bottom profile data will be used with these maps to provide a third dimension measurement and permit the estimation of fine grained sediment volumes in areas of concern.

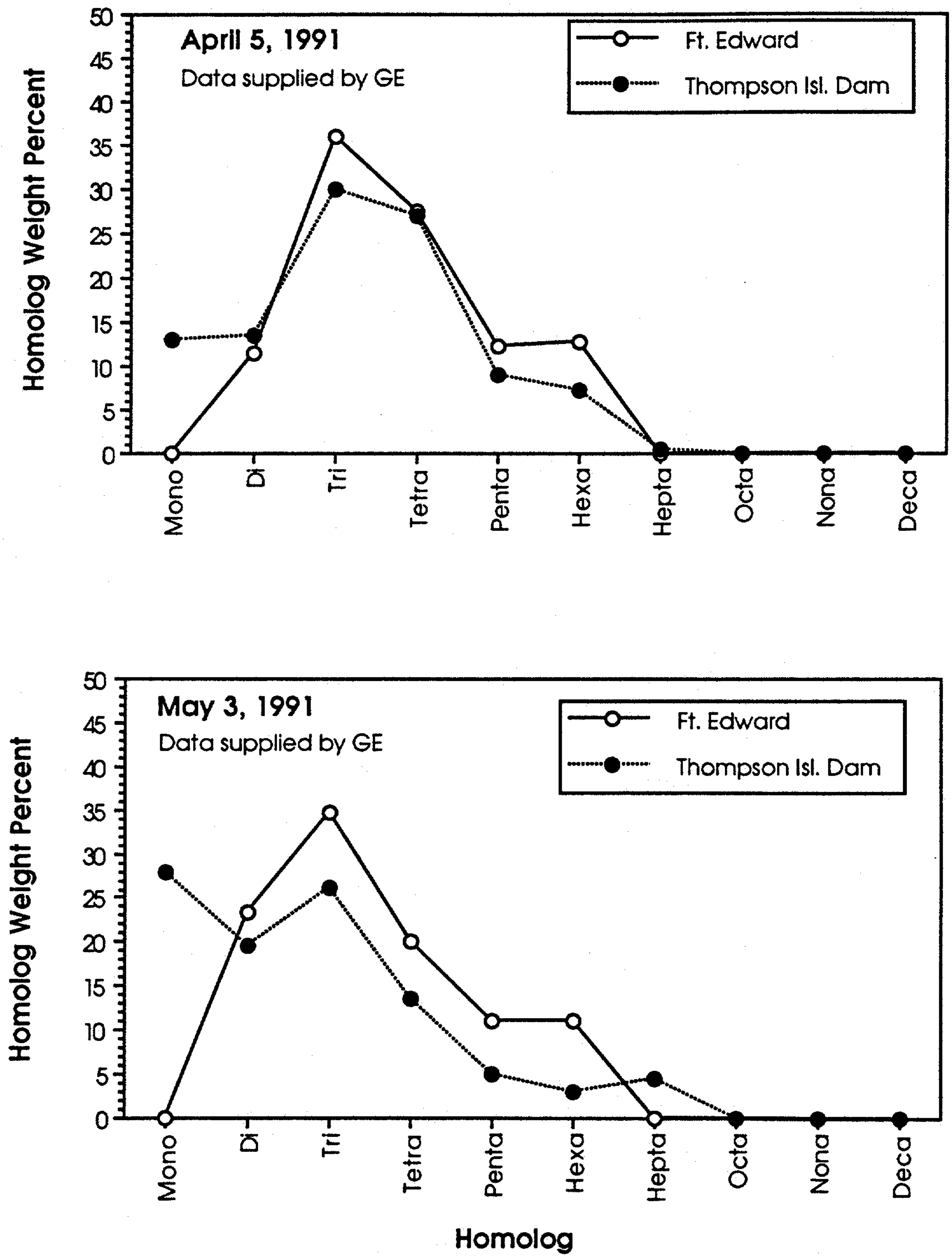
Figure 3.1
Homolog Content of Some Standard Aroclors



Note: The symbols indicate the mass percentage represented by the PCB homolog group on the horizontal axis. The lines connecting the symbols are intended to highlight the homolog group patterns and do not represent additional data.

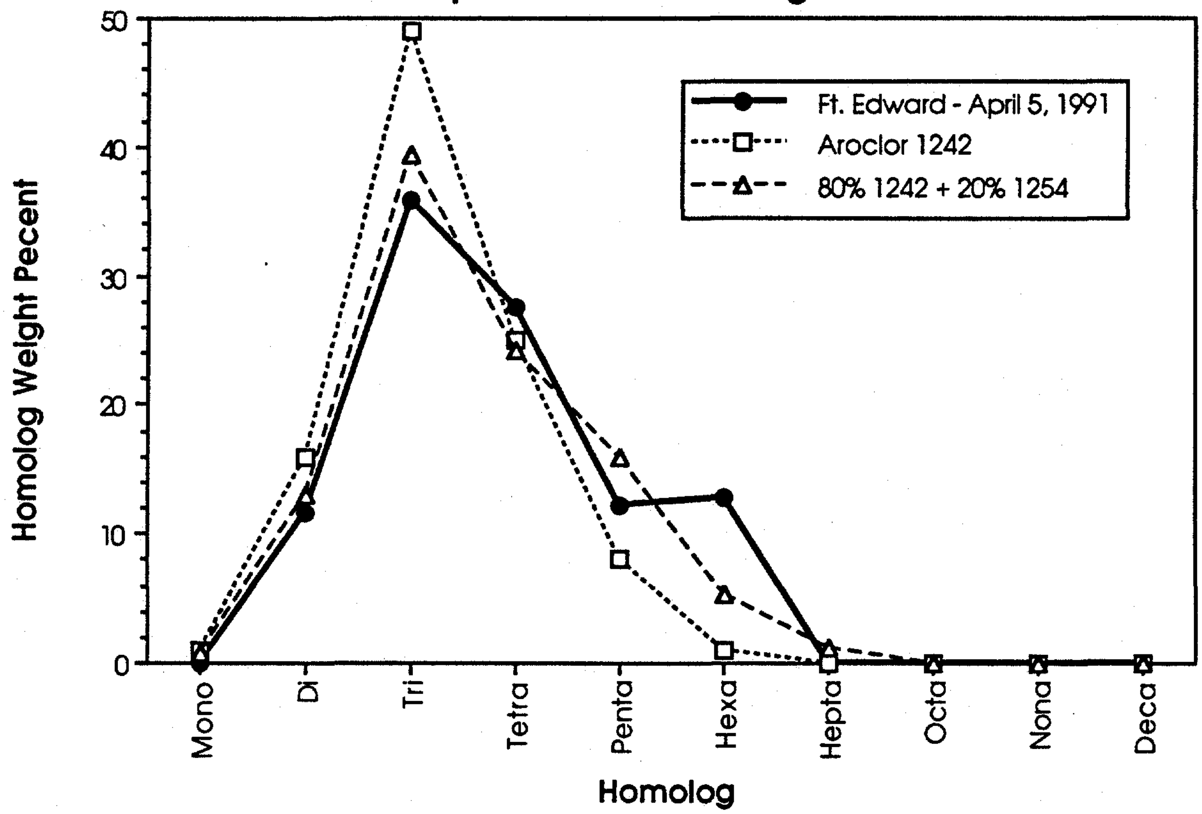
Figure 3.2

A Comparison of the Homolog Ratios in Total PCBs Across The Thompson Island Pool



Note: The symbols indicate the mass percentage represented by the PCB homolog group on the horizontal axis. The lines connecting the symbols are intended to highlight the homolog group patterns and do not represent additional data.

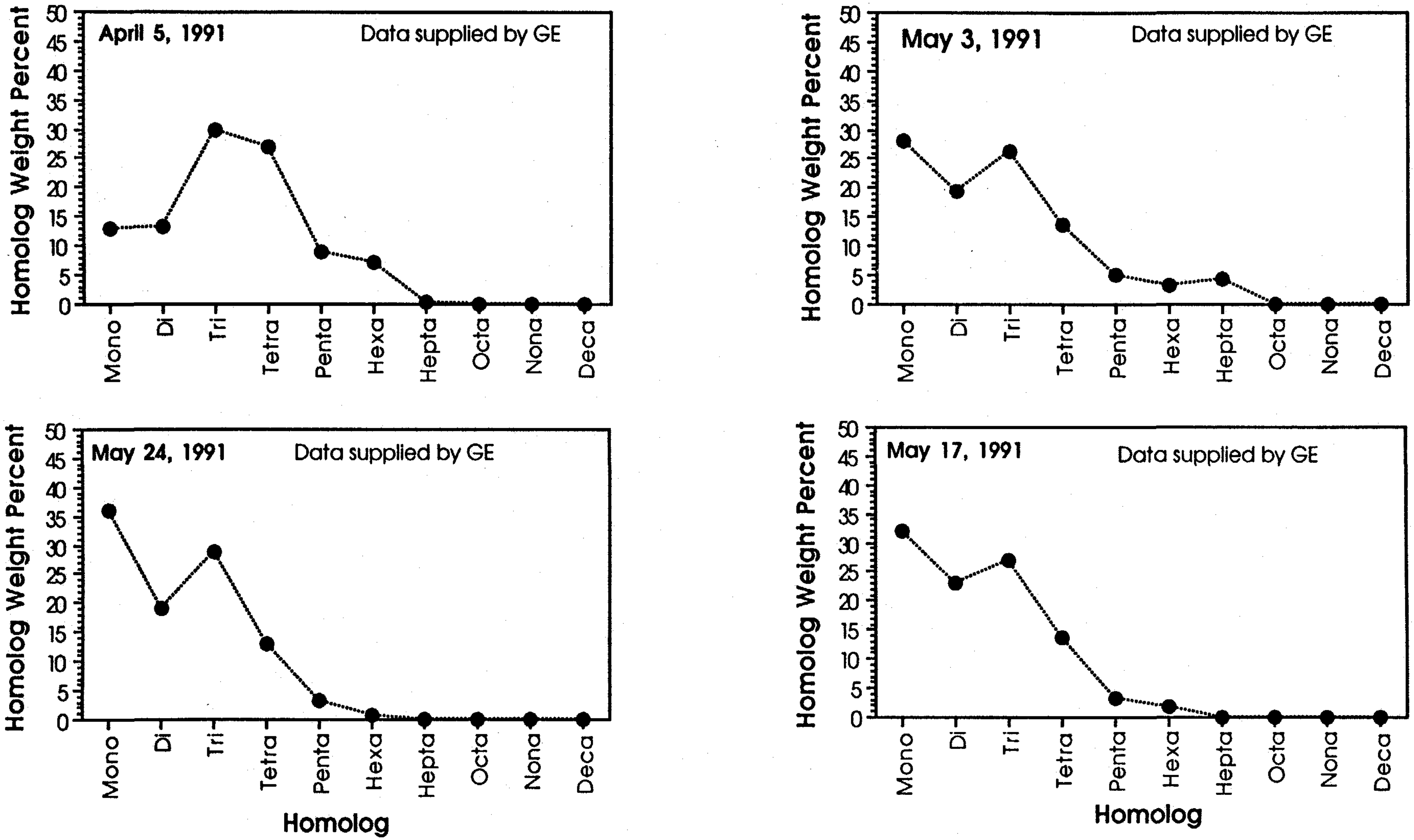
Figure 3.3
A Comparison of Homolog Mixtures



Note: The symbols indicate the mass percentage represented by the PCB homolog group on the horizontal axis. The lines connecting the symbols are intended to highlight the homolog group patterns and do not represent additional data.

Figure 3-4

Variation in the Homolog Distribution at the Thompson Island Dam with Time

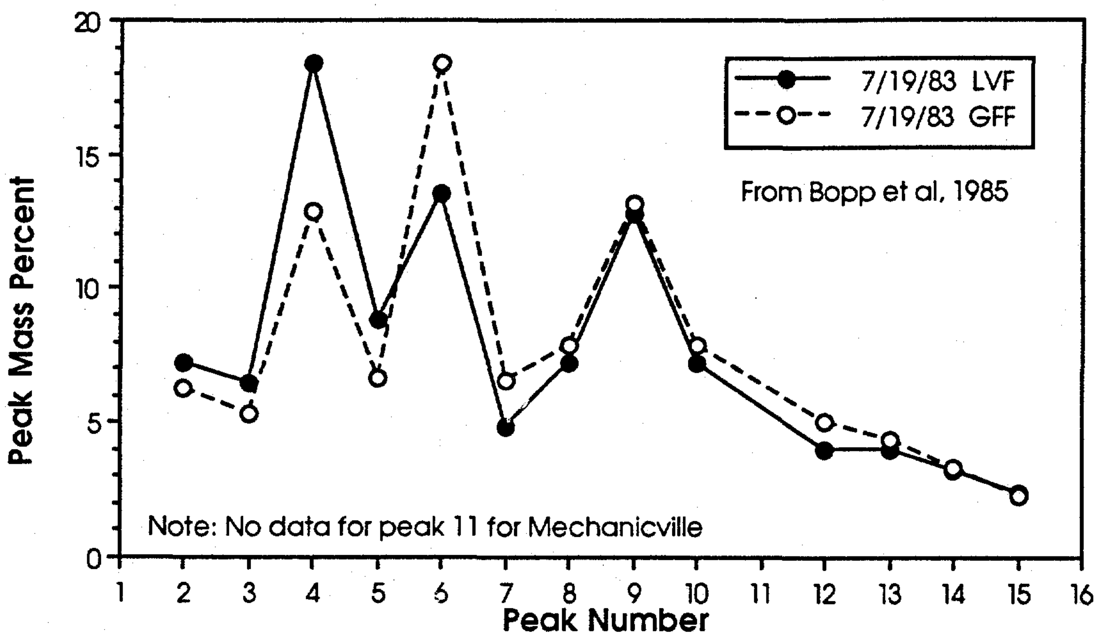


Note: The symbols indicate the mass percentage represented by the PCB homolog group on the horizontal axis. The lines connecting the symbols are intended to highlight the homolog group patterns and do not represent additional data.

312138

Figure 3.5

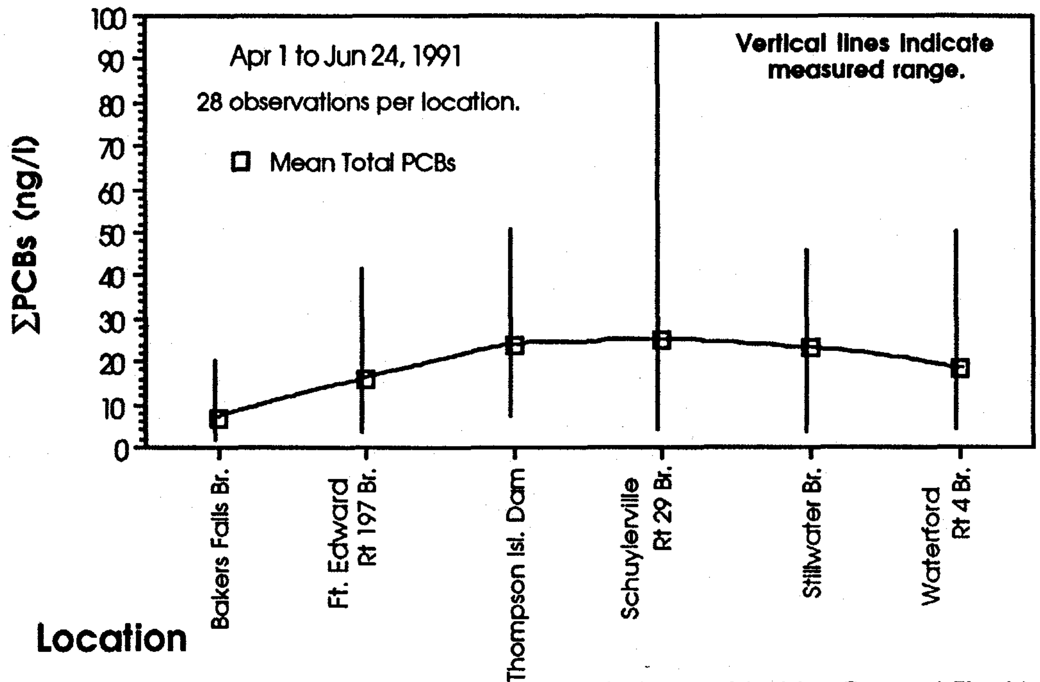
Comparison of Suspended Matter Packed Column Peak Results From Mechanicville, N.Y



Note: The symbols indicate the mass percentage represented by the PCB homolog group on the horizontal axis. The lines connecting the symbols are intended to highlight the homolog group patterns and do not represent additional data.

Figure 3.6

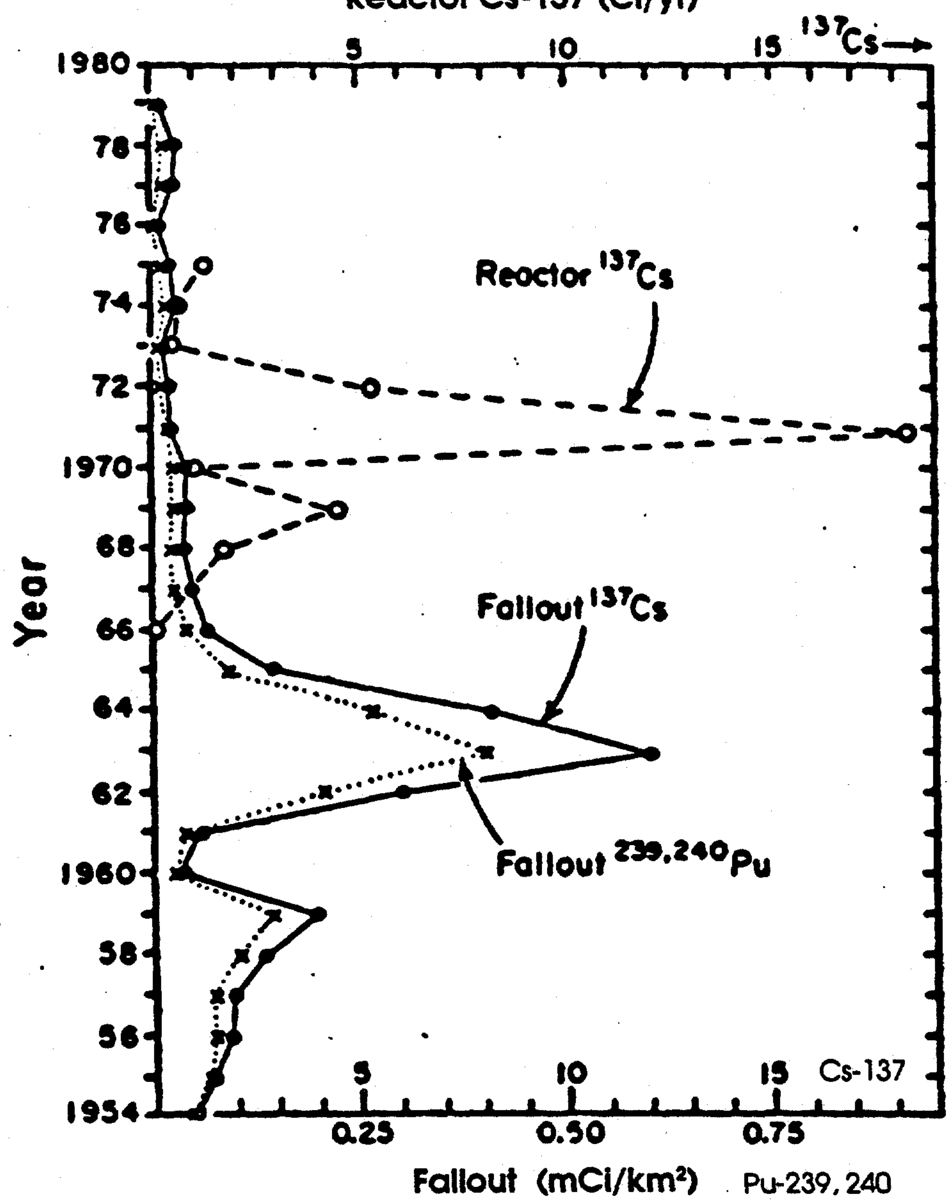
Total PCB Levels in the Hudson River



Data provided by General Electric

312140

Figure 3-7
Radionuclide Input to the Hudson Basin



Time history of fallout radionuclides delivered at New York and reactor releases from the Indian Point facility, decay corrected to 1980.

From Bopp et al, 1982

Figure 3.8

Cesium-137 and Total PCBs in a Core from RM 88.6 by Depth

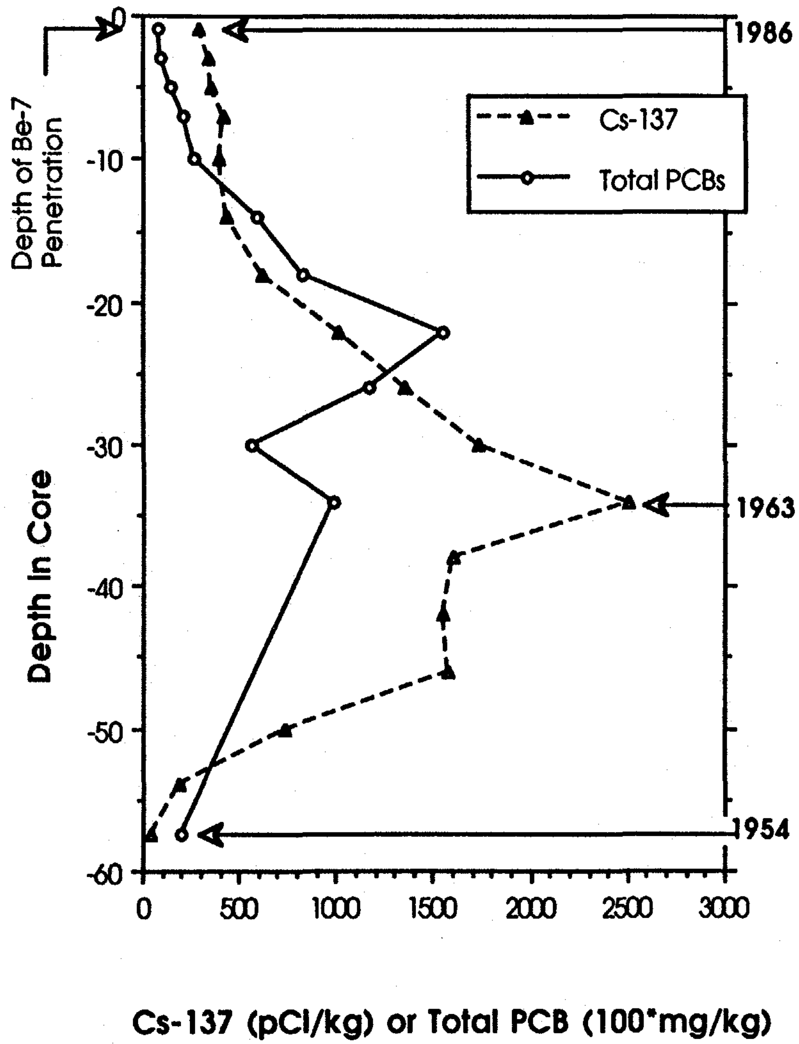
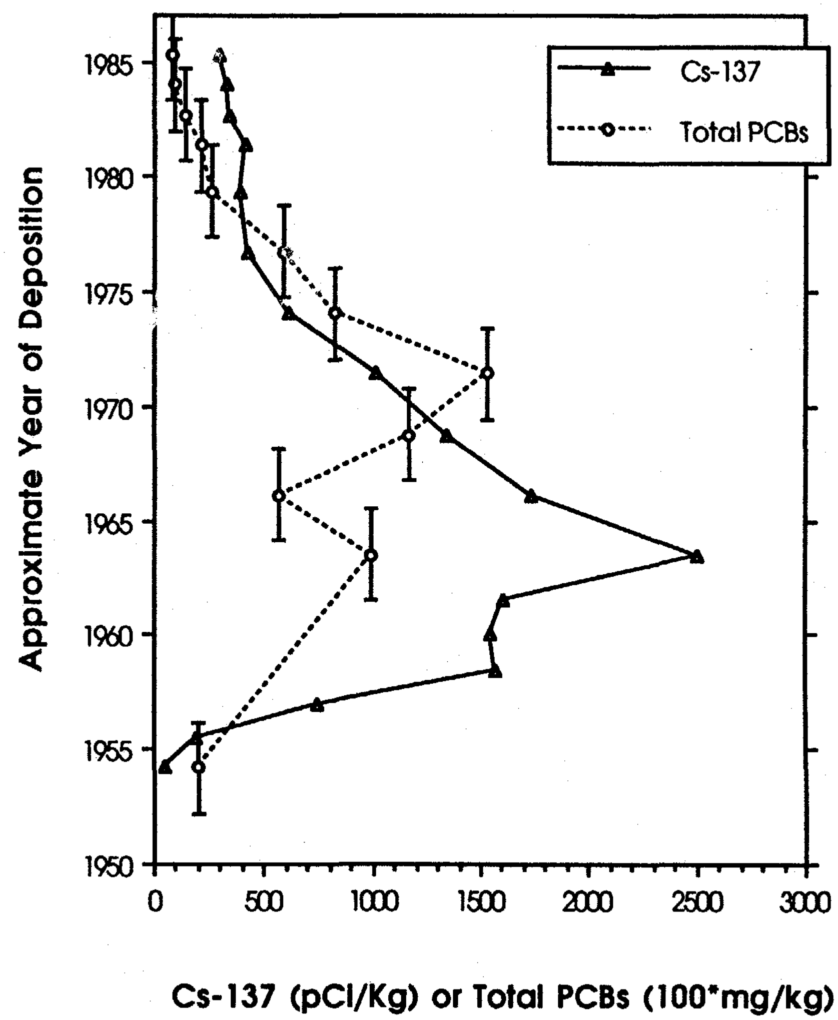


Figure 3.9

Cesium-137 and Total PCBs in a Core from RM 88.6 by Approximate Year of Deposition



312142

4. UPDATE OF TAMS/GRADIENT DATABASE

4.1 Computer Database

Phase 1 included the acquisition and analysis of available data on PCBs in the Hudson River. These data were assembled into a computerized database. Some minor omissions were noted in the Phase 1 Report, and others were noted in public comments on that report. In Phase 2, the TAMS/Gradient database will be updated for all four study areas to include:

- Data inadvertently omitted in Phase 1;
- Data collected by others which have, or will, become available, since Phase 1; and
- Data from Phase 2 sampling and analysis.

All additions to the database will be summarized and identified. When significant additions are made, analyses and findings of the Phase 1 Report will be checked, updated and utilized. In addition to the sampling and analysis data generated in Phase 2, additional data for upgrading the TAMS/Gradient database will include, but not be limited to, the items described in subsequent sections.

4.1.1 Historic Data in STORET Database

STORET includes many scattered and miscellaneous records of measurements of PCBs in water, sediment and fish in the Hudson and its tributaries in addition to those used in Phase 1. A complete listing of STORET PCB records for the State of New York will be examined for additional pertinent data. An important facet of this work for Study Area B will be accession of PCB measurements from the Hoosic and Mohawk Rivers.

4.1.2 GE Remnant Deposit Monitoring Data and HRRS Data

As part of the remedial activities associated with the Remnant Deposits, GE conducted an environmental baseline monitoring program. This program included monitoring of PCBs in sediment, water, aquatic biota and air. Ten aquatic sampling stations were established: two above the remnant deposits, six within the remnant deposit area, and two downstream. Sampling, performed by Harza in 1989 and 1990, was continued by O'Brien and Gere in 1991. The 1991 effort apparently includes biweekly water column analyses at six stations, with weekly congener-specific analyses at an 11 ppt (parts per trillion or ng/L) detection limit. The extensive sampling from this monitoring program will provide important input to the database. The recent congener-specific sampling will complement data to be collected in Phase 2.

The GE Hudson River Research Study (HRRS) was conducted between August and October, 1991 following completion of the Phase 1 Report; the data generated have not been integrated into the database, and will be in Phase 2. The HRRS was designed to (1) demonstrate that aerobic PCB biodegradation could occur under actual field conditions, based on prior laboratory investigations; (2) identify the key variables that influence the rate and extent of PCB biodegradation in Hudson River sediments; and (3) investigate the potential for natural aerobic degradation to occur in these sediments via indigenous PCB-degrading microorganisms.

4.1.3 USGS Water Column Monitoring

In Phase 1, USGS flow data were obtained through the end of Water Year 1990; PCB and other water quality data were obtained through the end of Water Year 1989. During Phase 2, attempts will be made to obtain the 1991 flow data as well as the 1990 and 1991 PCB and water quality data. The availability of PCB data will depend on the extent of analysis delays currently being experienced by USGS.

4.1.4 NYSDEC Fish Data

The Phase 1 Report utilized NYSDEC fish sampling through 1988. Data for 1990 and 1991 will be incorporated into the database in Phase 2, once the final data are available from NYSDEC.

4.2 Other Data Sources

4.2.1 Point Source Data

There are additional data to be collected on point sources of PCBs to the Hudson system. Table B.2-1 of the Phase 1 Report identified currently permitted PCB discharges into the Upper Hudson River drainage basin from the State of New York. In addition, another known source is permitted to discharge PCBs into the Hoosic River by the Commonwealth of Massachusetts. During Phase 1, only current (1991) SPDES Permits and Discharge Monitoring Reports were examined; examination of older SPDES files for these and other facilities may provide additional relevant information.

4.2.2 Other Current RI/FS Investigations

Currently, RI/FS investigations are being performed at the old GE Capacitor Manufacturing facility in Hudson Falls. According to NYSDEC, approximately 100 cubic yards of PCB-contaminated soils and oils were removed in January 1990 from an air plenum underneath the plant building. The data obtained from the NYSDEC study along with groundwater sampling for congener-specific data in Phase 2 will be assessed.

The results of another RI/FS study being performed at the Ciba-Geigy facility upstream of the GE facility will also be reviewed.

4.2.3 Dredge Spoil Disposal Sites

In Table B.2-2 of the Phase 1 Report, the PCB-contaminated dredge spoil disposal sites located near the Upper Hudson River (Study Area B) were identified. These are Old Moreau Dredge Spoil Area, Special Area 13 and Moreau Dredge Spoil Disposal Site. These sites are subject to ongoing monitoring by NYSDOT and NYSDEC. All pertinent records will be obtained and evaluated in Phase 2.

5. CONTAMINANT FATE AND TRANSPORT ANALYSIS

The Reassessment requires knowledge of the future impact of PCBs in the Hudson River system under conditions of No Action and various remedial alternatives; however, an exhaustive investigation of all aspects of the system, as proposed by some CIP participants, is not considered necessary. Rather, the effort in Phase 2 must be specifically focused on providing the information necessary for an informed decision among alternative remedial actions.

In the Phase 1 Report it was determined that human health risks from Hudson River PCBs are caused primarily by the consumption of contaminated fish. Therefore, the impacts of remedial alternatives on bioaccumulation of PCBs by the fish populations must be considered. Understanding bioaccumulation in fish is also essential for the evaluation of ecological impacts and risks. To accomplish this in Phase 2, it is necessary to develop a quantitative understanding of (1) future trends in environmental concentrations of PCBs, and (2) pathways for the accumulation of PCBs from the environment into the fish population.

The choice among remedial alternatives will require the answers to several specific questions relating to the future status of PCBs in Hudson River fish populations, including the following:

1. When will the PCB levels in the fish population recover to levels meeting human health criteria under continued No Action?

2. Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels, or could it make the current condition worse?

3. Are there sediments now buried and effectively sequestered from the food chain which are likely to become "reactivated" following a major flood, resulting in an increase in contamination of the fish population?

These questions reflect two different time scales, and a range of spatial scales. Possibilities of catastrophic flood scour, or sediment disequilibration following dredging, are events on a temporal scale of days or weeks, occurring in specific physical locations. On the other hand, the question of the general recovery of the fish population, particularly under conditions of No Action, appears to be measured on the scale of years. Assessing long-term impacts also has a broad spatial scale, which will be measured over whole reaches of the river.

Obtaining answers to these questions does not require the need of a highly detailed, dynamic transport model which attempts to describe all aspects of the system. For instance, modeling the short-term transport of PCBs in riparian systems utilizes computer codes which account for the time-dependent behavior of flocculating compressible organic sediments. Such state-of-the-art models, while difficult to parameterize and calibrate, are useful tools toward *understanding* the dynamic, micro-scale processes of PCB cycling in rivers. Fairly successful results have been obtained in simulating individual events, using a time step of seconds.[1] However, the spatial and temporal scales are not relevant to the questions we need to answer for the Reassessment (requiring long-term, spatially averaged mass balance analysis and event based analysis of scour, but not transport), and thus the expense of implementing such a model cannot be justified.

"What we need to know" can be best accomplished through a three component approach, focused to the Reassessment as follows:

1. **Long-term analysis of impacts using PCB mass balance approach.** This would involve analysis and prediction on a seasonal or annual time scale.

2. **Correlation analysis to predict average response of fish populations to environmental PCB levels.** This involves predicting future bioaccumulation through observed relationships to PCB levels in water *and* sediment.

3. **Erodibility analysis of contaminated sediment areas.** This involves analysis of specific local response to prospective

[1] Gailani, J., C.K. Ziegler and W. Lick. 1991. The Transport of Suspended Solids in the Fox River. (Draft). Dept. of Mechanical and Environmental Engineering, University of California, Santa Barbara.

flood events. Potential scour must be assessed in detail, but not necessarily the exact details of flood transport.

5.1 Component 1 - PCB Mass Balance Analysis

The objective of this component is to predict the PCB levels in water and sediment on a year by year and reach by reach average basis. It will be used to analyze the potential impacts of various remedial and source control schemes, and will provide the input to Component 2, from which fish burden impacts will be estimated. We will organize the mass balance analysis using the EPA modeling package WASP4 (version 4.31, EPA CEAM, Sept. 1991).

5.1.1 General Concept and Level of Detail

The mass balance analysis can be implemented in two stages, of which the second will be a detailed application. The first stage involves completion and evaluation of a general inventory of PCB stores and fluxes, and associated uncertainties. This serves to provide the "reality check" on more detailed analyses. In the second stage, the mass balance approach will be extended into a large-scale, long-term, *quasi-steady* model of PCB behavior in the system.[2] This is generally the approach that Thomann *et al*. used for the Lower Hudson (although there are a number of specific criticisms of their methods and assumptions.) Where our interest is in temporal and spatial average conditions, we can model long term PCB behavior by discretizing only to the spatial level of reaches with a seasonal time step for output, using WASP4. The transport portion of WASP4 is essentially a mass-balance accounting by segment. Thus, WASP4 provides the "accounting" framework in which to pose and answer questions relating to the mass balance.

The mass balance approach of WASP4 cannot handle the detailed simulation of a major flood/scour event and corresponding rapid redistribution

[2]*quasi-steady* here means that sediment derived inputs change only gradually with time and catastrophic releases are not modeled.

of contaminants. However, the mass balance approach is appropriate for evaluating the long term impacts of such a redistribution.

WASP4 is well suited to the task of macroscale analysis due to its link-node formulation. It allows incorporation of all the *stores* and *fluxes* most important to long term PCB status: sediment storage, multiphase transport in water, transport to and from sediments, volatilization, and degradation. The chemical transport module, TOXIWASP, allows detailed consideration of chemical reactions, and the model can simultaneously simulate a number of constituents. In this case we can simulate representative PCB congeners. The general partitioning/transport aspects of the model are summarized in Figure 5.1.

In order to implement WASP4, a number of flux parameters must be identified. Important fluxes include loadings to the river, transport from sediment to the water-column, from the water-column to air, and advective transport out of each reach. Loss or transformation of PCBs by degradation will also be considered.

5.1.2 Input from Sediments

Perhaps the most important aspect of the analysis is evaluation of transport of PCBs from in-place sediments to the water column. This consists of two separate issues: catastrophic mass erosion of contaminated sediments under extreme flood conditions, and transport from sediments to the water column under "typical" non-catastrophic conditions. The first aspect cannot be handled entirely in the context of macroscale, mass balance modeling, but will be evaluated through erodibility analysis, including hydrodynamic modeling, to be described below. However, the long term impacts of extreme floods can be evaluated in the mass balance context once the potential loading is estimated.

Transport of PCBs from the sediments under "typical" (non-catastrophic) conditions involves a number of processes:

1. Diffusion through and out of the sediments of the dissolved fraction and fraction sorbed to dissolved organic matter.

2. Advection through and out of the sediments in baseflow seepage, of both dissolved and sorbed components.

3. Sediment entrainment/exchange, involving exchange of sediment with the water column from an active mixing zone of the sediment bed.

The macroscale, mass balance model is most applicable to quasi-steady conditions, in which the sediments and bed configuration change only gradually with time and are not subject to massive disequilibration. This does not mean that no scour occurs, only that the bed configuration is nearly stable over time. The mass balance approach thus handles the quasi-steady case in which deposition and resuspension are both present, but nearly in balance with one another over a reasonably large area and time. This is appropriate for the Upper Hudson, where dam structures have a strong influence on sediment deposition, for the time period *since* the disturbance introduced by removal of the Fort Edward Dam in 1973 has died down. Analysis of the data in Phase 1 suggests this assumption is appropriate post-1983. The assumptions are also appropriate for the lower, estuarine Hudson where sedimentation velocities appear to be relatively steady on a year to year basis.

Phase 2 sampling is designed to identify this portion of the problem in several ways. First, we will be obtaining contemporaneous congener specific PCB levels in water and sediment, allowing direct examination of fluxes. Secondly, high resolution coring in areas without substantial degradation will allow the fitting of diagenetic models to describe sediment deposition and contaminant fluxes.[3] For instance, it has already been demonstrated that radionuclide profiles can be used to obtain accurate estimates of diffusion coefficients in Hudson River sediments.[4] Finally, the information obtained from dateable cores can be used to calibrate an annual model of transport in the system.

---

[3]Berner, R.A. 1980. "Early Diagenesis, A Theoretical Approach". Princeton University Press, Princeton, NJ

[4]Olsen, C.R., H.J. Simpson, T.-H. Peng, R.F. Bopp and R.M. Trier. 1981. Sediment mixing and accumulation rate effects on radionuclide depth profiles in Hudson estuary sediments. *Journal of Geophysical Research* 86(C11): 11020-11028.

5.1.3 Suspended Sediment/DOC/Water Partitioning

Even though PCB phase partitioning is not instantaneous and reversible it can be assumed so for the long time horizons of the mass balance model. We will also assume linear partitioning, which is generally appropriate when sorption sites are plentiful. WASP4 also provides the option of making the sorption coefficient dependent on solids concentration, as proposed by DiToro.[5]

Analysis of multiphase partitioning will be required in the modeling. Much of the transport of PCBs is expected to take place sorbed to fine sediments. However, it has also been observed that Hudson River PCB concentrations obtained by filtering water samples at 0.7 microns may be approximately a factor of 2 greater than concentrations obtained by in stream large volume filtration at 1.2 microns.[6] The reasons for this discrepancy are not clear. In general for strongly hydrophobic chemicals such as PCBs we can expect a significant role for facilitated transport involving binding of PCBs to dissolved organic compounds (DOC) or, more generally, to non-settling non-filterable organic matter (NSOM). Chin *et al*. note that "the amount of polymeric organic matter commonly found in natural aqueous systems is apparently enough to effect the partitioning of very hydrophobic...contaminants such as PCBS..." making the observed partition coefficients "highly dependent" on the organic carbon concentration.[7]

WASP4 provides the opportunity to simulate several sediment classes, including DOC. At least two classes would be needed for PCB modeling besides DOC, generally representing fine silt particles which are filterable but do not

---

[5]DiToro, D.M. 1985. A particle interaction model of reversible chemical sorption. *Chemosphere* 14(10):1503-1538.

[6]Bopp, R.F., H.J. Simpson and B.L. Deck. 1985. Release of Polychlorinated Biphenyls from Contaminated Hudson River Sediments. Final Report NYS C00708 to NYSDEC. Lamont Doherty Geological Observatory, Palisades, NY.

[7]Chin, Y.-P., W.J. Weber and B.J. Eadie. 1990. Estimating the effects of dispersed organic polymers on the sorption of contaminants by natural solids. 2. Sorption in the presence of humic and other natural macromolecules. *Environ. Sci. Technol.* 24(6): 837-842.

settle out in the upper Hudson, and heavier settleable particles. (Heavier mineral particles are not expected to play an important role in PCB transport.)

At present, data are rather limited on levels of non-filterable organic matter in the Hudson.

5.1.4 Evaluation of Degradation and Volatilization Rates

Degradation and volatilization rates may vary considerably among congeners. It will not be feasible to model all the PCB congeners present in the Hudson system. However, we will plan to model the behavior of a representative selection of congeners typical of Aroclor 1242, Aroclor 1254 and their breakdown products.

Rates of natural degradation of PCBs in the sediments of the Hudson have been the subject of considerable debate. In the Thompson Island Pool sediments, at least, it is clear that some degree of anaerobic dechlorination of various congeners is taking place. This may be an important source for the loading of mono- and dichlorobiphenyls into the water column. However, it is not yet clear if, or to what degree, these processes represent a significant reduction in mass of PCBs in the sediments.

A significant amount of laboratory scale work has been conducted on the degradation of PCBs. However, extrapolation of these results to field conditions is fraught with uncertainty. Therefore, we will attempt to verify degradation rates in the field. The primary source of information for this will be congener analysis of sediment cores. Shifts in congener patterns resulting from dechlorination have been reported by previous authors.[8] While there is no doubt that some reductive dechlorination does take place in the sediments, the average rate is difficult to determine and may be fairly slow. Further, the

---

[8]Bopp, R.F., H.J. Simpson and B.L. Deck. 1985. "Release of Polychlorinated Biphenyls from Contaminated Hudson River Sediments." Final Report NYS C00708 to NYSDEC, Albany, NY. Lamont Doherty Geological Observatory of Columbia University, Palisades, NY ; Brown, J.F., R.E. Wagner, and D.L. Bedard. 1988. PCB dechlorination in Hudson River sediment. *Science* 240: 1675-1676.

process may largely involve the reduction of more reactive congeners and accumulation of more recalcitrant congeners. Convincing evidence must thus be obtained to attribute anaerobic dechlorination as a significant means of mass loss of buried PCBs.

In investigating this problem we will continue the work of examining congener patterns in the hotspot sediments. If possible, this will be done in both low resolution sampling and in intact, dateable high resolution cores, which would yield an approximate time scale for the reduction process. Finally, we will attempt to reproduce locations of earlier analyzed and archived cores. This should enable direct comparison of the status of PCBs at two different points in time.

Aerobic degradation takes place in the oxygenated sediments and in the water column. Rates in the sediment are again difficult to determine, and difficult to distinguish from differential desorption of lighter chlorinated congeners. However, the net effect of these processes can be observed in the sediments. For degradation in the water column, our initial approach will be to investigate literature evidence on aerobic degradation rates in order to determine if this phenomenon is significant in terms of the PCB mass balance. Additional work to quantify degradation will be needed only to the degree that model results are sensitive to this rate.

Volatilization is known to play a significant role in the depletion of PCBs in the water column. Photolysis may also be an important loss mechanism (*vid* Lake Ontario TCDD work). Our present plan is to rely on published and theoretically derived values of these parameters. As with the aerobic degradation rates, model results would be subjected to an uncertainty analysis, which might suggest the need for further research on these parameters, if results are particularly sensitive to them.

5.1.5 Uncertainty Analysis

An important part of the mass balance will be the assessment of uncertainties. Confidence bounds will be developed for each significant store and flux in the mass balance. The cumulative impact of uncertainties will be assessed through implementing the mass balance model in a Monte Carlo simulation mode.

5.2 Component 2 - Biotic Effects/Fish Population Response

The previous section covers methods to estimate the long-term, steady-state environmental distribution of PCBs in the Hudson. This in itself does not yield decision criteria for the Reassessment: such criteria depend on analysis of risks, and human health risks are presented primarily through PCB levels in the fish population. Thus, the Reassessment requires us to estimate future concentrations in the fish population. PCBs may also present direct ecological risks to the fish population. To accomplish this we propose the use of a correlation analysis approach which relates observed fish PCB burden simultaneously to concentrations in both water and sediment.

A number of possible strategies were considered for the prediction of PCB burdens in the fish population, from the very complex to the very simple. A complex approach, which has previously been tried in the Lower Hudson[9], constructed a detailed model of PCBs in the food web, thereby enabling prediction of bioaccumulation. The other extreme is to assume a simple equilibrium partitioning approach, which attempts to relate the concentrations in target species to PCB levels in either the water or sediment, via a bioaccumulation factor (BAF). The approach proposed is related to the BAF approach, but does not require simplistic full equilibrium assumptions. This constitutes a multimedia correlation analysis, which can be thought of as a multivariate BAF which does not impose the assumption of equilibrium between the sediment and water

[9] Thomann, R.V., J.A. Mueller, R.P. Winfield and C.-R. Huang. 1989. "Mathematical Model of the Long-term Behavior of PCBs in the Hudson River Estuary." Report prepared for The Hudson River Foundation, June 1989. Grant Nos. 007/87A/030 and 011/88A/030.

components. It should be noted that the correlation approach implicitly accounts for all forms of uptake by the fish, from direct partitioning to food chain accumulation, although only the net effect is observed.

In the following paragraphs we will provide a detailed discussion of the characteristics and weaknesses of both the food web and equilibrium partitioning approaches. This will be followed by a description of the proposed correlation analysis.

5.2.1 Food Web Model Approach

The food web approach to predicting PCB bioaccumulation in the fish population is intuitively promising, because it appears to provide a global, causal description of PCB dynamics in biota. However, the approach has many difficulties. Our conclusion is that this approach would involve a high expense, yet not result in a clear increase in ability to predict PCB burdens. It is therefore not justified as cost effective for the Reassessment.

Essentially, the food web approach requires the prediction of PCB bioaccumulation of most species in the system, not just target species. This necessarily includes many lower trophic level species for which there is no historical database of PCB concentrations. Further, the predictive ability of a food web model is dependent on an accurate description of population dynamics - again an area where a historical database is lacking. Acquiring adequate data would require a massive sampling program, one that would necessarily extend over several years in order to remove the effects of natural year to year variability.

The difficulties inherent in the food web approach are quite evident in the work of Thomann *et al*. Their aim was predicting PCB status in the striped bass population. For this undertaking they had the advantage of detailed population dynamic studies conducted for the licensing of power plant water intakes. However, other data were lacking and numerous detailed assumptions had to be made considering the relative importance of different food sources in different age classes of the striped bass population. An important shortcoming seems to be that the benthic pathway into the food chain is essentially ignored. Application of the model resulted in a prediction that by 1992 the median PCB concentration in three to six-year old striped bass would be below the FDA threshold of 2 μg/g (wet weight). Although 1992 data are not yet available, the most recent data suggest that this prediction is unlikely to come true.

5.2.2 Equilibrium BAF Approach

Analysis of the historical database in Phase 1 has provided support for the idea that PCB concentrations in the fish population, on a lipid-adjusted basis, can be reasonably predicted directly from environmental concentrations without explicit modeling of population dynamics. The empirical evidence is summarized in Figures B.4-25 (reproduced here as Figure 5.2) through B.4-29 of the Phase 1 Report, as well as earlier work of Brown *et al.*[10] These show a strong linear relationship between summer average PCB concentration in water and lipid-adjusted PCB burden in fish. This suggests that summer average (*i.e.*, nonscouring) water concentrations provide an excellent predictor of fish concentrations, via a BAF. The strong relationship observed is even more striking when it is realized that it is accomplished without the benefit of a congener-specific analysis. Presumably, congener data would strengthen the predictive ability.

Of course, statistical correlations do not themselves imply either causality or the ability to extrapolate to future conditions. It is also clear that much of the statistical strength of the observed correlations between water column and fish PCB concentrations is due to a few early observations, in which PCB concentrations in both water and fish were high, while more recent observations are clustered about a constrained subsection of the line. This does not mean that the observed correlation is invalid; rather, it reflects the fact that concentrations in both fish and water have been relatively stable since 1981. Further, we must expect a certain amount of "noise" in any correlation

[10]Brown, M.P., M.B. Werner, R.J. Sloan and K.W. Simpson. 1985. Polychlorinated biphenyls in the Hudson River, recent trends in the distribution of PCBs in water, sediment and fish. *Environmental Science and Technology* 19(8): 656-661.

based on gross estimates of total PCBs rather than individual congeners given any shift in congener pattern over time.

The observations presented in Phase 1 address only the correlation between PCB concentrations in water and fish PCB burden. However, sediment stores of PCBs may also provide an important pathway into biota. In Phase 1 we did not develop a correlation between fish PCB burden and PCB concentrations in sediment, because of a lack of an adequate database: The direct sediment measurement we had for Phase 1 are primarily at two points in time (1978 and 1984) and, except for limited data in 1978, confined to a location (the Thompson Island Pool) where a contemporaneous database for fish concentrations does not exist. Further, most of the sediment data lack measurements of organic carbon fraction (foc), which is essential to calculating the dissolved and/or bioavailable fraction of PCBs in the sediments.

PCB analysis of dateable, high resolution sediment cores affords an opportunity to combine the signals of water column and surface sediment concentrations. Unfortunately, most of the core data prior to 1978 does not coincide with NYSDEC standardized analysis of fish PCB burden. In addition, the location of extant high resolution cores does not match the NYSDEC fish sample collection points. Thus, during Phase 1, it was not possible to examine the value of PCB data from dateable cores as a predictor of fish concentrations. The high resolution coring program proposed for Phase 2 will remedy this situation.

For a system in which sediment and water are in equilibrium there is also a strong theoretical basis for the BAF approach. This is based on the concepts of equilibrium partitioning and fugacity, which imply, for equilibrium conditions, that a BAF approach should be as effective a prediction tool as any identifiable food web model.[11]

---

[11]Di Toro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas and P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. *Environmental Toxicology and Chemistry* 10(12): 1541-1583.

The basic argument can be introduced by considering the case of a closed system, constituting a well mixed body of water with no influx or efflux. In this closed system PCB concentrations in all compartments would be in equilibrium, with the concentration in any one compartment derivable from observations in any other compartment via an equilibrium partitioning coefficient. Thus, a univariate BAF can be established from measurements in any single medium.

As noted above, for hydrophobic contaminants such as PCBs, it is necessary to describe a three-phase system, in which PCBs in both sediments and water column are found in dissolved form, sorbed to particulate matter, and complexed with dissolved organic compounds (DOC). Fish may accumulate PCBs through partitioning from the water column, through ingestion of sediment, or through the food chain, while organisms at lower trophic levels may also accumulate PCBs from both water column and sediments. Describing exact accumulation pathways is the complex task of food chain bioaccumulation models. For an equilibrated system, sediment pore water PCB dissolved concentrations might provide a good index of bioavailability, but it is typically a very difficult task to separate the dissolved and DOC fractions. Fortunately, for lipophilic compounds in sediments at normal organic carbon contents, the partition coefficients are such that the mass present in dissolved and DOC complexed forms is relatively small compared to the total particulate-sorbed mass. This implies that the dissolved portion can be quite well predicted from the sediment-water partition coefficient, regardless of DOC levels. (DOC complexed mass is, however, important in predicting total flux out of the sediments.) On the other hand, pore water concentrations will vary significantly in response to the organic carbon content in sediment, *i.e.*, the fraction of organic carbon in the sediments on a weight basis (foc). Therefore, sediment concentration <u>normalized to foc</u> is the best, readily available predictor of dissolved concentrations in an equilibrium system.[12] This approach is under

[12]Di Toro *et al.*, *op. cit*

consideration by EPA Office of Water for establishing sediment quality criteria.[13]

Of course, PCBs may enter the food chain both through the dissolved phase and through ingestion of particulate matter (the DOC complexed phase may be largely non-bioavailable, as noted above). As Di Toro *et al*. state, "biological effects appear to correlate to the interstitial water concentration. This has been interpreted to mean that exposure is primarily via pore water. However, the data correlate equally well with the organic carbon-normalized sediment concentration... This suggests that the sediment organic carbon is the route of exposure. In fact, neither of these conclusions necessarily follow from these data".

The reason for this surprising conclusion is contained in fugacity,[14] or chemical potential theory.[15] This holds that the biological activity of a contaminant is controlled by its chemical potential. As discussed by Di Toro *et al*., if pore water and organic carbon are in equilibrium then the chemical potentials exhibited by the two phases are equal. "Hence, so long as the sediment is in equilibrium with the pore water, the route of exposure is immaterial. Equilibrium experiments cannot distinguish between different routes of exposure." Thus, in the simplified equilibrium case, it is only necessary to estimate the chemical potential in one phase. The question then becomes one of which phase is easiest to measure. Where DOC complexing occurs it is clear that sediment PCB concentration normalized to organic carbon is the most directly measurable index of chemical potential.

The simple BAF approach thus has a strong theoretical basis. The drawback is that the analysis is based on simplification of reality, which

[13]U.S. Environmental Protection Agency Office of Water. 1991. "Proposed Technical Basis for Establishing Sediment Quality Criteria for Nonionic Organic Chemicals Using Equilibrium Partitioning." August 1991, Office of Science and Technology, Health and Ecological Criteria Division, Washington, DC.

[14]Fugacity is a measure of the escaping tendency of a chemical from one phase to another.

[15]Mackay, D. 1979. Finding fugacity feasible. *Environ. Sci. Technol.* 13:1218.

requires sediment and water column concentrations to be in equilibrium. This is likely not the case in the Hudson River, where the water column does not remain in one place long enough to allow diffusion limited equilibration between PCBs in the sediments and the water-column. The simple, single medium, BAF approach must thus be modified to account for non-equilibrium conditions.

5.2.3 Correlation Analysis Approach

A correlation analysis approach will be used which will examine the relationship between PCB levels in biota and PCB concentrations in both water and sediment. This is essentially a BAF approach which has been modified to account for the fact that full equilibrium partitioning does not occur. This is done by extending the analysis to account for the most significant disequilibrium in the system.

In a flowing river, the usual case is that the upper sediment layer and the water column are *not* in equilibrium with one another. Further, the upper, bioactive sediment zone is typically not in equilibrium with deeper, buried sediments. However, the sediment sorbed PCB concentrations and pore water PCB concentrations within the bioactive zone should be very close to equilibrium, while in the water column the dissolved and suspended sediment-bound PCB fractions should also be close to equilibrium (except during transient events) although their measurement may be hindered due to a DOC phase. The fact that the water and sediment compartments are not in equilibrium with each other, but are approximately internally equilibrated, suggests that the optimal predictors of concentrations in biota should be multivariate BAFs, relating body burden to *both* sediment and water column chemical potential. Correlating to both removes the difficulty of the water and sediment not being in equilibrium (which is equivalent to saying that the water concentration cannot be predicted solely from the local sediment concentration). It further accounts for bioaccumulation pathways from both water and sediment. Similar to the pure equilibrium case, a distinction may be observable between the water and sediment pathways, but the individual phase pathways within water or sediment should be indistinguishable.

The equilibrium partitioning/fugacity arguments set forth by Di Toro *et al.* also inform us that the best readily measurable index of chemical potential should be the sediment sorbed fraction normalized to foc, which removes the problem of estimating the magnitude of the DOC fraction. This should apply to both sediments and water column. These should be compared to the lipid-normalized burden in the organism.[16] The correlation analysis will thus be used to predict fish PCB burdens from future environmental concentrations through species-specific relationships of the following form:

$$\frac{Cf_i}{fl_i} = Bw_i \cdot \frac{Cs_w}{foc_w} + Bs_i \cdot \frac{Cs_s}{foc_s}$$

in which, for species i:

Cf	=	PCB concentration in fish (wet weight)
fl	=	lipid fraction in fish
Bw	=	Partial BAF relating fish concentration to water column concentration
Cs_w	=	PCB concentrations on suspended solids
foc_w	=	organic carbon fraction of suspended solids
Bs	=	Partial BAF relating fish concentration to upper zone sediment concentration
Cs_s	=	PCB concentration in upper zone sediments (dry weight basis)
foc_s	=	organic carbon fraction of the sediments

[16] Chiou, C.T. 1985. Partition coefficients of organic compounds in lipid-water systems and correlations with fish bioconcentration. *Environ. Sci. Technol.* 19: 57-62.

Phase 2 data gathering is designed to allow the examination and testing of the suitability of this proposed method for predicting future PCB burdens in fish from environmental PCB concentrations. If the method proves feasible it will be used to assess the likely impact of the various remedial options under consideration, as well as the recovery time under No Action.

5.3 Component 3 - Erodibility Analysis

Sediments constitute the major store of PCBs in the Hudson. The Thompson Island Pool is of particular concern, as large quantities of PCB contaminated sediments were deposited in this reach following the removal of the Fort Edward Dam in 1973. PCBs are also stored in depositional areas throughout the Hudson below the Thompson Island Dam. However, much of the contaminated sediment is currently buried at depth, and not in ready contact with the water column or biota. Stored PCBs in buried sediments affect water column PCB concentrations only through slow diffusive flux.

The mass balance approach to the analysis (Component 1) addresses current and future PCB dynamics in the Hudson given a quasi-steady state situation for contaminated sediments. This refers to a situation in which a sudden change in PCB flux due to extensive scour of currently buried contaminated sediments does not occur. This appears to fit the observed data on PCB load, where we have noted that the load appears to have stabilized over the years. Furthermore, a significant gain in load, which could be attributed to scour of contaminated sediments, is not observed between the upstream and downstream ends of the Thompson Island Pool (see Figure 5.3).

The quasi-steady state approach assumes that introduction of PCBs into the water column by flood scour is currently a process of relatively minor significance which occurs at an approximately constant annual rate. Although this appears to represent the situation observed in recent years, it is not sufficient to assume, without further investigation, that no change in the system will occur in response to future major flood events. Therefore, a third component must be added to the analysis. This is an assessment of the potential for flood scour of buried, contaminated sediments. This includes the possibility that a major flood might reintroduce quantities of now segregated PCBs into the water column and surface sediment layers available to the water column and biota.

Hence, the objective of Component 3 is to evaluate the probability of flood erosion of contaminated hot spot sediments during realistic future extreme flood events. One result of the analysis will include a map of erosion probability which can be superimposed on the map of PCB sediment distribution. This will serve to identify the relative risk posed by different PCB hotspots, as well as yielding the overall likelihood of significant remobilization of buried PCBs. Such a map will also be a guide to planning remediation of sediments, if necessary. To accomplish this analysis laboratory experiments, field studies, mathematical modeling, and statistical analyses will be necessary. The map will incorporate statistical techniques to show upper and lower bounds in the critical regions of erosion. The work is divided into two studies, hydraulic and sediment transport/erodibility studies.

5.3.1 Hydraulic Studies

The first requirement is the determination of the maximum hydraulic energy available for erosion. Phase 1 included analysis to determine the 50 year, 100 year, 200 year and 500 year recurrence floods. These flows can be routed through the Study Area and the local water velocities and elevations determined. Local water velocities will determine the shear and sediment transport capacity during high flows.

Phase 1 included preliminary efforts at modeling flows in the Thompson Island Pool using one- and two-dimensional applications of a link-node model, WASP4. For the purposes of assessing erodibility we have determined that one-dimensional flow routing will be sufficient, and is the appropriate level of detail in light of both available calibration data and uncertainties inherent in modeling sediment properties.

While it would be of technical interest to utilize a computer code written to solve a two or three dimensional representation of flow, this effort would not necessarily result in any improvement in accuracy of the predictions. This is because model results are dependent on representation of the physical process, numerical solution procedure, initial and boundary conditions, and calibration of parameter values, all of which introduce errors. Therefore, the model results are also subject to uncertainty, and this uncertainty will increase if, for instance, the calibration data are inadequate to the discretization detail of the model. A detailed review of uncertainty in models is given by Beck.[17]

A classic application of an appropriate type of model for a large river system, the Rhine-Meuse estuary, is described by Roelfzema *et al.*[18] These researchers have used a one-dimensional model to represent areas where the width/depth ratio is less than 100. For an area whose width is extremely large they used a two-dimensional depth averaged model. In regions where stratified salinity distribution is observed, a two-dimensional laterally averaged model was utilized. A three-dimensional model was employed to represent the sea-area at the mouth of the estuary.

The width-depth ratio of the Hudson within the study area is less than 100. Therefore, a one-dimensional approach is appropriate to both hydraulic and sediment transport modeling.

5.3.2 Sediment Erodibility

Characterizing scourable areas in the river will depend on the type of bed material. Certain reaches may be cohesive while, others may be non-cohesive. Therefore, demarcating the Study Area as to whether it contains cohesive or, non-cohesive material is important. This will be accomplished

---

[17]Beck, M.B. 1987. Water quality modeling: a review of the analysis of uncertainty. *Water Resources Research* 23(8): 1393-1442.

[18]Roelfzema, A., M. Karelese, A.J. Strujik and M. Adriaanse. 1984. "Water Quantity and Water Quality Research for the Rhine-Meuse Estuary". Publication No. 325. Delft Hydraulics Laboratory

primarily by the geophysical survey and confirmatory sampling. For the present purpose, sediments having more than 10% clay sized particles, (< 4 μm), by weight will be considered cohesive.[19]

The critical factor considered in this study is bed erosion. The mechanisms causing bed erosion are different for cohesive and non-cohesive soils. The formulations used to account for erosion are based on the hypothesis that the hydraulic shear stress has to exceed a critical bed shear stress, τ^*c, for erosion/resuspension to take place. Some of the formulas available in the literature are tabulated in Table 5.1 for cohesive material. These formulae are material and site specific. Therefore, for the cohesive bed material encountered in the study area, τ^*c must be determined in the laboratory.

A laboratory set up described in the Sampling Plan (Appendix A) is to be employed to study erosion. This experiment can be used to measure depths of erosion and critical shear stress at different threshold levels. This is due to the fact that different threshold levels of erosion can be defined.[20] The critical shear stress determined in the laboratory will be compared with the formulas available in the literature. The advantages in this technique are: the entire water column is represented and undisturbed sediment core is utilized.

It is intended to fit a statistical distribution for the critical bed shear stress and use this as a model input for the different simulations. The concept of a probability distribution for critical stress has been used by Einstein as quoted by Vanoni[21] and Partheniades.[22] It is felt that the distribution will vary depending on the type of material leading to different distributions being used at different locations. The predefined quantiles and

---

[19]Raudkivi, A.J. 1990. "Loose Boundary Hydraulics" (3rd edition), p.300. Pergamon Press.

[20]Lavalle, J.W. and H. O. Mofjeld. 1987. Do critical stresses for incipient motion and erosion really exist? *ASCE Journal of Hydraulic Engineering* 113(JHY 3)(3): 370-385.

[21]Vanoni, V.A. 1977. "Sedimentation Engineering". ASCE Manuals and Reports No. 54, pg. 94.

[22]Partheniades, E. 1965. Erosion and deposition of cohesive soils. *ASCE Journal of Hydraulic Engineering* 104(HY2): 279-283.

their upper and lower limits could also be used as model inputs in preparing the probability maps.

No laboratory experiments will be conducted to determine critical shear stress for cohesionless material. Formulas available in the literature will be used to determine values. As there are numerous formulas available to determine critical shear stress for cohesionless sediments they have not been summarized in a table. However, field studies will be conducted to determine the composition of cohesionless material on the bed.

To summarize, Component 3 encompasses:

(a) Mathematically modeling hydraulic flows,

(b) Conducting experiments to determine physical properties of sediment,

(c) Conducting laboratory experiments to determine statistical distribution for the critical shear stress,

(d) Identifying areas of erosion/sedimentation,

(e) Employing a statistical distribution of critical shear stress to provide upper and lower probability limits for the hazard prediction.

PAGE INTENTIONALLY LEFT BLANK

Table 5.1
Summary of Critical Stress Formulae for Cohesive Sediment

Reference	Expression
Ariathurai, R. and K. Arulanandan. 1978. Erosion rates of cohesive soils. ASCE Journal of Hydraulic Engineering 104(HY2): 279-283.	$\varepsilon=\alpha\left(\frac{\tau_b-\tau_c}{\tau_c}\right)$
Raudkivi, A.J. 1982. "Grundlagen des Sediment-transports", pp.90-91.	$\varepsilon=K\left(\frac{u_*^2}{u_{*c}^2}-1\right)$
Parchure, T.M. and A.J. Mehta. 1985. Erosion of cohesive sediment deposits. ASCE Journal of Hydraulic Engineering 111(HY10): 1308-1326.	$\varepsilon=\varepsilon_f e^{\alpha_2(\tau_b-\tau_c)^{1/2}}$
Dunn, quoted by E. Partheniades and R.E. Paaswell. 1970. Erodibility of channels with cohesive boundary. ASCE Journal of Hydraulic Engineering 96(HY3): 755-771.	$\tau_c \propto S_v$
Nother, B. 1989. "Untersuchungen zum Resuspensionsverhalten von Astuarschwebstoff". GKSS 89/E/38. GKSS Research Centre, Germany.	$\varepsilon=1.18(\tau-\tau_{*c})$ $\varepsilon=0.84(\tau-\tau_{*c})$
Smerdon and Beasley, quoted by Partheniades and Paswell 1970. Erodibility of channels with cohesive boundary. ASCE Journal of Hydraulic Engineering 96(HY3): 755-771.	$\tau_c=0.0034(P.I)^{0.84}$
Teisson, C. 1991. Cohesive suspended sediment transport: feasibility and limitations of numerical modeling. Journal of Hydraulic Research 29(6): 755-770.	$u_{*c}=3.2\times10^{-5}C_s^{1.175}$ $u_{*c}=5.06\times10^{-8}C_s^{2.35}$

Figure 5.1

Schematic PCB Mass Balance Model

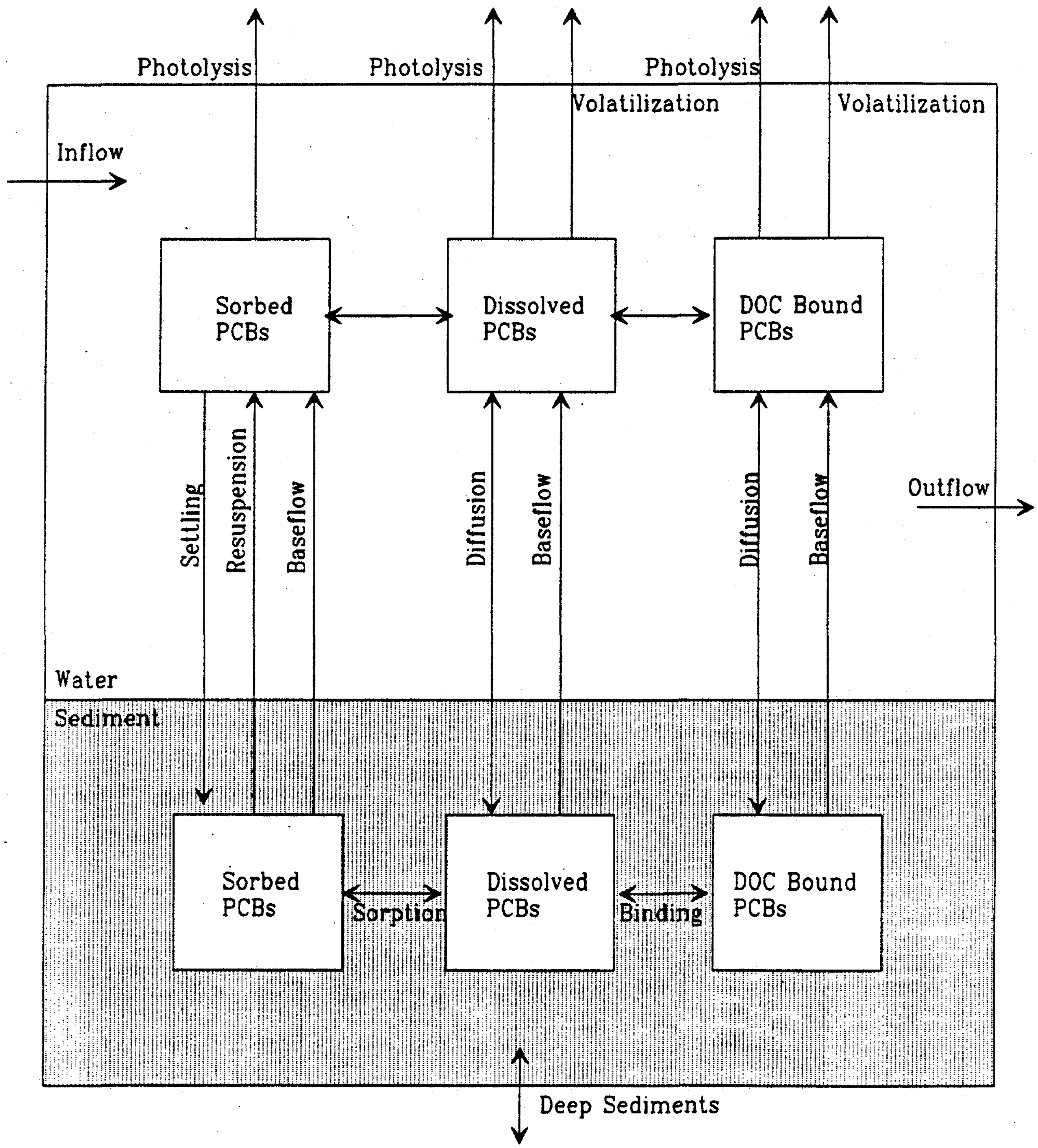
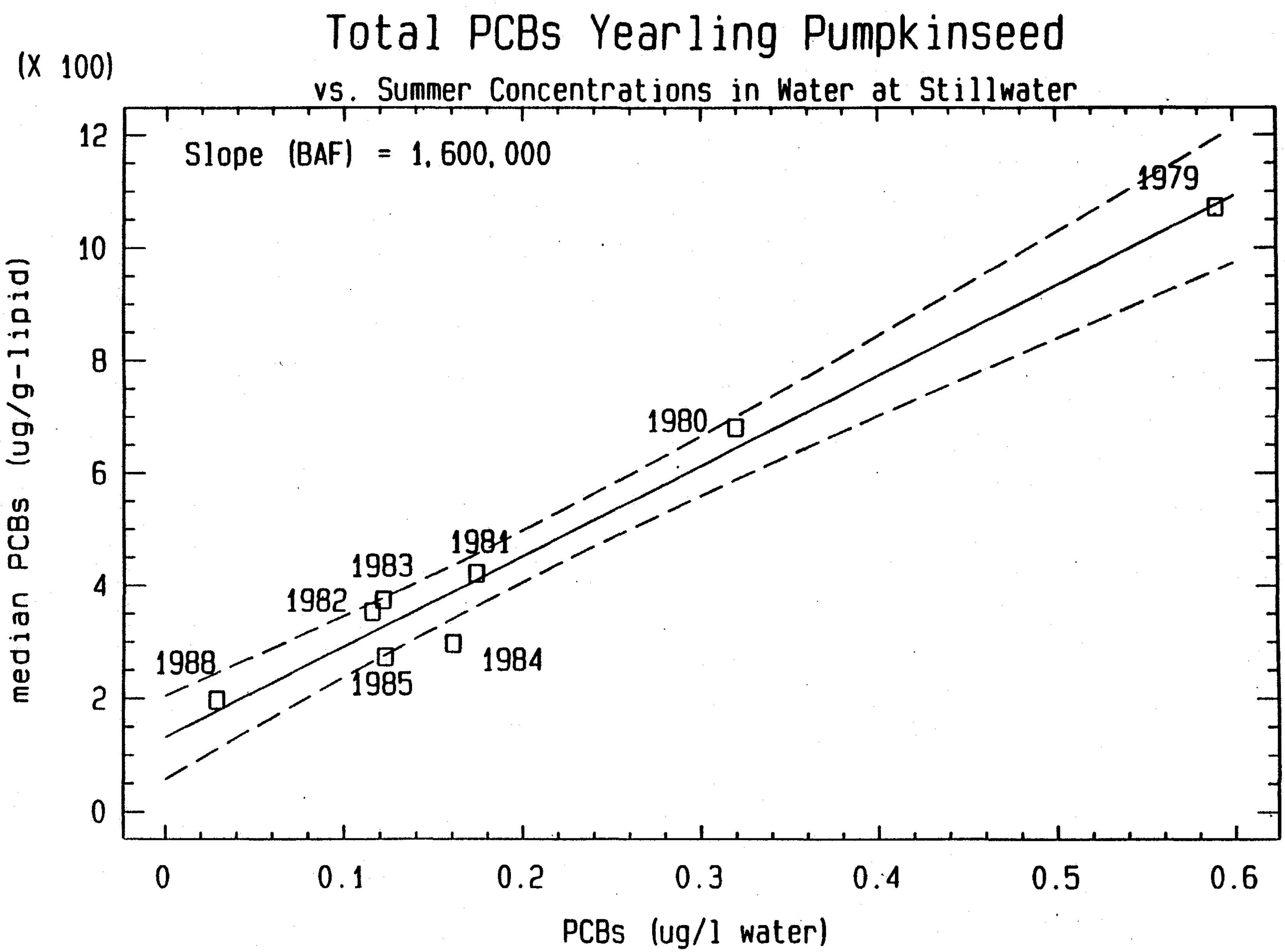


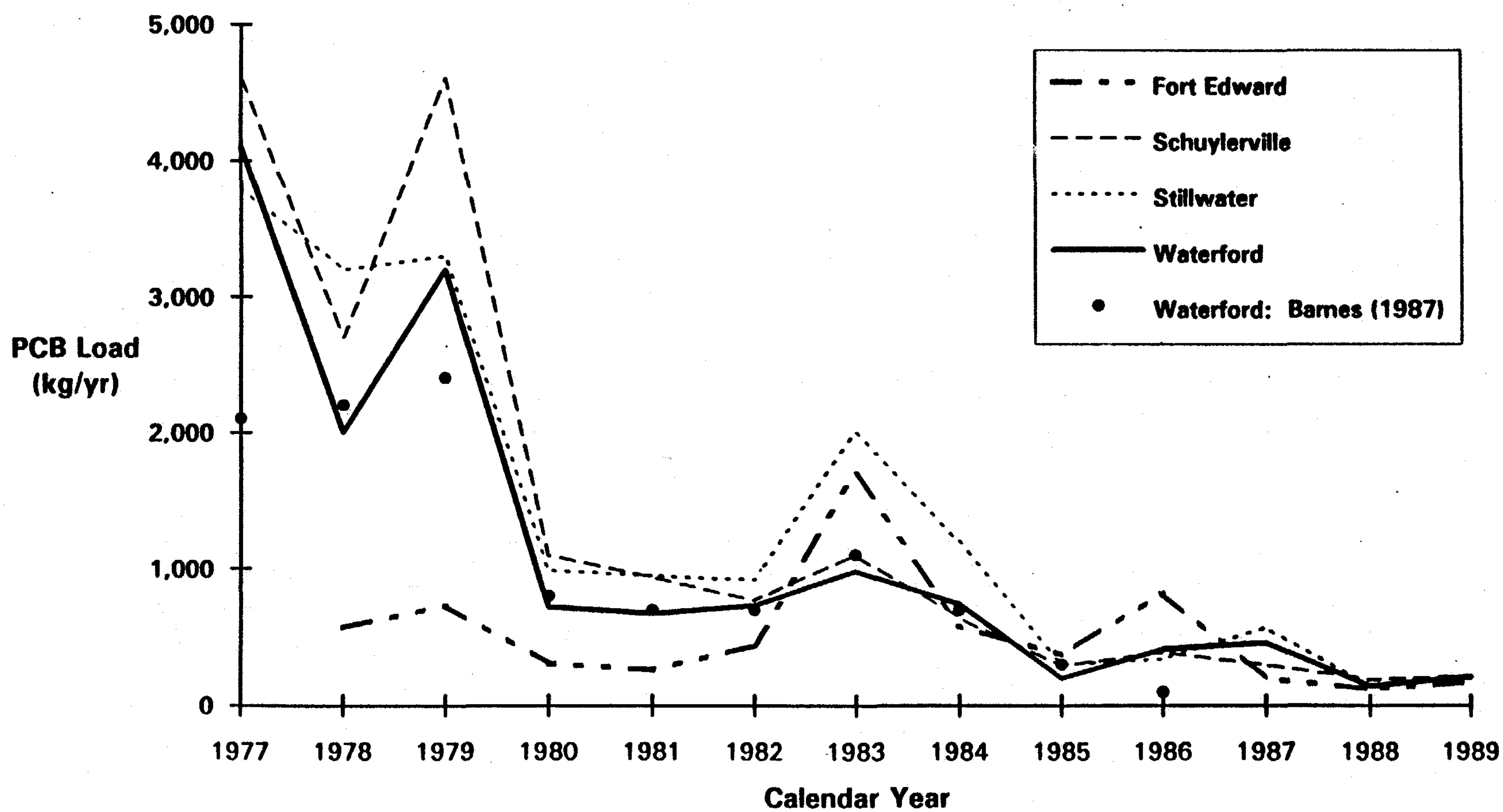
Figure 5.2



312171

Figure 5.3

PCB Mass Transport: Corrected Mean Method Estimates



312172

6. BASELINE HUMAN HEALTH RISK ASSESSMENT

The Phase 1 Report provided a preliminary baseline human health risk assessment and indicated that there was an unacceptable human health risk associated with eating fish from the Upper Hudson River. To perform a final baseline risk assessment in Phase 2, additional data will be utilized, *e.g.*, 1990 and 1991 fish data, sediment, water-column and air monitoring data collected in Phase 2, and relevant new information on PCB health risks, if any.

6.1 Study Area B

The preliminary human health risk assessment for the Upper Hudson was presented in the Phase 1 Report. Where updated site-specific information can be obtained, it will be incorporated into the final risk assessment. This information falls into two categories: exposure assessment and toxicity information, as described below.

6.1.1 Exposure Assessment

6.1.1.1 Fish Consumption

The Phase 1 preliminary human health risk assessment adopted the average recreational fish consumption value of 30 g/day that is recommended by the USEPA for the fish consumption pathway. The Phase 2 baseline assessment will evaluate whether there are adequate data to justify a different, site-specific or region-specific, *e.g.*, northeast, value for fish consumption that would apply in the Hudson River area in the absence of a fishing ban. Additionally, the Phase 2 human health risk baseline assessment will provide a discussion of the specific population that is targeted by the intake estimate, *e.g.*, whether it is appropriate to target recreational or subsistence anglers, both in the absence of a fishing ban.

6.1.1.2 Exposure Point Concentrations in Fish

The Phase 1 preliminary human health risk assessment relied on fish data collected through 1988. NYSDEC fish sampling data for 1990 will be available for Phase 2. These data, along with any data available for 1991 and 1992, will be used to refine the estimates of current and projected, future PCB concentrations in fish.

During Phase 1 exposure point concentrations for PCBs in fish from the study area for the Upper Hudson were calculated without differentiating among species. During Phase 2, the possibility of refining the estimates of exposure point PCB concentration in fish to reflect inter-species variability will be evaluated. This evaluation will include the possibility of establishing an exposure point concentration specific to individual fish species caught by Upper Hudson fishermen and the relative frequency with which these particular species are consumed.

Human uptake of PCBs from fish may also be affected by handling of fish following capture from the river. Specifically, as discussed in the Phase 1 Report, cooking practices may affect the final concentrations of PCBs in fish flesh prior to its consumption. The Phase 2 assessment will determine whether there are new and adequate data available to determine confidently an appropriate adjustment factor to account for the effects of cooking.

6.1.1.3 Uncertainty Analysis

In Phase 2, a quantitative uncertainty analysis using Monte Carlo simulation techniques will be conducted. This analysis will provide an indication of appropriate upper-bound exposures to PCBs from the consumption of Hudson River fish and take into account components of uncertainty such as fish species, fishing preference, location within the river, fish consumption, future PCB levels in fish and other exposure factors.

6.1.2 Toxicity Assessment

6.1.2.1 Carcinogenic Toxicity

The Phase 1 preliminary human health risk assessment used a Carcinogenic Slope Factor (CSF) of 7.7 $(mg/kg\text{-}d)^{-1}$ to estimate the cancer risk associated with exposures to PCBs from the Hudson. This value was applied to total PCB exposure. Toxicity studies upon which this Slope Factor is based were recently reevaluated by the Institute for Evaluating Health Risks (IEHR). The results of the IEHR Reassessment may affect the estimated CSF for PCBs. The Office of Research and Development (ORD) of USEPA is considering the new information provided by the IEHR Reassessment to determine its impact on the CSF. Should the ORD determine that an adjustment of the CSF is appropriate in light of the new information, the new CSF will be incorporated into the Phase 2 human health risk assessment. If USEPA establishes separate CSF values for distinct Aroclor mixtures or to account for degree of chlorination, this approach will be adopted to determine cancer risks from PCB exposures.

6.1.2.2 Non-Cancer Toxicity

The Phase 1 preliminary human health risk assessment evaluated potential risks from non-cancer toxicities of PCBs by using an interim Reference Dose (RfD) value that had been reviewed by USEPA, but was not promulgated. The Environmental Criteria Assessment Office (ECAO) of USEPA is currently evaluating available non-cancer toxicity data on PCBs to determine whether the data support promulgation of an RfD. This evaluation should be completed prior to the completion of the Phase 2 human health risk assessment. If available, the new RfD or non-cancer toxicity endpoints will be incorporated into the assessment. Should the ECAO fail to establish an RfD for PCBs, then an evaluation of the potential non-cancer toxicities associated with exposure to PCBs in the Hudson River will not be reported.

6.2 Study Area C

A complete human health risk assessment for the Lower Hudson (Study Areas C and D), incorporating identification of all PCB sources and exposure pathways, is complicated by the large geographic area and sources of PCBs other than the Upper Hudson (Study Area B) that contribute to PCB levels found in sediment and fish. Efforts will be limited to Area C where the effects of sources other than those from the Upper Hudson are less extensive than in Area D.

Efforts in Study Area C during Phase 2 will be directed to characterizing better the relative magnitude of the Upper Hudson PCB source compared to other sources in the Lower Hudson. Potential exposures and concomitant risks, as a result of river-borne PCBs in this section of the river will be evaluated with a focus on fish and water consumption (Poughkeepsie water supply).

7. BASELINE ECOLOGICAL RISK ASSESSMENT

The Phase 2 baseline ecological risk assessment will adhere to current USEPA Superfund guidance for ecological risk assessment[1] and incorporate the assessment process outlined in the recent ECO Update[2] for ecological assessments within the Superfund program. Phase 2 efforts will build upon the Phase 1 interim assessment and quantify, where possible, ecological risks and impacts associated with the presence of PCBs in the Hudson River.

An ecological assessment will be performed for the freshwater aquatic environment of the non-tidal and tidal portions of the Hudson River from Bakers Falls (RM 195) to approximately RM 75, *i.e.*, Study Area B and the majority of Study Area C. This ecological study area includes the spawning regions of most anadromous fish species in the Hudson River as well as a number of other habitats considered to be of special importance as defined by NOAA, DOI, NYSDEC, and USFWS. The more saline zones of the Hudson River from River Mile 0 to the general vicinity of the salt front at approximately RM 55 and the transitional zone from RM 55 to RM 75 are not included. While PCBs occur in these zones, the presence of additional sources complicates determining the relationship between environmental PCB levels and the Upper Hudson source areas considered for remediation.

The freshwater region of the Hudson River was selected for two primary reasons. First, the PCBs in this section of the Hudson can be linked directly to Upper Hudson discharges and are likely to represent the greatest ecological risk posed by PCBs within a significant portion of the Hudson River. Second, the freshwater region can be viewed as a more ecologically consistent portion of the Hudson River compared to the complex ecological mosaic indicative of either the transition or more marine zones. Although the importance of transition and marine zones is widely recognized, the ability to characterize

---

[1] USEPA. 1989. "Risk Assessment Guidance for Superfund. Volume II: Environmental Evaluation Manual." Office of Emergency and Remedial Response, USEPA: Washington, DC. Interim final, March 1989.

[2] USEPA. 1991. Ecological assessment of Superfund sites: an overview. ECO Update 1(2). Office of Solid Waste and Emergency Response, USEPA: Washington, DC

ecological risks in the saline region of the river is beyond the scope of this assessment. Furthermore, the ability to characterize ecological risk will be more clearly ascertained without the added component of salinity, which causes increased spatial heterogeneity within the Hudson River.

Phase 2 will carry forward and refine elements of the Phase 1 interim assessment. The principal tasks of the assessment are summarized below.

- Site Characterization and Identification of Ecological Receptors. Receptors include benthic invertebrates, fish species, keystone species, and shoreline birds and mammals that may be exposed to PCBs associated with existing conditions. This effort was initiated in Phase 1 and will be expanded downriver to RM 75.

- Exposure Assessment. Exposure pathways, the routes by which ecological receptors may be exposed to PCBs, will be examined and exposure point concentrations will be quantified.

- Toxicity Assessment. Ecological assessment endpoints will be defined and toxicity data describing the measured effects of PCBs will be evaluated. The Phase 1 interim assessment examined toxicity endpoints such as reproduction, growth, survival, *etc.* and reviewed literature describing harm to selected species. Toxicity information gathered in Phase 1 will be expanded and enhanced in conjunction with reconnaissance surveys.

- Risk Characterization. This requires combining the above evaluations and quantifying, where possible, risks to selected ecological receptors or indicator species.

- Evaluation of Uncertainties. This effort involves assessing the uncertainties of different types of test data and limitations of the various methods utilized to assess ecological risk.

The ecological risk assessment will rely upon a weight of evidence approach, supported by literature reviews, reconnaissance surveys and an evaluation of chemical analytical data relative to environmental benchmarks. As illustrated in Figure 7.1, the ecological risk assessment process is dynamic and incorporates a multidirectional flow of information among its components. For example, the problem formulation, exposure assessment and ecological effects assessment all share common elements, such as receptors. The entire ecological assessment process set forth by the USEPA (Figure 7.1) recognizes the necessity of evaluating many lines of evidence, *e.g.* weight of evidence, in order to interpret and characterize adequately ecological risk.

7.1 Ecological Study Area Description and Characterization

This subtask will expand upon the characterization performed in Phase 1, described characteristics pertinent to ecological receptors and the presence of PCBs in media to which these receptors may be exposed. Physical/chemical conditions will be reviewed. The summary of aquatic and surrounding terrestrial habitats will include those areas identified as Hudson River Reserves by NOAA or considered by NYSDEC, USFWS, DOI and NOAA to be of special interest. As recommended in USEPA guidance, habitats that "are unique or unusual or necessary for continued propagation of key species" will also be described.

The nature and composition of aquatic and terrestrial communities will be identified in greater detail than in the Phase 1 Report. In order to provide qualitative field verification of the types of habitats and communities within or near the ecological study area, a reconnaissance survey of selected shoreline areas will be conducted. NYSDEC, NOAA, USFWS, and DOI representatives will be consulted prior to the initiation of the survey. This effort is expected to provide more site-specific observations regarding the condition of the habitats and species. A more detailed description of the reconnaissance survey is presented in the Phase 2 Sampling Plan (Appendix A).

7.2 Problem Formulation

During Phase 1, the basic framework for the ecological assessment was formulated, *i.e.* identification of exposure pathways, ecological receptors, endpoints of concern, and reported ecological effects. This framework will be expanded and refined in Phase 2.

The ecological receptors identified in Phase 1 will be reconsidered. A final species list, comprising various habitats and trophic groups representing a reasonable cross section of the major functional and structural components of the site, will be chosen and presented to NYSDEC, NOAA, USFWS, and DOI for review.

This approach entails identification of a limited number of species, representing major trophic levels and species for which toxicity information is available or measurable. Information concerning feeding habits, life histories, habitat preferences, trophic status, migratory habits, reproductive patterns and other attributes influencing exposure or sensitivity to PCBs will be evaluated. Every effort will be made to include as many species as possible from the lists which will be provided by the various state and federal agencies. Nevertheless, USEPA guidance indicates that the ecological risk assessment must focus on a limited number of receptors in order to develop a "reasonable and practical evaluation."

In the Phase 1 Report, ecological effects of PCBs reported in the scientific literature were summarized and compared to PCB levels. A variety of assessment endpoints, such as reduction in growth, impaired reproduction, and mortality were reported in these studies. Additional data to be reviewed are: USEPA's Ambient Water Quality Criteria (AWQC) documents and supporting studies; Aquatic Toxicity Information Retrieval (AQUIRE); fish or wildlife consumption advisories issued by NYSDOH; and published toxicity studies.

7.3 Exposure Assessment

The exposure assessment will characterize exposure point concentrations, which are needed to compare against toxicity assessment endpoints. Sediment, water column, fish and invertebrate PCB data in the TAMS/Gradient database will be used to refine exposure point PCB concentrations. Exposure point concentrations will be based on both measured data and fate and transport models (see Section 5). For example, estimates of future PCB levels in fish will be based on PCB bioaccumulation from both water and sediments, accounting for non-equilibrium between these media.

7.4 Ecological Effects Assessment

Toxicity data for selected, or similar indicator species will be examined through literature reviews. Species similar to selected study area receptors may be substituted in the event toxicity studies are unavailable for the identified receptors. The toxicity assessment provides the link between concentrations of PCBs within the ecological study area and observed or demonstrated adverse effects in receptors. The reconnaissance surveys will enhance this effort by confirmatory field evidence obtained on ecological effects (*e.g.*, absence of species normally occurring in the study area, reduction in species richness, etc.) Literature reviews will provide information on the specific dose-response for the selected receptors. Important bibliographic sources to be consulted include the AQUIRE database as well as databases available through Dialogue Information Services, *e.g.*, Pollution Abstracts, Water Resources Abstracts, Environmental Bibliography.

7.5 Risk Characterization

This component will involve interpretation of the results of the exposure assessment and comparison to the ecological effects assessment. A variety of techniques will be used to present both qualitative and quantitative risk characterizations. As indicated previously, a weight of evidence approach will be used to characterize risk. This approach will utilize the combined information generated from literature reviews, reconnaissance surveys and evaluation of chemical analytical data relative to environmental benchmarks.

A Toxicity Quotient (TQ) or, if data are available, an Analysis of Extrapolation Error (AEE), will be calculated for the indicator species. The TQ method involves comparing an exposure point concentration to a benchmark, such as a toxicity endpoint. Values of TQ exceeding one are considered to indicate the potential for adverse effects. The method assumes that the toxicity benchmark adequately reflects the assessment endpoint. This assumption is most reliable when toxicity tests have been performed for site-specific species or when scientific literature values closely reflect site conditions and species. The AEE method calculates the probability that an exposure point concentration will exceed the toxicity endpoint rather than comparing them arithmetically as in the TQ.[3]

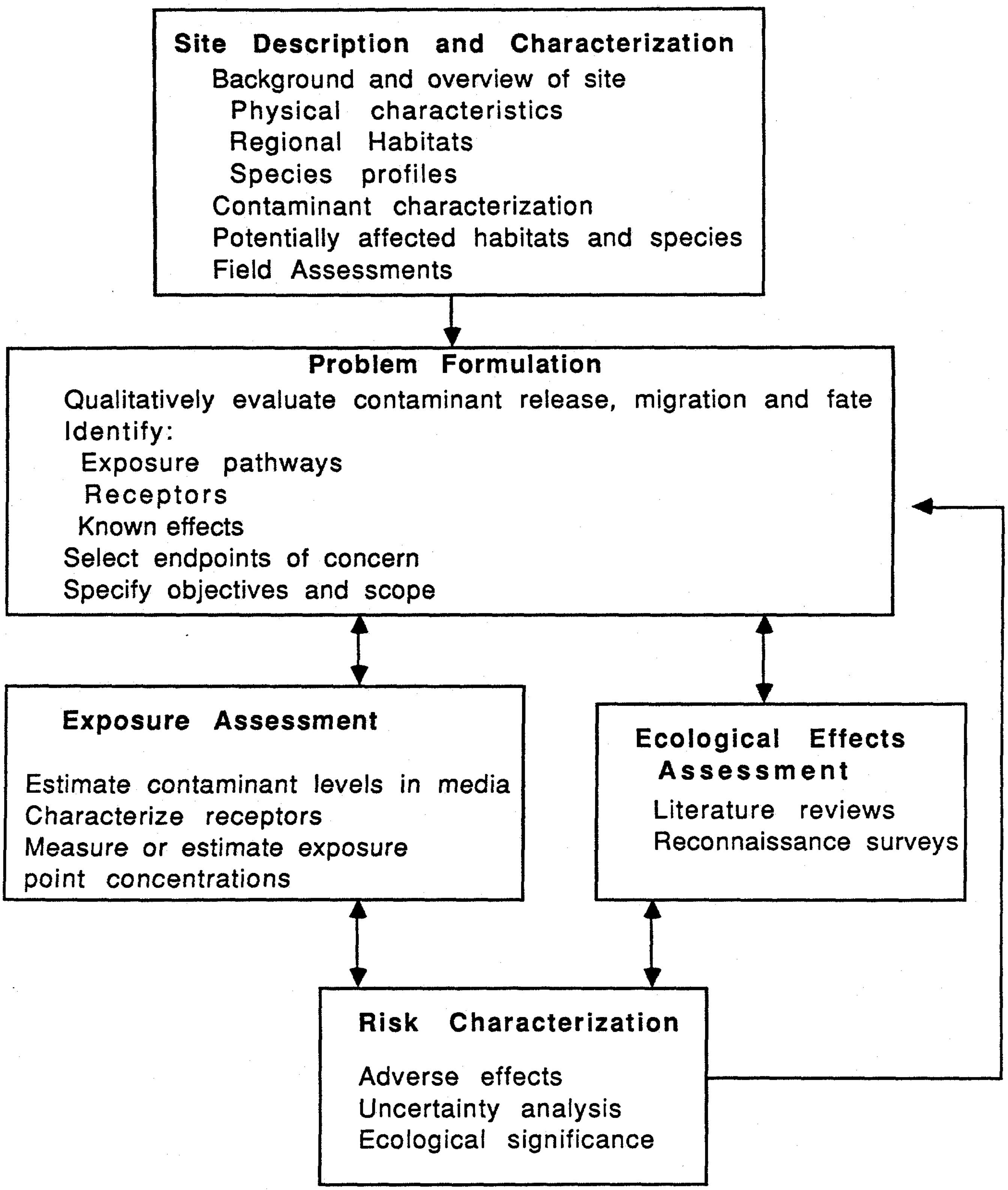
Uncertainty analyses of the exposure point concentrations, toxicity endpoints, and exposure pathways will be performed. Quantification of uncertainty is directly incorporated into the AEE[3], but is not directly addressed in the TQ. If sufficient data are available to conduct a Monte Carlo simulation, uncertainty can be quantified also for the TQ approach.

The risk characterization will conclude with a summary of the risks and uncertainties and an interpretation of the ecological significance of the findings. This phase of the risk assessment will offer professional interpretations and judgments concerning the magnitude of the overall ecological effects from the contaminated media.

---

[3] Barnthouse, L.W., G. W. Suter II, S. M. Bartell, J. J. Beauchamp, R. H. Gardner, E. Linder, R. V. O'Neil and A. E. Rosen. 1986. "User's Manual for Ecological Risk Assessment." Oak Ridge Nat. Lab., Oak Ridge, TN, Env. Sci. Div. Public No. 2679.

Figure 7.1
Components of Ecological Risk Assessment*



* **Modified from Figure 1 in ECO Update (USEPA, 1991)**

8. Feasibility Study Analyses

The Phase 1 Report presented general response actions and potential clean-up technologies and process options for PCB-contaminated sediments in Study Area B. Engineering analyses and treatability studies will be performed in Phase 2 for utilization in the Phase 3 Feasibility Study.

8.1 Sediment Volumes and Areas

During Phase 2 the areas and volume of sediments within Study Area B subject to possible remedial action will be identified. Geophysical survey and confirmatory sampling data from Phase 2 will be used to identify likely depositional areas within the various reaches of the river and will, in turn, enable computation of the contaminated sediment volume. Together with the historical and recent or planned PCB analyses of the sediments, identification of approximate areas of sediment subject to possible treatment, *i.e.* sediment with PCBs exceeding preliminary remedial action criteria, will be made. The volume of sediment requiring treatment will also be analyzed in terms of PCB concentrations and current and future availability to the water column and biota. A map of potential remediation areas and sediment volumes will be prepared to aid in the evaluation of remedial alternatives.

8.2 Technology and Process Option Screening

During Phase 1, a number of established and innovative technologies within several response action categories were identified. These and potentially other technologies will be examined for their implementability. Those technologies that are infeasible to implement will be eliminated from further evaluation.

The criterion for elimination of a particular technology or process option during Phase 2 will be technical feasibility. Technologies or process options will be determined to be technically infeasible based on study area-specific factors. Conditions, such as a sediment matrix being incompatible with a technology or process, restricted access of the process equipment to the possible remediation areas, and other such factors will be grounds to evaluate technically infeasible processes. All technologies or processes that are removed from further consideration will be documented in the Phase 2 Report.

8.3 Identification and Evaluation of Technology Process Options

Those technologies and processes carried forward for more detailed consideration will be evaluated based on three criteria:

- effectiveness;
- implementability; and
- relative cost.

This screening step will evaluate each process option within the same technology type to determine which are most effective. The process option determined to be most effective will be carried forward in the screening evaluation for further development. Typically, process effectiveness depends on such factors as: 1) ability to handle the range of sediment volumes that could require remediation; 2) the ability to meet a range of remediation goals; 3) potential impacts to human health or the environment during construction and implementation; and 4) whether the process or technology is proven and reliable for site-specific contaminants and conditions.

Implementability is evaluated based on both the technical and administrative ability to implement a technology process. Technologies that are technically infeasible would not be considered implementable, so this screening step typically focuses on administrative factors. Administrative considerations include any permits, availability of treatment or storage and disposal services within the vicinity and the availability of technology vendors.

Relative capital and operation and maintenance (O&M) costs, rather than detailed estimates, are used for this evaluation. An evaluation is made of high, moderate, and low cost process technologies at this stage.

8.4 Treatability Study Literature Assessment

During Phase 1, a number of technologies were evaluated to assess their suitability for remediating the Upper Hudson's contaminated sediments. Technologies considered during Phase 1 included those associated with response actions not requiring sediment removal as well as technologies that would be components of actions involving sediment removal and treatment. Part of the program to be accomplished during Phase 2 will be to evaluate experiences at other Superfund sites where contaminated sediments are either being remediated or are about to undergo remediation. In addition, considerable developmental activity has been occurring within the private sector and by federal agencies on systems and technologies that treat contaminated soils; these developments were reviewed during Phase 1 and that review will be updated during Phase 2. Finally, several comments were received on the Phase 1 Report related to treatment technologies and these also will be further evaluated.

8.4.1 In Situ Remediation

Technologies in this category include engineered approaches to stabilize or cap sediments so that sediment-bound contaminants are not scoured and released to the water-column. The geophysical program described earlier in this work plan will generate significant new data describing the distribution and physical characteristics of contaminated sediments. That information will provide the basis for further evaluation of *in situ* engineered solutions; no specific treatability studies are envisioned with regard to *in situ* remedial response actions, such as capping and/or stabilization of sediments.

Alternatively, *in situ* treatment of contaminants may be accomplished through bioremediation whereby natural biodegradation processes are enhanced by manipulation of environmental conditions conducive to microbial activity. Bioremediation was discussed in the Phase 1 Report and it was reported that, as of that time, no full scale *in situ* programs had been conducted using those techniques. It is expected that the General Electric Hudson River Research Study (HRRS) will provide the most relevant data on the viability of *in situ* treatment.

Consequently, its results will be reflected in the Phase 2 Report and the final Feasibility Study. In addition, analysis of historic and recent sediment cores will be useful in assessing rates of natural biodegradation. No further treatability studies directed at bioremediation are planned during Phase 2.

8.4.2 Thermal/Chemical/Physical Sediment Treatment Systems

The Phase 1 Report identifies a number of technologies that may successfully treat the river's contaminated sediments, if they are removed (dredged). Included in the technologies are solvent extraction, dechlorination, and incineration systems. Once a status update has been obtained for these systems as discussed above, a limited number will be selected for bench or laboratory scale analysis to determine their general performance characteristics on actual river sediments. Using data from the geophysical program, representative samples of river sediments will be collected and shipped to vendor facilities for treatability testing; duplicate samples will be independently analyzed to verify chemical and physical properties of the shipped materials. The treatability program is expected to provide information relevant to handling and dewatering of sediments, extractability of the PCBs by various solvents and reacting agents, and the temperature at which PCBs will be released from the sediment matrix. Treatability Study Plans for each technology including QA/QC and deliverable requirements will be prepared prior to performance of these studies.

8.5 Sediment Disturbance Impact Assessment

Before any of the physical/chemical/thermal treatment technologies can be applied, it will be necessary to remove or disturb the contaminated sediments. Dredging or caisson installation may disrupt the river's ecosystem by both resuspension of bottom materials and disturbance or removal of aquatic habitat. Response actions involving dredging of sediments have been studied for the Hudson River and widely applied at other Superfund sites. The ramifications of the processes will be evaluated in Phase 2 and will continue to be evaluated in Phase 3. Data for the assessment will be obtained from the geophysical program. In particular, the contaminant/sediment distribution maps generated by that program are expected to provide a relatively complete characterization of the material that would have to be removed to achieve various remedial objectives.

Among the outputs of the geophysical program will be maps of sediment distribution patterns illustrating various classes of bottom materials. Using both the maps and laboratory data, an engineering assessment will be performed of sediment disturbance impacts. Factors that will be considered include presence of obstructions such as boulders and cobbles, the continuity of contaminated sediment formations composed of removable materials, the extent to which contaminants adhere to homogeneous formations of suspendable sandy/silty materials, and the problem of access for equipment. Estimates of sediment resuspension particularly during dredging will be made using published data for various dredging systems, assuming they would operate on the same type of materials that would be removed from the Hudson as part of a remedial action.

PAGE INTENTIONALLY LEFT BLANK

APPENDIX A

PHASE 2 SAMPLING PLAN

PAGE INTENTIONALLY LEFT BLANK

APPENDIX A
PHASE 2 SAMPLING PLAN

A.1 Introduction

In accordance with the Scope of Work for the Reassessment, a Phase 2 investigation will be performed to characterize and analyze further site conditions. The Phase 2 program is based on the review and synthesis of the information collected and reported in the Phase 1 Report entitled "Interim Characterization and Evaluation" (August 1991) and on the input of the Hudson River Oversight Committee and the participants in the Community Interaction Plan. The various data needs and the major data collection tasks have been discussed in the Phase 2 Work Plan to which this sampling plan is attached.

The Phase 2 sampling effort consists of two parts, Phase 2A, which began in December 1991 and Phase 2B, which will begin upon approval of the Phase 2 Work Plan. For each phase, a Sampling and Analysis Plan/Quality Assurance Project Plan is required and is reviewed by USEPA-Region II. The Phase 2A SAP/QAPP has already been approved by USEPA; the Phase 2B SAP/QAPP, describing in detail the protocols for the sampling program presented here, will be submitted upon approval of this document.

The description of the Phase 2A sampling tasks was the subject of the Phase 2A Sampling Plan (September 1991). Because the scope of some tasks has been subsequently adjusted and refined, these changes are described here. This Sampling Plan also describes the Phase 2B sampling tasks. A summary of the work to be performed for all tasks in Phases 2A and 2B is presented in Tables A.1.1 and A.1.2.

A.2 Phase 2A Sampling

A.2.1 Establishment of Control Points for Precision Navigation

The success of the Phase 2 program is dependent upon precise navigation in the Hudson River. The ability to compare results among the various sampling tasks is contingent upon knowing precisely all sampling locations in the Hudson. For this reason, a system of shoreline points will be established to enable precision navigation, nominally accurate to one meter. To the extent that shoreline control points still exist from previous investigations, these will be utilized. It is anticipated that for the geophysical survey of Upper Hudson, between the Bakers Falls Pool and the Lock 4 Dam about 20 shoreline points will need to be established, either from existing points from prior investigations, or from appropriate surveying techniques, with about one control point every one and one-half miles.

For the high resolution coring locations that do not fall within the geophysical survey area, additional shoreline control points will need to be established. Because of the distance between the individual coring locations, one control point will be established for each coring location. For the Lower Hudson, 12 control points will be required. For the Upper Hudson, four to five additional control points will be required.

All shoreline points will be referenced to the N.Y.S. Plane Coordinate System, North American Datum (NAD27), the historic reference system for most previous surveys. Vertical data will be referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929). This task, begun in December 1991, will continue in spring 1992.

A.2.2 Geophysical Surveys from the Bakers Falls Pool to the Lock 4 Dam

This task, using geophysical measurement techniques, will involve the study of river bottom sediment textures, bathymetry, topography and sediment thickness in the most PCB-laden region of the Hudson. These data will be used to construct a computer-generated map of the river bottom conditions, effectively providing an aerial photograph type perspective of the river bottom conditions. The information will be calibrated and confirmed by sample collection described in a following section. The many important potential uses of this information are to: provide a basis for the selection of additional coring locations in Phase 2B, identify areas of river sediment susceptible to scour, and estimate volumes of mobile sediments, among others.

The geophysical surveys proposed here include side-scan sonar, bathymetry and single frequency sub-bottom profiling. Plate A.1 is a map of the Upper Hudson, showing the areas to be surveyed as a part of this effort. About three quarters of the survey will cover areas believed to contain PCB hot spots or remnant deposits. The remaining survey effort, more exploratory in nature, will examine areas that would appear to represent depositional conditions similar to those found at the hot spots, but not delineated as hot spot areas. This effort began in December 1991 and will continue this spring. Following are brief descriptions of the individual sub-tasks to be completed as a part of the geophysical survey effort.

A.2.2.1 Bakers Falls Pool to River Mile 182

1. A side scan sonar survey of all accessible areas in this region of the river will be conducted using 100 and 500 kHz sonar. Data on the river bottom will be collected at relatively high resolution, covering a swath roughly 75 m across. The swath width may be adjusted in the field to allow for variations in the width of the river at the discretion of the field scientists. The survey lines will generally run parallel to the direction of river flow. Each survey line will be roughly one to two miles long, depending on navigational constraints. Each of these lines will be separated by about 40 m, yielding bottom coverage for the river of about 150 percent. This method will ensure that the edges of each swath overlap and that the bottom of the river will be

completely surveyed. Figure A.2.1 is a schematic showing the approximate layout of the survey grid. The survey of the Thompson Island Pool will cover the entire navigable area between the former dam site at Fort Edward and the Thompson Island Dam. This survey will cover 20 of the 40 previously defined hot spots. The survey of the Bakers Falls Pool will cover the area behind the Bakers Falls Dam to roughly one quarter-mile upstream. The survey between the Thompson Island Dam and River Mile 182 will cover all accessible areas in this region and an additional 15 of the 40 previously defined hot spots. The survey coverage of the river bottom in the last region may be somewhat limited because of the unknown and potentially shallow water depths in some areas of this region. In addition to the areas described above, the survey will also cover the river area between Bakers Falls and the former dam site at Fort Edward. This last survey area represents an addition to the areas originally listed in the Phase 2A Sampling Plan.

- Navigation will be nominally accurate to 1 m and referenced to the N.Y.S. Plane Coordinate System, North American Datum (NAD27).
- Vertical data will be referenced to the National Geodetic Vertical Datum of 1929 (NGVD 1929).
- Data from the bathymetry and sub-bottom profiling equipment will be collected concurrently with the side-scan sonar data, except where limited water depths require the use of a smaller boat. In these cases, data will be collected on separate survey runs.

2. A bathymetric survey will be conducted for the areas defined for the side-scan sonar survey. The survey will consist of survey lines about 150 m apart perpendicular to the direction of flow. These data will be used in conjunction with the bathymetry data obtained during the side scan sonar survey,

effectively generating a wire net of coverage of the river bottom.

- Navigational and vertical data will be of the same quality as that for the side-scan sonar survey.

3. A single frequency sub-bottom profile survey will be conducted for all surveyed areas.

   - Navigational and vertical data will be of the same quality as that for the side-scan sonar survey.
   - Data will be collected concurrently with the bathymetry and side-scan sonar surveys except as noted above.

A.2.2.2 Upper Hudson River from River Mile 182 to the Lock 4 Dam

1. This area was originally proposed in the Phase 2A Sampling Plan. However, the addition of the area between the Baker Falls dam and the former dam site at Fort Edward precludes the coverage of this area. This change in the geophysical survey plan will yield essentially continuous coverage from the Bakers Falls pool to RM 182.

A.2.3 Confirmatory Sampling for Calibration of Geophysical Surveys

To ensure proper interpretation of the geophysical data to be collected, confirmatory sediment samples will be collected following the completion of the geophysical surveys. Sediments from an anticipated 200 locations will be collected by hand coring or by grab sampling at the geophysical survey areas. The confirmatory sampling locations will be selected, based on the geophysical results, and placed using the same navigational controls and precision as that for the geophysical surveys so that the two sets of data can be directly correlated and mapped. All samples will be visually examined and classified. Based on the field classifications, a large fraction of the sediment samples will be analyzed for grain size distribution and total organic carbon content. Additional activities are noted below.

- Sediment samples will be visually examined for sediment texture and stratification for calibration of both the side-scan sonar and the sub-bottom profiling survey data.

- Cores will be photographed to record visible sedimentological structures.

- Some cores will be X-rayed to detect *in situ* density variations before extrusion of the core.

- Core samples will be extruded in the field for visual and manual examination.

- Surficial sediments (0 to 2 inches) will be analyzed for grain size distribution and for total carbon/total nitrogen content and total inorganic carbon content. (Total organic carbon content is obtained as the difference between the total carbon and total inorganic carbon analyses.)

A.2.4 High Resolution Coring

This task will involve the collection of sediment cores from locations in Study Areas A, B, C and D (see Section 2 for definitions). These cores will be analyzed for radionuclides on a two to four cm layer basis in order to establish the year of deposition of a given sediment layer. These same layers will be analyzed for PCB concentration on a congener-specific basis as well as other parameters. A total of 23 core locations have been chosen.

The Phase 2A effort will begin with core collection from Study Areas C and D. This effort, as outlined below, contains the same number of core locations as given in the Phase 2A Sampling Plan, although one location has been dropped from Area C and one has been added to Area B.

1. Cores will be collected from eleven locations in Study Areas C and D. Their locations are shown in Figure A.2.2.

- Cores will be collected from the following, previously sampled approximate locations: RM -1.7, -1.65, 3, 44, 53.8, 60, 88.6, 91.8, 143.4 and Newtown Creek.

- Cores will be collected from approximate RM location 115 to expand the core database. The proposed location at RM 130 has been dropped.

2. Cores will be collected from twelve locations in Study Areas A and B. Their locations are shown in Figure A.2.3.

   - Cores will be collected from the following, previously sampled approximate locations: RM 168, 189, 190, 191, and 203.

   - Cores will be collected from the following new locations to expand the core database: RM 158, 166, 195, and 197. The core location at RM 158 represents an addition to the Phase 2A effort. The core at RM 158 will be used in conjunction with the extensive fish flesh PCB data collected from that general location by the NYSDEC.

   - Cores will be collected from the Hoosic and Mohawk Rivers (two cores) near their confluence with the Upper Hudson to evaluate the relative historical contribution of PCBs from each river.

3. All cores will be collected using a hand coring technique whenever possible.

   - Cores will be transported in a vertical position as collected to a field laboratory location or to the Lamont-Doherty Geological Observatory for subsequent sample preparation.

   - Cores will be sectioned into approximately 2 cm layers for the uppermost eight centimeters. The remainder of the core will be sectioned into 4 cm layers. These sections will be subsampled by removing representative portions of each section for the various analysis whenever possible. When a core section cannot be subsampled in this fashion, the core section will be homogenized while wet and subsequently subsampled. Portions will be reserved for PCB, total organic nitrogen, and grain size distribution analyses. The remaining portion of each layer will be dried under a PCB-free atmosphere and analyzed for radionuclide (Cs-137, Be-7 and Co-60), total carbon/total nitrogen, and total inorganic carbon concentrations. Subsequently, this portion of the sample (typically about half of a given layer) will be archived in a sealed aluminum can.

- To the extent that a core does not yield an interpretable radionuclide chronology, one additional core may be collected from the original location to replace the first core. If the second attempt does not yield an interpretable core chronology, the location will be abandoned.

A.2.5 Water Column Transect Monitoring from Glens Falls to Waterford

Water column sampling tasks are designed to determine current waterborne PCB levels and congener mixtures in both dissolved and suspended matter fractions in the river. Data obtained from this effort will be used to investigate the approximate location of the current PCB sources in Study Area B and the effect, if any, of recent remedial efforts on the water column levels. The effort is also designed to examine the correlation of PCB loads with water flow. Finally, the results will be used to examine the partitioning of PCB congeners between the dissolved and suspended matter phases. This task is expected to extend over several months, with sampling events separated by four to six weeks. The task efforts are described below.

1. Water monitoring stations will be sampled on at least seven separate occasions at 9 locations from Glens Falls to Waterford plus a location on the Mohawk River. The locations are shown in Figure A.2.4.

   - Seven locations (constituting one transect in the direction of flow) will be sampled along the main river axis in order to delimit the area of the Upper Hudson where the current base load originates, as follows: Glens Falls, Bakers Falls, upper remnant deposit pool, Rogers Island at Fort Edward, Thompson Island Dam, Schuylerville, and Waterford. Based on an evaluation of recent data, the stations at Stillwater and the lower remnant deposit pool have been dropped from the Phase 2A program. Additional samples will be obtained from the Hoosic and Mohawk Rivers just upstream of their confluences with the Upper Hudson and on the Champlain Canal just above Lock 7. These stations are additions to the Phase 2A Sampling Plan.

- A sample will be collected during each transect sampling round from an off-site location to serve as a sampling blank.

- At each station, data will be collected on water column conductivity, temperature, dissolved oxygen, and pH.

- Water will be collected at each station for PCB analysis (in a 20-liter aliquot), dissolved organic carbon analysis, total suspended matter analysis, total organic carbon analysis on suspended matter, and chlorophyll-a analysis. A small subset of samples will be analyzed for PCBs using one liter samples. The total organic carbon analysis on suspended matter represents an addition to the Phase 2A Sampling Plan.

- Each 20-liter sample collected for PCB analysis at each station will be separated by filtration into a dissolved fraction and a particulate fraction. The samples will be filtered in the field as soon as possible after collection but no more than four hours after collection. Each fraction will be analyzed on a congener-specific basis.

- Four separate sampling events along the transect will attempt to coincide with low flow (less than 8,000 cfs at Fort Edward) to typify current low flow PCB transport conditions.

- Three separate sampling events along the transect will attempt to coincide with higher flow events to examine current high flow PCB transport conditions. When possible, these events will coincide with sustained high flow for at least one to two days prior to sampling.

- Samples will be collected from north to south (upstream to downstream) while monitoring the flow at the USGS hydrographic stations in the Upper Hudson so as to generally follow the same parcel of water through the Upper Hudson River.

- During one low flow and one high flow event, two 20-liter samples will be collected at each station along the transects, one to be field-filtered, and one to be laboratory-filtered. The laboratory sample will be held a minimum of four days before filtering to ensure that an effective equilibrium between dissolved and particulate phases is reached.

- At each station, samples will be collected at several points across the river and mixed together to account for cross-section heterogeneity in the PCB levels.

A.3 Phase 2B Sampling

A.3.1 Flow-Averaged Water Column Sampling

As discussed in the Phase 2 Work Plan, the purpose of this task is to define better the net PCB loads to the Upper Hudson that enter the river as it travels through the remnant deposit area above Fort Edward and to the Thompson Island Dam. This task will involve regular collection of water column samples at four locations in the Upper Hudson, specifically Glens Falls, Fenimore Bridge at Bakers Falls, Route 197 Bridge at Fort Edward and the Thompson Island Dam, at a frequency of one every other day (see Figure A.2.4). The river sections under study represent regions of known or suspected historic PCB input to the river. Mean differences in PCB levels between sampling stations represent net changes in PCB load resulting from a PCB source in the intervening river section. Actual loadings will be calculated using USGS flow data and the measured PCB values.

The water column samples will be collected so as to generate a flow-averaged sample. Prior to the collection of any samples in this task, a scale of sample volume to river discharge will be established. This scale will be used to determine the volume of sample to be collected at each station on any sampling day. Prior to the collection of a day's samples, the USGS monitoring stations will be queried electronically to obtain the day's flow conditions. Based on these flow conditions, an appropriate volume of sample will be obtained from each station. At the end of each sampling period the individual samples will be combined, producing a single flow-averaged sample for each station. In this manner, the sample will have sufficient volume to permit the measurement of PCB congeners at the required detection limits.

This technique avoids the inherent day to day variability in water column levels, which has been noted in the historical data, by creating a flow-averaged sample for each location. It also avoids the large analytical costs involved in establishing a sufficiently large database of daily or weekly samples to permit a statistically valid analysis of the mean PCB loads.

The above technique has one disadvantage. It requires that samples be held beyond the USEPA allowed holding times for PCB analyses. For this reason, the data quality objective for these samples will be less than the Data Quality Level (DQL) level 5 applied to most other Reassessment analyses.

The sample analysis will include the determination of the following:

- Dissolved phase PCBs on a congener specific basis;
- Suspended matter PCBs on a congener specific basis;
- Total suspended solids; and
- Dissolved organic carbon.

Dissolved oxygen, pH, temperature and conductivity will be measured at each location at the time of sample collection. Samples will be collected for three one month intervals to generate twelve sample analyses for each of the parameters listed above, excluding duplicates and quality control samples.

A.3.2 Analysis of Archived Water Column Samples on a Congener-Specific Basis

During the period 1977 to 1986, Hudson River water column samples were collected by the scientists of the Lamont-Doherty Geological Observatory. These samples were extracted and analyzed for PCBs near the time of collection, using packed column gas chromatography. The extracts of these samples have been stored by the Observatory and can be reanalyzed on a congener-specific basis. The task will involve the reanalysis of about 100 water column sample extracts, representing both dissolved phase and suspended matter PCB fractions. The integrity of the archived extracts will be confirmed by comparing the original analytical results, which were obtained by a packed column gas chromatograph technique, with a comparable analysis in Phase 2. The scientists at the Observatory have reproduced PCB analyses of previously analyzed, archived samples, demonstrating the viability of this procedure.

A.3.3 Low Resolution Coring of Upper Hudson Sediments

As described in Phase 2 Work Plan, the specific implementation of this task is contingent upon the results of the geophysical investigation in Phase 2A. A detailed description of the number of samples and the general low resolution coring locations will be submitted to USEPA when the geophysical results become available, in early summer 1992.

As part of the low resolution coring efforts, cores are anticipated to be collected from the following areas: the Bakers Falls Pool, the river section between Bakers Falls and the former dam site at Fort Edward (particularly at Remnant Deposit 1), the Thompson Island Pool, and the river reach below the Thompson Island Dam (see Figure A.3.1). The low resolution coring effort is expected to concentrate on the first three areas.

The main intent of the low resolution core collection is estimation of total PCB storage in the sediments, a distinctly different objective from the high resolution core collection in Phase 2A, which is designed to collect information on current and historic water column transport as recorded in the sediments. High resolution core locations are separated by distances of miles, whereas the low resolution core locations will be comparatively close together and clustered. In addition, for a high resolution core to be useful, it must be obtained from a zone of high deposition and produce an interpretable radionuclide chronology with depth. A low resolution core is not subject to these stringent criteria.

The collection of a low resolution core follows the same techniques used for high resolution core collection. Once collected, the low resolution core is subdivided in a different manner from the high resolution core. Instead of the relatively thin slices obtained from high resolution cores (2-4 cm thick), low resolution cores are subdivided into thick sections, approximately 13 cm (5 inches) thick. Low resolution cores are typically expected to obtain 40 to 50 cm (15 to 20 inches) of sediment, yielding three to four samples per core. The minimum recovery for a low resolution core is 20 cm (8 inches).

Each core section will be analyzed for the following parameters:

- PCB concentration on a congener specific basis;
- Radionuclides Beryllium-7 (Be-7) and Cesium-137 (Cs-137);
- Total organic carbon;
- Total organic nitrogen;
- Grain size distribution; and
- Reduction/oxidation potential (redox).

The redox potential will be a field measurement obtained during core extrusion. The data on total organic carbon and total organic nitrogen levels will be obtained by either direct measurement or by analysis of total carbon, total nitrogen, total inorganic carbon and total organic nitrogen, similar to the high resolution core sections.

A.3.4 Sediment Critical Shear Stress Analysis

Sediments of the Thompson Island Pool and the Remnant Deposit area will be collected for critical shear stress analysis as part of the scourability assessment. The number of samples required for laboratory analysis will be determined based on an assessment of the sediment classes mapped by the geophysical survey and the confirmatory sampling. Large diameter cylindrical (4 to 6 in) or box coring techniques will be used to collect sediment samples, because these techniques preserve the sediment structure, particularly the surface sediment conditions. An additional sample will be collected with each core sample for grain size analysis.

The method for shear stress measurement is based on the work of Schunemann and Khul (1991).[1] It involves the use of a stirring mechanism and a

[1] Shünemann M. and H. Khul, A device of erosion-measurements on naturally formed, muddy sediments: the EROMES System, GKSS 91/E/19, GKSS Research Centre, Germany, 1991.

turbidity meter to determine sediment response to shear stress. Figure A.3-2 shows a schematic of the measurement system.

A.3.5 Assessment of In Situ Degradation

The goal of this task is to determine an effective rate of *in situ* degradation for PCBs in various regions of the Hudson. In the Phase 2A sampling work, 25 high resolution cores will be collected from Study Areas A, B, C and D. Many of these coring locations have been studied and cored historically by the scientists of the Lamont-Doherty Geological Observatory (see Figures A.3.3 and A.3.4). The sediments from the historic cores and, in most cases, the sample extracts from these cores, still exist and can be re-analyzed on a congener-specific basis for direct comparison with the Phase 2A sediment core results.

This task will involve the reanalysis of sediment core layer extracts whose time of deposition is fairly well known. Historic core extracts will only be re-analyzed to correspond with the successful Phase 2A high resolution sediment cores, *i.e.*, a Phase 2A sediment core will have to yield an interpretable radionuclide deposition history and then have unqualified PCB analytical results before the corresponding historic core extracts are reanalyzed. In most instances, only four to five historic sediment extracts will be run for each coring location. For the Upper Hudson, the sediment layers corresponding to the following events will be reanalyzed, assuming they can be identified in each sediment core pair:

- 1954 appearance of Cesium-137;
- 1963 Cesium-137 maximum;
- Mid 1970's PCB maximum; and
- Time of the historic core collection.

For the Lower Hudson, these same sediment layers will be analyzed plus the layer corresponding to:

- 1971 Cesium-137, Cobalt-60 maximum

The integrity of the stored sediment extracts will be confirmed by comparison of the reanalysis results with the packed column results originally obtained. The two sets of results should agree for total PCB concentration and the concentration of the individual homolog groups.

This task will involve up to 15 pairs of historic and Phase 2A high resolution cores. It is likely that not all historic core locations will be successfully re-cored in Phase 2A, so that the actual number of core pairs will be lower. Based on five cores from the Upper Hudson and ten cores from the Lower Hudson, up to 70 sediment extracts will be re-analyzed. No other analytical work is required for this task. Like the reanalysis of water column samples, the data quality level for these results will be less than level 5.

A.3.6 Reconnaissance Survey

The purpose of this task is to provide qualitative field verification of the types of habitats and wildlife on and near the ecological study area (Study Area B and most of C). Field biologists will conduct a field assessment of the various terrestrial wetland and aquatic habitat types. Prior to the initiation of the survey, state and federal agencies will be consulted in order to develop a list of flora and fauna which may be expected to occur in the areas surveyed.

The surveys require dawn and dusk walkovers of selected shoreline areas. In addition, surveys in Area C will also include tidal elements. Positioning will be by line of sight and will therefore be approximate. A field map will be used to guide the survey and for recording observations. The walkover path will be planned and modified as appropriate in the field. The path will be dictated by the types of environments encountered and their extent as based upon visual observations. The exact course of the walkover will be determined by the biologist in the field. The course of the walkover will be based on such observations as nesting sites, physical signs of wildlife, audible signs of birds, changes in vegetation patterns, obvious changes in hydrologic conditions, changes in slope, and physical accessibility.

A qualitative assessment of the freshwater aquatic environments will also be made during the reconnaissance survey. Seines or dip nets will be used nearshore in several of the major surface water bodies to sample fish and larger invertebrates. Kick net and/or ponar grab samples will be obtained and sieved on-site to determine the species richness of dominant benthic invertebrates.

The reconnaissance survey will be qualitative rather than quantitative, since the objective is to provide an inventory of shoreline terrestrial aquatic biota and site specific observations concerning the diversity, *i.e.* number and type of species, rather than data for assessment of population structure or community analyses. The data products from the reconnaissance survey will include tables and maps, which will allow a qualitative biological characterization of the ecological study area.

PAGE INTENTIONALLY LEFT BLANK

TABLE A.1.1
SUMMARY OF PHASE 2A ANALYTICAL PROGRAM

SEDIMENT PROGRAM

TASK	NUMBER OF LOCATIONS	NUMBER OF SAMPLES PER LOCATION	PCB CONGENER ANALYSIS	TOTAL CARBON AND NITROGEN ANALYSIS
Confirmatory Sampling Sediment Cores and Grab Samples	200	1-2[4]	–	200-400[4]
High Resolution Sediment Coring[1]	23[3]	10-12	230-280	230-280
SEDIMENT TOTAL	223	–	230-280	430-680

TASK	TOTAL INORGANIC CARBON ANALYSIS[6]	GRAIN SIZE DISTRIBUTION	RADIONUCLIDE ANALYSIS[5]	TOTAL ORGANIC NITROGEN ANALYSIS
Confirmatory Sampling Sediment Cores and Grab Samples	–	200-400[10]	–	–
High Resolution Sediment Coring[1]	230-280	255-305[13]	230-280	115-140
SEDIMENT TOTAL	230-280	455-705	230-280	115-140

WATER COLUMN PROGRAM[2]

TASK	NUMBER OF TRANSECTS	NUMBER OF SAMPLES PER TRANSECTS	DISSOLVED PHASE PCB CONGENER ANALYSIS	SUSPENDED MATTER PCB CONGENER ANALYSIS
Water Column Monitoring				
– Field Filtered Samples	7	11[8]	77	77
– Laboratory Filtered Samples	2[7]	11[8]	22	22
WATER COLUMN TOTAL	7	–	99[11]	99[11]

TASK	DISSOLVED ORGANIC CARBON ANALYSIS[9]	TOTAL SUSPENDED MATTER ANALYSIS	TOTAL WATER COLUMN PCB ANALYSIS	CHLOROPHYLL-A ANALYSIS	TOTAL CARBON ANALYSIS ON SUSPENDED MATTER
Water Column Monitoring					
– Field Filtered Samples	77	77	10	77	77
– Laboratory Filtered Samples	22	–	–	–	–
WATER COLUMN TOTAL	99	77	10[12]	77	77

TABLE A.1.1 (Continued)
SUMMARY OF PHASE 2A ANALYTICAL PROGRAM

Notes

1. Sediment samples to be analyzed for redox potential in the field.

2. All water column stations to include field measurements of conductivity, temperature, pH and dissolved oxygen.

3. Eleven locations to be placed in the Lower Hudson, twelve in the Upper Hudson.

4. Grab samples will generate 1 sample per location. Core samples will generate up to 2 samples per core, one core per location. It is anticipated that 50% of the locations will yield sediment cores and 50% will yield grab samples.

5. Samples to be analyzed by Lamont-Doherty Geological Observatory for radionuclides, including Cesium-137(Cs-137), Beryllium-7 (Be-7), and Cobalt-60 (Co-60).

6. Total organic carbon data to be obtained by a difference method, subtracting a total inorganic carbon measurement from a total carbon measurement.

7. These represent duplicates of the samples collected for one low flow transect and one high flow transect.

8. This total includes seven samples from the Upper Hudson, one each from the Hoosic River, Mohawk River and Champlain Canal, and one background sample per transect.

9. These data will be obtained from two separate measurements of dissolved organic carbon, one based on a persulfate digestion and one based on a complete combustion of the sample.

10. 200 to 400 samples will be analyzed for grain size distribution by a laser particle analyzer technique. A subset of these samples (about 50) will be run for grain size distribution by the standard ASTM method.

11. Samples derived from 20 liter aliquots.

12. Samples derived from one liter aliquots.

13. 230 to 280 (one for each core slice) samples will be run using a laser particle analyzer based technique for a small sample volume. 25 samples (roughly one for each core) will be run using a laser particle analyzer based technique for a large sample volume.

TABLE A.1.2
SUMMARY OF PHASE 2B ANALYTICAL PROGRAM

WATER COLUMN SAMPLING

TASK	DISSOLVED PHASE PCB CONGENERS	SUSPENDED MATTER PCB CONGENERS	DISSOLVED ORGANIC CARBON	TOTAL SUSPENDED SOLIDS	pH DISSOLVED O_2 TEMPERATURE CONDUCTIVITY[1]
Flow-Averaged Water Sampling	12	12	12	12	300
Analysis of Water Sample Archives	50[2]	65[2]	--	--	--
TOTAL	62	77	12	12	300

SEDIMENT SAMPLING

TASK	PCB CONGENERS	TOTAL CARBON/ TOTAL NITROGEN	TOTAL INORGANIC CARBON	RADIO-NUCLIDES	TOTAL ORGANIC NITROGEN	GRAIN-SIZE DISTRIBUTION
Low Resolution Coring	[4]	[4]	[4]	[4]	[4]	[4]
Critical Shear Stress	--	--	--	--	--	[3]
In situ Degradation	70	--	--	--	--	--

TASK	CRITICAL SHEER STRESS	REDOX POTENTIAL
Low Resolution Coring	--	[4]
Critical Shear Stress	[5]	--
In situ Degradation	--	--

312212

TABLE A.1.2 (Continued)
SUMMARY OF PHASE 2B ANALYTICAL PROGRAM

<u>Notes</u>

1. These parameters will be measured at the time of sample collection.

2. These samples represent about 50 dissolved phase/suspended matter pairs plus 15 additional suspended matter samples.

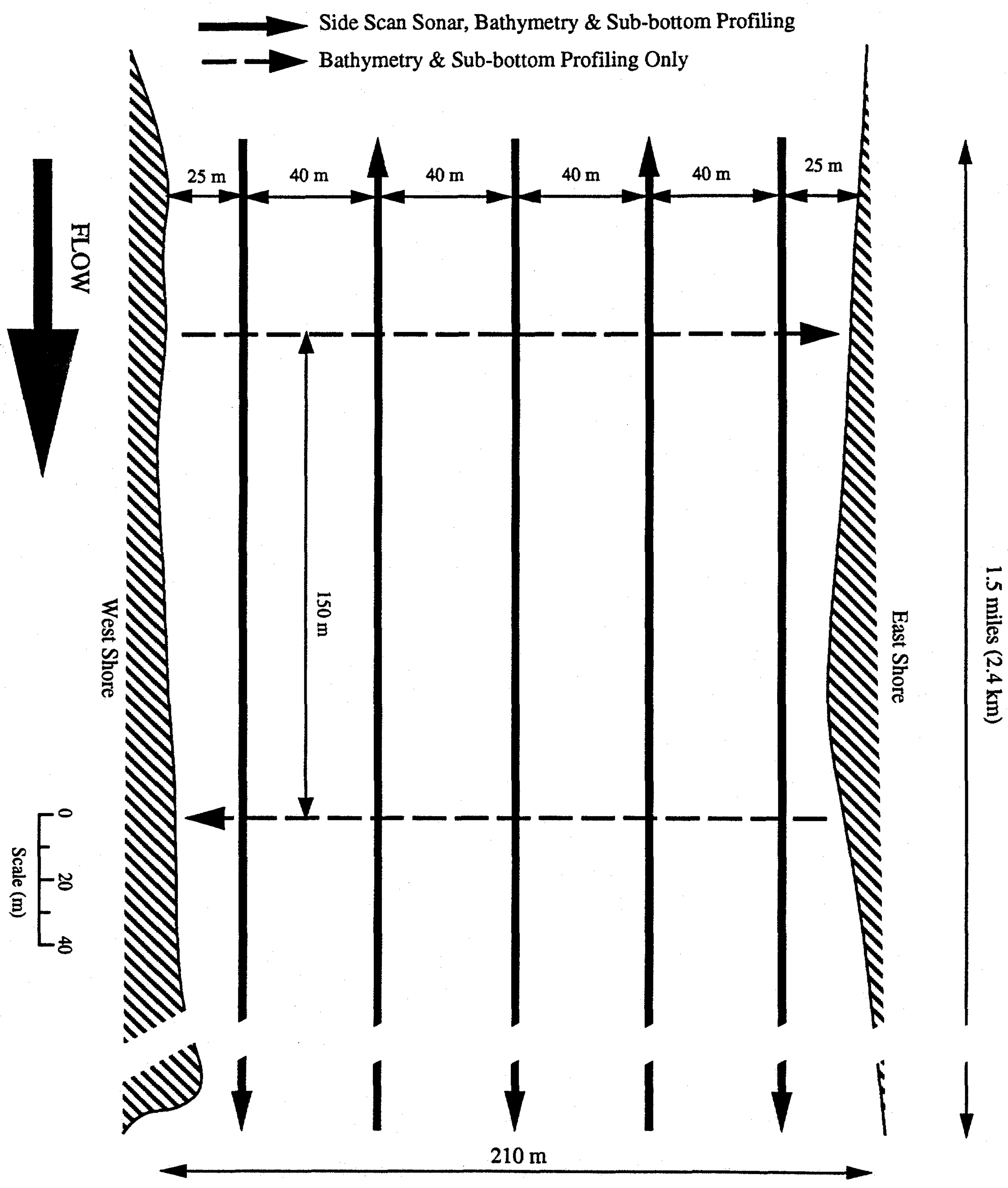
3. Samples collected for critical shear stress analysis will also be run for grain-size analysis.

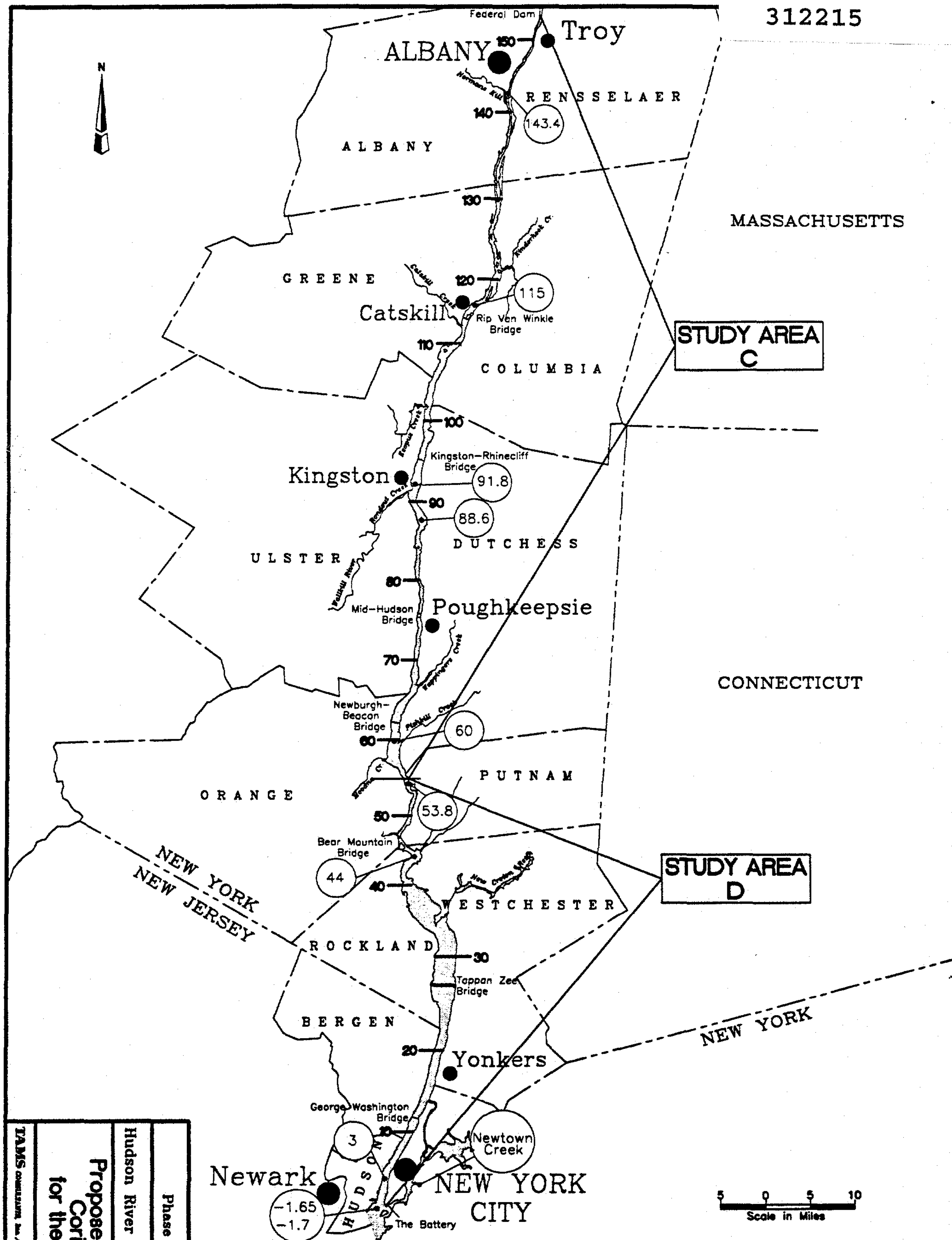
4. The number of samples will be determined after the completion of the geophysical surveys.

5. It is expected that about 25 samples will be collected for critical shear stress analysis during the low resolution coring effort.

Figure A.2.1

Schematic of Proposed Geophysical Survey Grid





Phase 2 Sampling Plan

Hudson River PCB Reassessment RI/FS

Proposed High Resolution Coring Locations for the Lower Hudson

TAMS Consultants Inc./Gradient Corporation

Figure A.2.2

Legend

(60) Location of Proposed Core

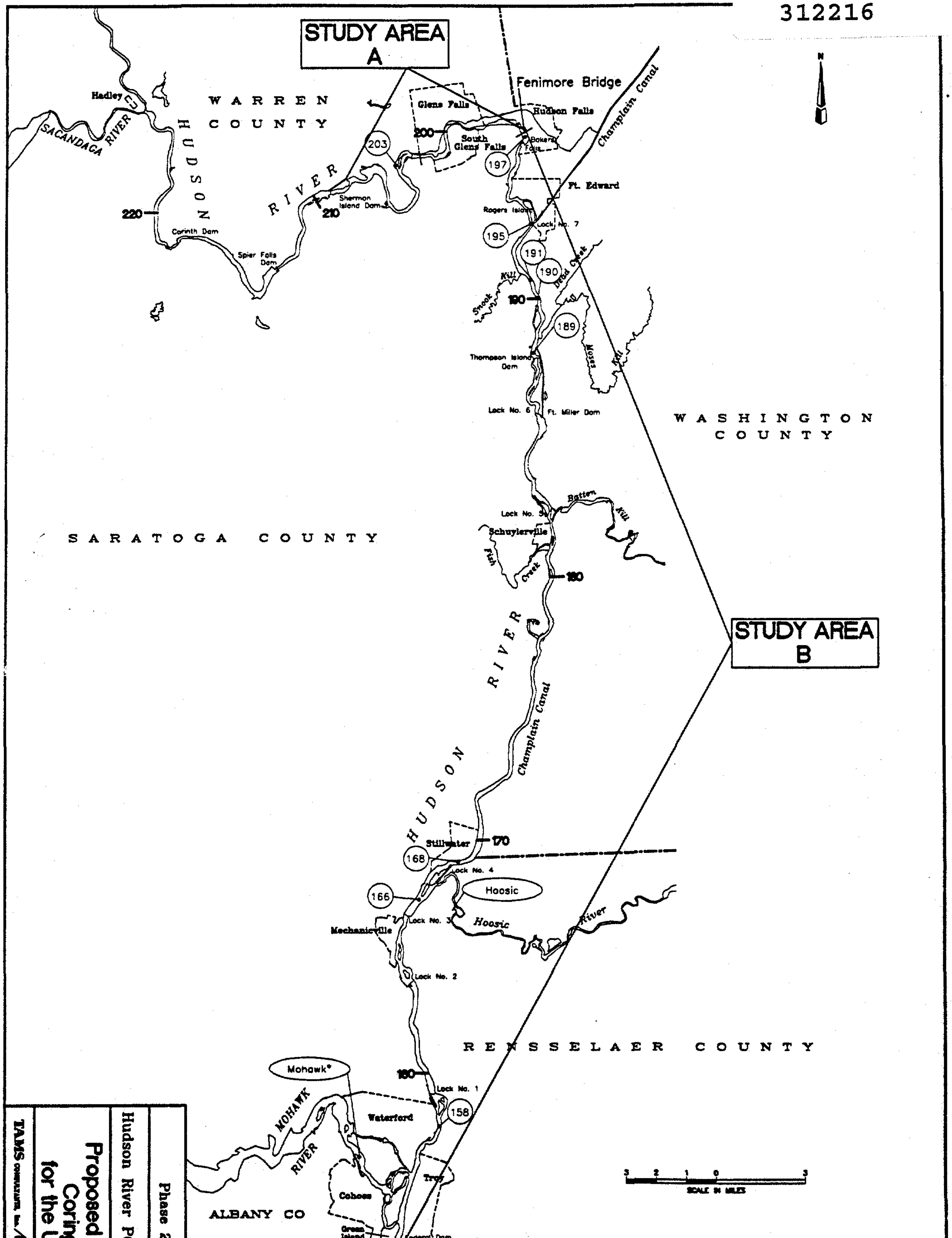
100 River Mile

Note:

1. Study Area C: Federal Dam to River Mile 55
2. Study Area D: River Mile 55 to The Battery

Figure A.2.2

312216



Legend

188 Location of Proposed Core

180 River Mile

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

* Note: Mohawk has two proposed core locations near this point.

Figure A.2.3

Phase 2 Sampling Plan

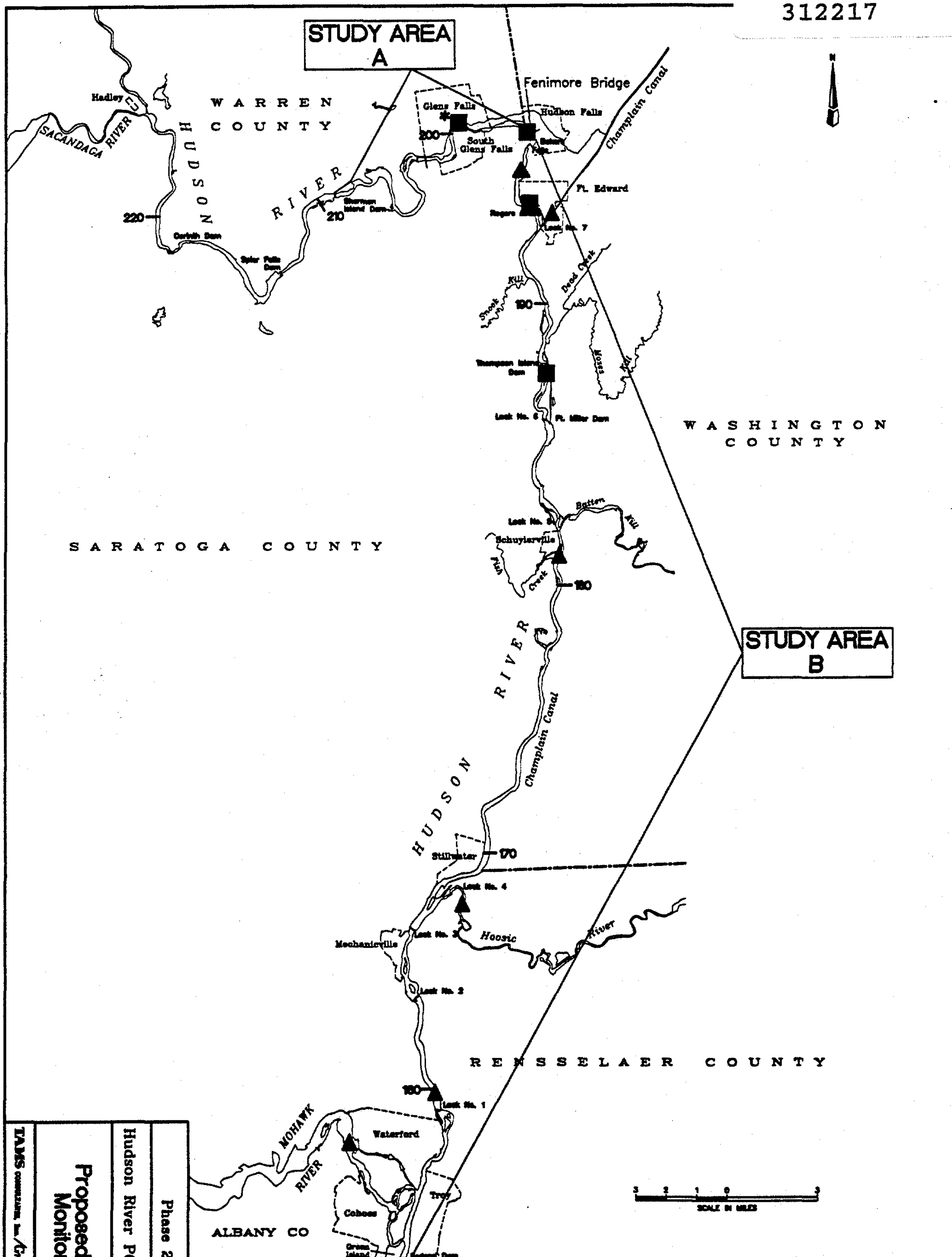
Hudson River PCB Reassessment RI/FS

Proposed High Resolution Coring Locations for the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation

Figure A.2.3

312217



Legend

- 190 River Mile
- ▲ Proposed Water Column Transect Sampling Station
- ■ Proposed Combined Water Column Transect and Flow – Averaged Water Column Sampling Stations
- * A suitable location closer to the downstream limit of Study Area A will be used if available

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

Figure A.2.4

Phase 2 Sampling Plan

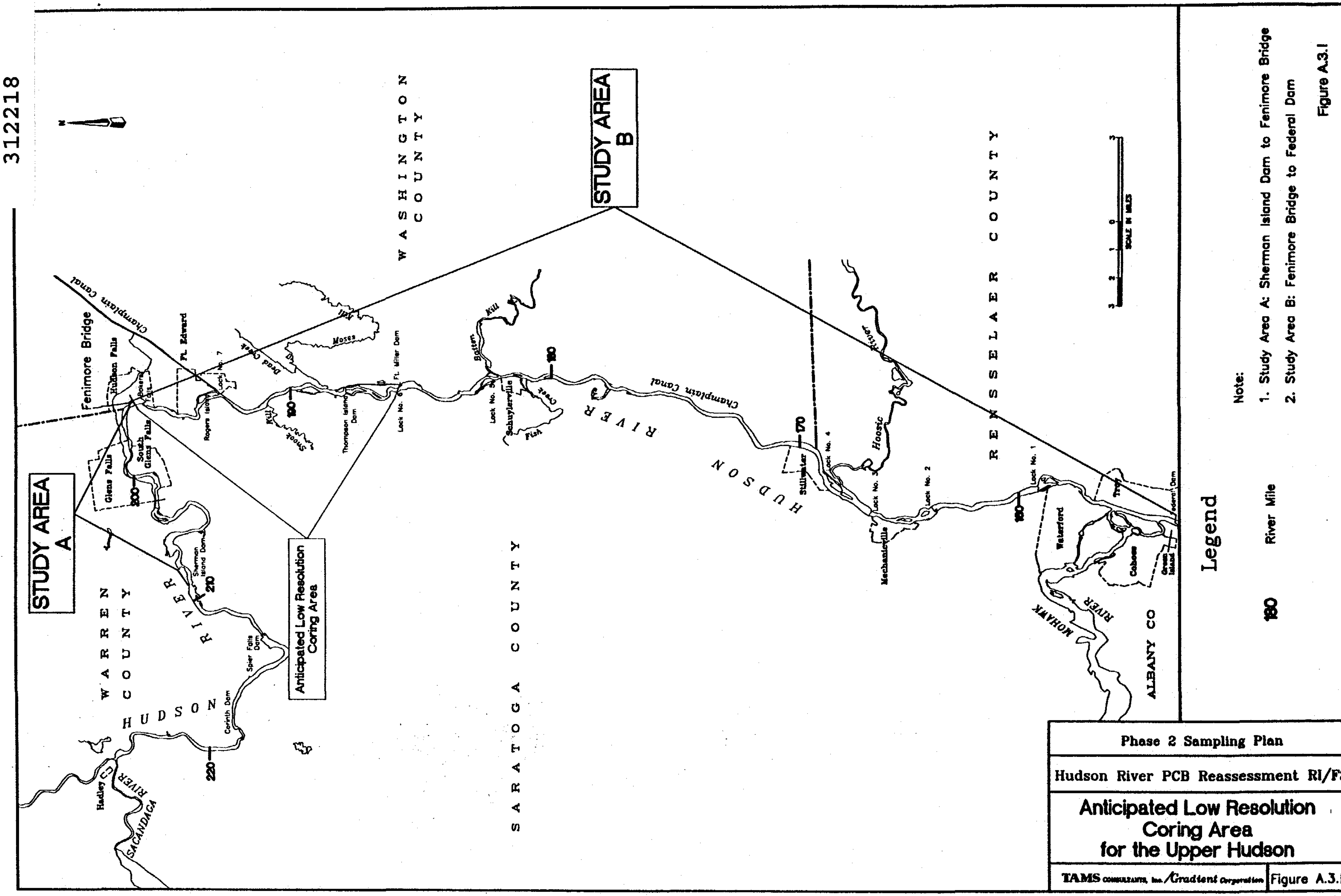
Hudson River PCB Reassessment RI/FS

Proposed Water Column Monitoring Stations

TAMS Consultants, Inc./Gradient Corporation

Figure A.2.4

312218



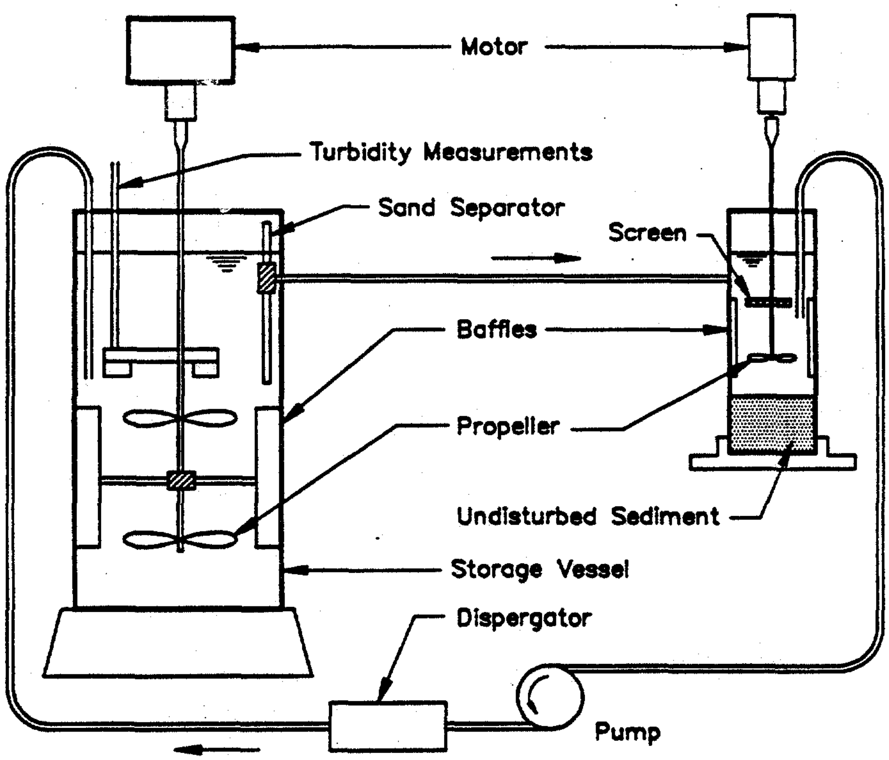
Phase 2 Sampling Plan

Hudson River PCB Reassessment RI/FS

Anticipated Low Resolution Coring Area for the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation | Figure A.3.1

Figure A.3.2
Critical Shear Stress Measurement System

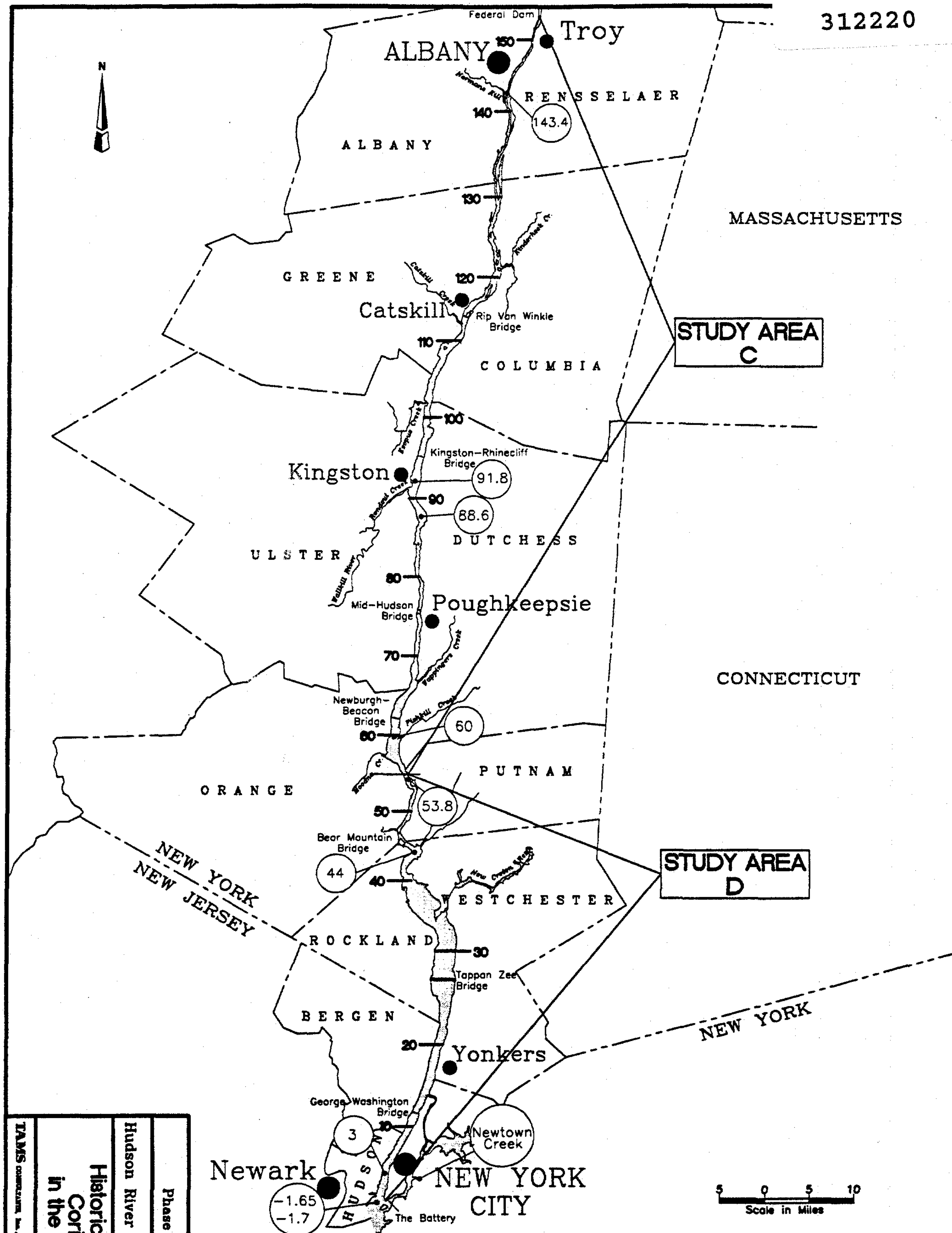


LABORATORY SETUP TO MEASURE EROSION

(Not To Scale)

From Schünemann et al, 1991

312220



Phase 2 Sampling Plan

Hudson River PCB Reassessment RI/FS

Historic High Resolution Coring Locations in the Lower Hudson

TAMS CONSULTANTS, Inc. / Gradient Corporation

Figure A.3.3

Legend

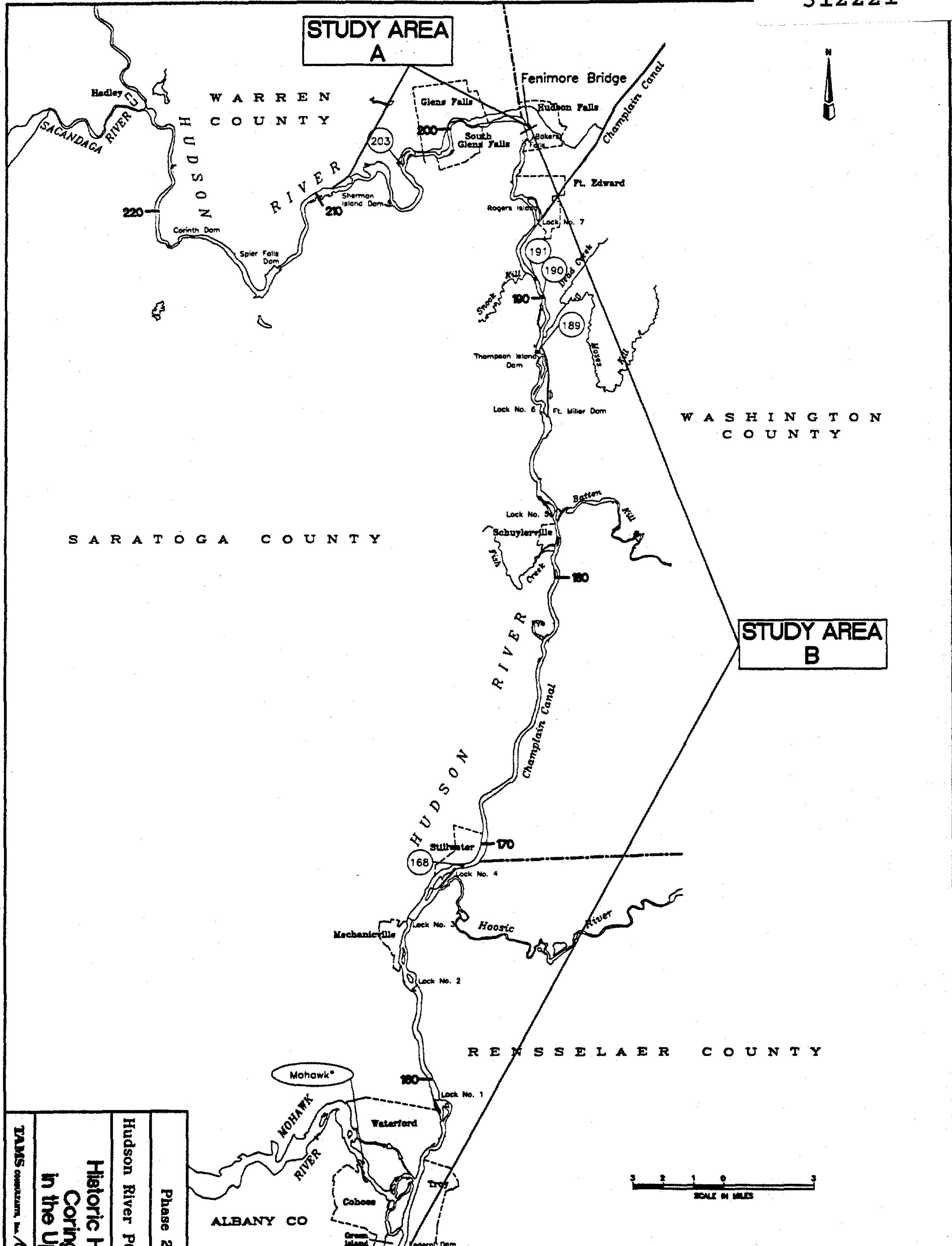
(60) Location of Historic Sediment Core

100 River Mile

Note:

1. Study Area C: Federal Dam to River Mile 55
2. Study Area D: River Mile 55 to The Battery

Figure A.3.3



Legend

188 Location of Historic Sediment Core

180 River Mile

* Mohawk has two historic core locations near this point.

Note:

1. Study Area A: Sherman Island Dam to Fenimore Bridge
2. Study Area B: Fenimore Bridge to Federal Dam

Figure A.3.4

Phase 2 Sampling Plan

Hudson River PCB Reassessment RI/FS

Historic High Resolution Coring Locations in the Upper Hudson

TAMS Consultants, Inc./Gradient Corporation | Figure A.3.4

THE MAP IS AVAILABLE FOR REVIEW AT THE FOLLOWING LOCATION:

HUDSON RIVER PCBS ADMINISTRATIVE RECORD

U. S. EPA, REGION 2 SUPERFUND RECORDS CENTER, 290 BROADWAY, 18TH FLOOR, NEW YORK, NY 10007